Request by Scripps Institution of Oceanography for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during Low-Energy Marine Geophysical Surveys by R/V *Thomas G. Thompson* in the South Atlantic Ocean, November–December 2019

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14 May 2019

LGL Report FA0175-04

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SUMMARY

Scripps Institution of Oceanography (SIO) plans to support a research activity that would involve low-energy seismic surveys in the South Atlantic Ocean during November–December 2019. The research activity would be funded by the U.S National Science Foundation (NSF). The seismic surveys would use a pair of low-energy Generator-Injector (GI) airguns with a total discharge volume of ~90 in^3. The seismic surveys would take place in International Waters of the southwest and southeast Atlantic Ocean. SIO requests that it be issued an Incidental Harassment Authorization (IHA) allowing non-lethal takes of marine mammals incidental to the planned seismic surveys. 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).

Numerous species of marine mammals inhabit the proposed project area in the South Atlantic Ocean. Under the U.S. Endangered Species Act (ESA), several of these species are listed as ***endangered***, including the sperm, sei, fin, blue, and southern right whales. SIO is proposing a marine mammal monitoring and mitigation program to minimize the potential impacts of the proposed activity on marine mammals present during conduct of the proposed research, and to document the nature and extent of any effects.

ESA-listed sea turtle species that could occur in the project area include the ***endangered*** leatherback and hawksbill sea turtles, and the ***threatened*** loggerhead (South Atlantic Ocean Distinct Population Segment or DPS), green (South Atlantic DPS), and olive ridley sea turtles. The ***endangered*** African penguin, band-rumped storm-petrel, and freira are ESA-listed seabirds that could be encountered in the project area. In addition, the ***endangered*** Eastern Atlantic DPS of scalloped hammerhead shark; and the ***threatened*** oceanic white tip shark and giant manta ray could occur in the proposed project area.

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 project 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

SIO plans to conduct low-energy seismic surveys in the South Atlantic Ocean from ~3 November to 5 December 2019. The majority of the surveys would take place in the Southeast Atlantic Ocean between ~33.2°–21°S and 1°W–8°E (see Fig. 1). A small survey area is proposed for the Southwest Atlantic Ocean between ~33.2°–34.3°S and 30.8°–31.8°W (Fig. 1). The seismic surveys would be conducted in International Waters with water depths ranging from ~500–5700 m. Representative survey tracklines are shown in Figure 1. Some deviation in actual tracklines and timing could be necessary for reasons such as science drivers, poor data quality, inclement weather, or mechanical issues with the research vessel and/or equipment.

The proposed project consists of low-energy seismic surveys to understand the volcanic and tectonic development of Walvis Ridge and Rio Grande Rise in the South Atlantic Ocean. To achieve the program's goals, the Principal Investigators (PIs), Drs. W.W. Sager and H.-W. Zhou, propose to collect low-energy, high-resolution multi-channel seismic (MCS) profiles. The procedures to be used for the seismic surveys would be similar to those used during previous seismic surveys by SIO and would use conventional seismic methodology. The surveys would involve one source vessel, R/V *Thomas G. Thompson* (R/V *Thompson*), using the portable MCS system operated by marine technicians from SIO. R/V *Thompson* (managed by University of Washington [UW]) would deploy up to two 45-in^3 GI airguns as an energy source with a maximum total volume of ~90 in^3. The receiving system would consist of one hydrophone streamer, 200–1600 m in length, as described below. As the airguns are towed along the survey lines, the hydrophone streamer would receive the returning acoustic signals and transfer the data to the on-board processing system.

The proposed cruise would consist of digital bathymetric, echosounding, and MCS surveys within five areas to improve our understanding of volcanic and tectonic development of oceanic ridges and to enable the selection and analysis of potential future IODP drillsites. Two types of surveys would be implemented with the airgun array operated in different modes:

(1) High-Quality Surveys: To collect the highest-quality seismic reflection data, 2 GI airguns would be deployed with the ship travelling at 5 kt for a total of 10 survey days. A 400, 800, or 1600 m steamer would be used to collect reflected seismic energy. The two GI airguns would be spaced 2-m apart.

(2) Reconnaissance Surveys: To collect reconnaissance seismic reflection data or when weather is too poor to safely use a ≥400 m steamer, 1 or 2 GI airguns would be deployed with the ship travelling at 8 kt for a total of 4 survey days. A 200-m steamer would be used to collect reflected seismic energy. If two GI airguns are deployed, they would be towed 8 m apart.

Reconnaissance Surveys are planned for three survey areas (Gough, Tristan, Central) and High-Quality Surveys are planned to take place along the proposed seismic transect lines in the main survey area (Valdivia Bank) and Libra Massif survey area. However, High-Quality Surveys may be replaced by Reconnaissance Surveys depending on weather conditions and timing (e.g., 10% of survey effort at Valdivia Bank is expected to consist of Reconnaissance Surveys). Reconnaissance Survey operations are quicker and less impacted by adverse weather conditions, while the High-Quality Survey operations yield more resolved imagery and sediment velocity values. Seismic data would be collected first as a single profile over the rift at Libra Massif, the most southeastern edifice of Rio Grande Rise. After crossing the Atlantic,

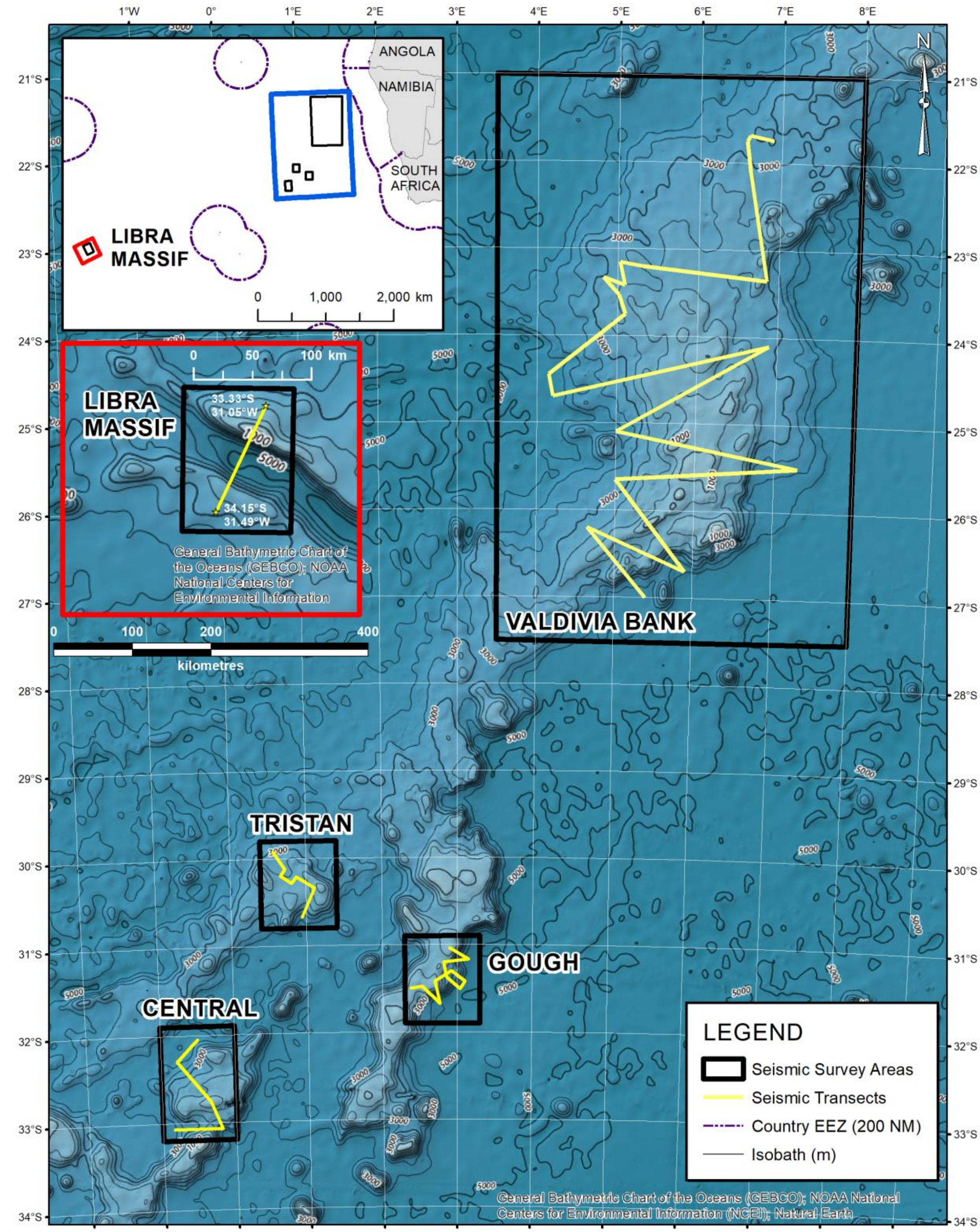

FIGURE 1. Location of the proposed low-energy seismic surveys in the South Atlantic Ocean, November–December 2019.

data would be collected over three seamounts (Gough, Tristan, Central) in the "Guyot Province" of Walvis Ridge. Approximately 24 hr of seismic profiling is proposed at each location, before moving on to the Valdivia Bank survey area, where most survey effort (75%) would occur.

At the proposed survey areas, ~2715 km of seismic data would be collected. Although representative lines for the proposed survey areas are depicted in Figure 1, the line locations are preliminary and could be refined in light of information from data collected during the study. All data acquisition in the Tristan survey area would occur in water >1000 m deep; all other survey areas have effort in intermediate (100–1000 m) and deep (>1000 m) water. Most of the survey effort (97%) would occur in water >1000 m deep. There could be additional seismic operations in the project area associated with equipment testing, re-acquisition due to reasons such as but not limited to equipment malfunction, data degradation during poor weather, or interruption due to shut-down or track deviation in compliance with IHA requirements. In our calculations [see § VII], 25% has been added in the form of operational days for those additional operations.

In addition to the operations of the airgun array, a hull-mounted multibeam echosounder (MBES) and a sub-bottom profiler (SBP) would also be operated from R/V *Thompson* continuously throughout the seismic surveys, but not during transits to and from the project area. All planned data acquisition and sampling activities would be conducted by SIO and UW with on-board assistance by the scientists who have proposed the project. The vessel would be self-contained, and the crew would live aboard the vessel for the entire cruise.

Source Vessel Specifications

R/V *Thompson* has a length of 83.5 m, a beam of 16 m, and a full load draft of 5.8 m. It is equipped with twin 360°-azimuth stern thrusters each powered by 3000-hp DC motors and a water-jet bow thruster powered by a 1100-hp DC motor. The motors are driven by three 2250-hp, 1500kW main propulsion generators. An operation speed of ~9–15 km/h (~5–8 kt) would be used during seismic acquisition. When not towing seismic survey gear, R/V *Thompson* cruises at 22 km/h (12 kt) and has a maximum speed of 26.9 km/h (14.5 kt). It has a normal operating range of ~24,400 km. R/V *Thompson* would also serve as the platform from which vessel-based protected species visual observers (PSVO) would watch for marine mammals and sea turtles before and during airgun operations.

Other details of R/V *Thompson* include the following:

Owner:	U.S. Navy
Operator:	University of Washington
Flag:	United States of America
Launch Date:	8 July 1991
Gross Tonnage:	3250 LT
Compressors for Airguns:	3 x Stark Industries D-100, 100 SCFM at 2000 psi
Accommodation Capacity:	60 including 36 scientists

Airgun Description

R/V *Thompson* would tow two 45-in^3 GI airguns and a streamer containing hydrophones. The generator chamber of each GI gun, the one responsible for introducing the sound pulse into the ocean, is 45 in^3. The larger (105 in^3) injector chamber injects air into the previously generated bubble to maintain its shape and does not introduce more sound into the water. The 45-in^3 GI airguns would be towed 21 m behind R/V *Thompson*, 2 m (during 5-kt high-quality surveys) or 8 m (8-kt reconnaissance surveys) apart, side by side, at a depth of 2–4 m. High-quality surveys with the 2-m airgun separation configuration would use a streamer up to 1600-m long, whereas the reconnaissance surveys with the 8-m airgun separation configuration would use a 200-m streamer. Seismic pulses would be emitted at intervals of 25 m for the 5-kt surveys using the 2-m GI airgun separation and at 50 m for the 8 kt surveys using the 8-m airgun separation.

GI Airgun Specifications

Energy Source	Two GI guns of 45 in^3
Gun positions used	Two inline airguns 2- or 8-m apart
Towing depth of energy source	2–4 m
Source output (2-m gun separation)*	0-peak is 3.5 bar-m (230.9 dB re 1 µPa·m); peak-peak 6.9 bar-m (236.7 dB re 1 µPa·m)
Source output (8-m gun separation)*	0-peak is 3.7 bar-m (231.4 dB re 1 µPa·m); peak-peak is 7.4 bar-m (237.4 dB re 1 µPa·m)
Air discharge volume	Approx. 90 in^3
Dominant frequency components	0–188 Hz
Gun volumes at each position (in^3)	45, 45

*Source output downward based on a conservative tow depth of 4 m.

As the airguns are towed along the survey lines, the towed hydrophone array in the streamer would receive the reflected signals and transfer the data to the on-board processing system. The turning rate of the vessel with gear deployed would be much higher (~20º) when a short streamer is towed compared with a turning rate of ~5º when a longer streamer (1600 m) is towed. Thus, the maneuverability of the vessel would be limited during operations.

The source levels can be derived from the modeled farfield source signature, which is estimated using the PGS Nucleus software. The nominal downward-directed source levels indicated above do not represent actual sound levels that can be measured at any location in the water. Rather, they represent 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 combined GI airguns. The actual received level at any location in the water near the GI airguns would not exceed the source level of the strongest individual source. Actual levels experienced by any organism more than 1 m from either GI airgun 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 far field 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 Lamont-Doherty Earth Observatory (L-DEO) for both the exclusion zones (EZ) for Level A takes and safety zones (160 dB re $1\mu Pa_{rms}$) for Level B takes. The background information and methodology for this are provided in Appendix A and briefly summarized here.

The proposed surveys would acquire data with the 2-GI airgun array at a tow depth of ~2–4 m. L-DEO model results are used to determine the 160-dB_{rms} radius for the 2-GI airgun array in deep water (>1000 m) down to a maximum water depth of 2000 m. 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- and 175-dB re $1\mu Pa_{rms}$ sound levels are expected to be received for the two different airgun configurations at a 4-m tow depth. The 160-dB level is the behavioral disturbance criterion that is used to estimate anticipated Level B takes for marine mammals; a 175-dB level is used by NMFS, as well as the U.S. Navy (USN 2017), to determine behavioral disturbance for sea turtles.

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 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). As required by the *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* (NMFS 2016a, 2018a), the largest distance of the dual criteria (SEL_{cum} or Peak SPL_{flat}) was used to calculate takes and Level A threshold distances (Table 2).

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). At the time of preparation of this document, how the technical guidance would be implemented operationally, along with other potential monitoring and mitigation measures, remains somewhat uncertain. For other recent low-energy seismic surveys supported by SIO, NMFS required protected species observers (PSOs) to establish and monitor a 100-m EZ and a 200-m buffer zone beyond the EZ.

Description of Operations

The proposed surveys would involve one source vessel, R/V *Thompson*. R/V *Thompson* would tow a pair of 45-in^3 GI airguns and a streamer up to 1600-m in length containing hydrophones along predetermined lines. As the GI airguns are towed along the survey lines, the hydrophone streamer would receive the returning acoustic signals and transfer the data to the on-board processing system.

The proposed cruise would acquire ~2715 km of seismic data in the South Atlantic Ocean to collect data on the volcanic and tectonic development of ocean ridges and to enable the selection and analysis of potential future IODP drillsites. All data acquisition in the Tristan survey area would occur in water >1000 m deep; all other survey areas have effort in intermediate (100–1000 m) and deep (>1000 m) water. Most of the survey effort (97%) would occur in water >1000 m deep.

Along with the airgun operations, two additional acoustical data acquisition systems would be operated during the seismic survey, but not during transits. The ocean floor would be mapped with the Kongsberg EM300 MBES and a Knudsen 3260 SBP. These sources, or similar, are described in § 2.2.3.1 of the 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 (NSF-USGS 2011), and Record of Decision (NSF 2012), referred to herein as the PEIS.

TABLE 1. Level B. Predicted distances to the 160 dB re 1 μPa_{rms} and 175-dB sound levels that could be received from two 45-in^3 GI guns (at a tow depth of 4 m) that would be used during the seismic surveys in the South Atlantic Ocean during November−December 2019 (model results provided by L-DEO). The 160-dB criterion applies to all marine mammals; the 175-dB criterion applies to sea turtles.

Airgun Configuration	Water Depth (m)	Predicted Distances (m) to Various Received Sound Levels	
		160 dB re 1 μPa_{rms}	**175 dB re 1 μPa_{rms}**
Two 45-in^3 GI guns / 2-m gun separation	>1000	539[1]	95[1]
	100-1000	809[2]	142[2]
Two 45-in^3 GI guns / 8-m gun separation	>1000	578[1]	103[1]
	100-1000	867[2]	155[2]

[1] Distance is based on L-DEO model results.
[2] Distance is based on L-DEO model results with a 1.5 × correction factor between deep and intermediate water depths.

TABLE 2. Level A threshold distances for different marine mammal hearing groups. As required by NMFS (2016a, 2018a), the largest distance (in bold) of the dual criteria (SEL_{cum} or Peak SPL_{flat}) was used to calculate takes and Level A threshold distances.

	Level A Threshold Distances (m) for Various Hearing Groups				
	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
Highest-quality seismic Two 45-in^3 GI guns/2-m separation; towed at 5 kt					
PTS SEL_{cum}	**6.5**	0	0	0.1	0
PTS Peak	4.9	**1.0**	**34.6**	**5.5**	**0.5**
Reconnaissance seismic Two 45-in^3 GI guns/8-m separation; towed at 8 kt					
PTS SEL_{cum}	2.4	0	0	0	0
PTS Peak	**3.1**	0	**34.8**	**4.0**	0

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 majority of the survey would take place in the Southeast Atlantic Ocean between ~33.2°–21°S and 1°W–8°E (see Fig. 1). A small survey area is proposed for the Southwest Atlantic Ocean between ~33.2°–34.3°S and 30.8°–31.8°W (Fig. 1). Seismic acquisition would occur in five survey areas including Libra Massif in the Southwest Atlantic and Valdivia Bank, Gough, Tristan, and Central survey areas in the Southeast Atlantic; representative survey tracklines are shown in Figure 1. R/V *Thompson* would likely depart from Montevideo, Uruguay, on or about 3 November 2019 and would arrive in Walvis Bay, Namibia, on or about 5 December 2019. If the arrival port is Cape Town instead of Walvis Bay, an additional 2 days would be required for transit. Some deviation in timing could also result from unforeseen events such as weather or logistical issues. Seismic operations would occur for ~14 days; 16 days are allotted to transit to and from the project area and between survey areas, and equipment deployment and recovery is expected to take ~3 days.

III. Species and Numbers of Marine Mammals in Area

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

Forty-eight marine mammal species could occur or have been documented to occur in or near the proposed project area in the South Atlantic Ocean, including 9 mysticetes (baleen whales), 34 odontocetes (toothed whales), and 5 pinnipeds (seals) (Table 3). 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.

Thirteen additional species that are known to occur in the South Atlantic but are unlikely to occur within the proposed project area are not discussed further here, as they are either (1) coastally-distributed (e.g., Atlantic humpback dolphin, *Sousa teuszii*; Heaviside's dolphin, *Cephalorhynchus heavisidii*; Chilean dolphin, *C. eutropia*; long-beaked common dolphin, *Delphinus capensis*; Franciscana, *Pontoporia blainvillei*; Guiana dolphin, *Sotalia guianensis*; Burmeister's porpoise, *Phocoena spinipinnis*; West Indian manatee, *Trichechus manatus*; African manatee, *T. senegalensis;* South American fur seal, *Arctocephalus australis*); or (2) occur further south (spectacled porpoise, *Phocoena dioptrica*; Ross seal, *Ommatophoca rossii*; Weddell seal, *Leptonychotes weddellii*). Although a gray whale (*Eschrichtius robustus*) was sighted off Namibia in 2013 (Elwen and Gridley 2013), and the remains of a stranded Omura's whale (*Balaenoptera omurai*) were reported for Mauritania in western Africa (Jung et al. 2016), these species are not considered further as they typically do not occur in the Atlantic Ocean.

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. Five of the 48 marine mammal species that could occur in the proposed project area are listed under the ESA as ***endangered***, including the sperm, sei, fin, blue, and southern right whales. General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of marine mammals are given in § 3.6.1, § 3.7.1, and § 3.8.1 of the PEIS. The rest of this section deals specifically with species distribution in the proposed project area in the South Atlantic Ocean.

TABLE 3. The habitat, occurrence, regional population sizes, and conservation status of marine mammals that could occur in or near the proposed project area in the South Atlantic Ocean.

Species	Occurrence	Habitat	Population Size	ESA[1]	IUCN[2]	CITES[3]
Mysticetes						
Southern right whale	Uncommon	Coastal, shelf, pelagic	12,000[4] 3,300[5]	EN	LC	I
Pygmy right whale	Rare	Coastal, pelagic	N.A.	NL	LC	I
Blue whale	Rare	Coastal, shelf, pelagic	2300 true[4]; 1500 pygmy[6]	EN	EN	I
Fin whale	Uncommon	Coastal, pelagic	15,000[6]	EN	VU	I
Sei whale	Uncommon	Shelf edges, pelagic	10,000[6]	EN	EN	I
Bryde's whale	Common	Coastal, pelagic	48,109[7]	NL	LC	I
Common minke whale	Common	Shelf, pelagic	515,000[4,8]	NL	LC	I
Antarctic minke whale	Uncommon	Shelf, pelagic	515,000[4,8]	NL	NT	I
Humpback whale	Uncommon	Coastal, shelf, pelagic	42,000[4]	NL[9]	LC	I
Odontocetes						
Sperm whale	Uncommon	Slope, pelagic	12,069[10]	EN	VU	I
Pygmy sperm whale	Rare	Shelf, slope, pelagic	N.A.	NL	DD	II
Dwarf sperm whale	Uncommon	Shelf, slope, pelagic	N.A.	NL	DD	II
Arnoux's beaked whale	Uncommon	Pelagic	599,300[11]	NL	DD	I
Cuvier's beaked whale	Uncommon	Slope	599,300[11]	NL	LC	II
Southern bottlenose	Uncommon	Pelagic	599,300[11]	NL	LC	I
Shepherd's beaked	Uncommon	Pelagic	N.A.	NL	DD	II
Blainville's beaked whale	Rare	Slope, pelagic	N.A.	NL	DD	II
Gray's beaked whale	Uncommon	Pelagic	599,300[11]	NL	DD	II
Hector's beaked whale	Rare	Pelagic	N.A.	NL	DD	II
Gervais' beaked whale	Rare	Pelagic	N.A.	NL	DD	II
True's beaked whale	Rare	Pelagic	N.A.	NL	DD	II
Strap-toothed beaked whale	Uncommon	Pelagic	599,300[11]	NL	DD	II
Andrew's beaked whale	Rare	Pelagic	N.A.	NL	DD	II
Spade-toothed beaked whale	Rare	Pelagic	N.A.	NL	DD	II
Risso's dolphin	Common	Slope, shelf, pelagic	18,250[12]	NL	LC	II
Rough-toothed dolphin	Common	Coastal, pelagic	N.A.	NL	LC	II
Common bottlenose dolphin	Uncommon	Coastal, shelf	77,532[12]	NL	LC	II
Pantropical spotted dolphin	Common	Coastal, slope, pelagic	3333[12]	NL	LC	II
Atlantic spotted dolphin	Rare	Shelf, offshore	44,715[12]	NL	LC	II
Spinner dolphin	Uncommon	Coastal, pelagic	N.A.	NL	LC	II
Clymene dolphin	Rare	Pelagic	N.A.	NL	LC	II

Species	Occurrence	Habitat	Population Size	ESA[1]	IUCN[2]	CITES[3]
Striped dolphin	Uncommon	Mainly pelagic	54,807[12]	NL	LC	II
Short-beaked common dolphin	Uncommon	Coastal, pelagic	70,184[12]	NL	LC	II
Fraser's dolphin	Uncommon	Pelagic	N.A.	NL	LC	II
Dusky dolphin	Rare	Coastal, shelf	7252[13]	NL	DD	II
Hourglass dolphin	Rare	Pelagic	150,000[6]	NL	LC	II
Southern right whale dolphin	Uncommon	Pelagic	N.A.	NL	LC	II
Killer whale	Uncommon	Coastal, pelagic	25,000[14]	NL	DD	II
Short-finned pilot whale	Uncommon	Mostly pelagic	200,000[6]	NL	LC	II
Long-finned pilot whale	Uncommon	Shelf, slope, pelagic	200,000[6]	NL	LC	II
False killer whale	Uncommon	Pelagic	N.A.	NL	NT	II
Pygmy killer whale	Uncommon	Pelagic	N.A.	NL	LC	II
Melon-headed whale	Uncommon	Pelagic	N.A.	NL	LC	II
Pinnipeds						
Subantarctic fur seal	Uncommon	Coastal, pelagic	400,000[15]	NL	LC	II
Cape fur seal	Uncommon	Coastal, shelf	~2 million[16]	NL	LC	II
Crabeater seal	Rare	Coastal, pelagic	5-10 million[17]	NL	LC	NL
Leopard seal	Rare	Coastal, pelagic	222,000-440,000[18]	NL	LC	NL
Southern elephant seal	Uncommon	Coastal, pelagic	750,000[19]	NL	LC	II

N.A. = Data not available. NL = Not listed

1 U.S. *Endangered Species Act* (NOAA 2019): EN = Endangered

2 International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2019): EN = Endangered; NT = Near Threatened; VU = Vulnerable; LC = Least Concern; DD = Data Deficient

3 Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2017): Appendix I = Threatened with extinction; Appendix II = not necessarily threatened with extinction but may become so unless trade is closely controlled

4 Southern Hemisphere (IWC 2019)

5 Southwest Atlantic (IWC 2019)

6 Antarctic (Boyd 2002)

7 Southern Hemisphere (IWC 1981)

8 Dwarf and Antarctic minke whales combined

9 There are 14 distinct population segments (DPSs) of humpback whales recognized under the ESA; the Brazil and Gabon/Southwest Africa DPSs are not listed (NOAA 2019)

10 Estimate for the Antarctic, south of 60°S (Whitehead 2002)

11 All beaked whales south of the Antarctic Convergence; mostly southern bottlenose whales (Kasamatsu and Joyce 1995)

12 Estimate for the western North Atlantic (Hayes et al. 2018)

13 Estimate for Patagonian coast (Dans et al. 1997)

14 Minimum estimate for Southern Ocean (Branch and Butterworth 2001)

15 Global population (Hofmeyr and Bester 2018)

16 Butterworth et al. (1995 *in* Kirkman and Arnould 2018)

17 Global population (Bengtson and Stewart 2018)

18 Global population (Rogers 2018)

19 Total world population (Hindell et al. 2016)

Mysticetes

Southern Right Whale (*Eubalaena australis*)

The southern right whale is circumpolar throughout the Southern Hemisphere between 20°S and 55°S (Jefferson et al. 2015), although it may occur farther north where cold-water currents extend northwards (Best 2007). It migrates between summer foraging areas at high latitudes and winter breeding/calving areas in low latitudes (Jefferson et al. 2015). In the South Atlantic, known or historic breeding areas are located in the shallow coastal waters of South America, including Argentina and Brazil, as well as the Falkland Islands, Tristan da Cunha, Namibia, and South Africa (IWC 2001). For 2009, Rowntree et al. (2013) reported that primary calving grounds included an estimated 3373 southern right whales off Argentina, 3864 off South Africa, 1980 off Australia, and 2702 off New Zealand.

Although southern right whale calving/breeding areas are located in nearshore waters, feeding grounds in the Southern Ocean apparently are located mostly in highly-productive pelagic waters (Kenney 2018). Waters south of South Africa are believed to be a nursery area for southern right whales, as females and calves are seen there (Barendse and Best 2014). Right whales with calves are seen in nearshore waters of South Africa during July–November (Best 2007). Nearshore waters off western South Africa might be used as a year-round feeding area (Barendse and Best 2014). The highest sighting rates off western South Africa occur during early austral summer, and the lowest rates have been reported from autumn to mid-winter (Barendse and Best 2014). Although right whales were depleted in the early 19th century by whaling, they are now reappearing off Namibia; this likely indicates a range expansion of the stock from South Africa rather than a separate stock (Roux et al. 2001, 2015). Numerous sightings were made in the area from 1971 through 1999; most sightings were made from July through November, with one sighting during December (Roux et al. 2001). A total of 10 calves were born off Namibia between 1996 and 1999 (Roux et al. 2001). However, Roux et al. (2015) postulated that Namibian waters currently serve as mating grounds rather than a calving area. Best (2007) reported a summer feeding concentration between 30° and 40°S, including the Guyot Province of Walvis Ridge, where three proposed survey areas (Gough, Tristan, Central) are located.

Travel by right whales from the coasts of South America and Africa to the waters of the mid-Atlantic have been documented (Best et al. 1993; Rowntree et al. 2001; Mate et al. 2011). Based on photo-identification work, right whales were reported to have traveled between Gough Island and South Africa, and from Argentina to Tristan da Cunha (Best et al. 1993). Adult right whales at Gough Island were sighted on 10 September 1983, and two adult whales and a calf were observed at Tristan da Cunha on 14 October 1989 (Best et al. 1993). Six right whale sightings were also made in Tristan waters from August–October 1971 (Best and Roscoe 1974). Right whales were also documented to travel from feeding areas off Argentina to South Georgia (Best et al. 1993) and Shag Rocks (Moore et al. 1999). In September 2001, 21 right whales were equipped with radio tags in South Africa (Mate et al. 2011). Five of them migrated southward to waters southeast of Gough Island, Bouvet Island, and beyond; four whales traveled into a potential feeding area in St. Helena Bay on the west coast of South Africa (Mate et al. 2011). Other tagged whales moved southward and appeared to remain near the Subtropical Convergence and Antarctic Polar Front, presumably to feed (Mate et al. 2011). Thus, there is potential for mixing of populations between calving grounds on either side of the South Atlantic Ocean, and at foraging areas near South Georgia (Best et al. 1993; Best 2007; Patenaude et al. 2007).

Best et al. (2009) also reported southern right whale sightings and catches in the Tristan da Cunha archipelago. From 1983 to 1991, 75 sightings totaling 116 right whales were observed during aerial surveys of Tristan waters (Best et al. 2009). One sighting was made off Inaccessible Island; all others were made at Tristan Island (Best et al. 2009). The majority of sightings occurred during September–October, but sightings were also made during April, June–August, and November–December (Best et al. 2009). This region is likely an oceanic nursing area for the right whale (Best et al. 2009). A single southern right whale has been reported for waters near St. Helena, ~15.9°S, 5.7°W (Clingham et al. 2013).

Historically, right whale catches were made between 30 and 40°S, from the coast of Africa to the coast of South America; most catches were made from October–January at whaling grounds including the Tristan and Pegeon grounds, and False and Brazil banks (Townsend 1935 *in* Best et al. 1993; Best et al. 2009). Right whale catches were also made at the Tristan da Cunha archipelago from 1951 to 1971 by Soviet fleets (Tormosov et al. 1998). There are ~3843 records of southern right whales for the South Atlantic in the Ocean Biogeographic Information System (OBIS) database, including nearshore and offshore waters (OBIS 2019). Southern right whales could be seen in any of the proposed survey areas at the time of the survey, in particular in the Gough, Tristan, and Central survey areas.

Pygmy Right Whale (*Caperea marginata*)

The distribution of the pygmy right whale is circumpolar in the Southern Hemisphere between 30°S and 55°S in oceanic and coastal environments (Jefferson et al. 2015; Kemper 2018). The pygmy right whale appears to be non-migratory, although there may be some movement inshore in spring and summer (Kemper 2002; Jefferson et al. 2015), possibly related to food availability (Kemper 2018). Foraging areas are not known, but it seems likely that pygmy right whales may feed at productive areas in higher latitudes, such as near the Subtropical Convergence (Best 2007). There may be hotspots of occurrence where mesozooplankton, such as *Nyctiphanes australis* and *Calanus tonsus*, are plentiful (Kemper et al. 2013).

In the South Atlantic, pygmy right whale records exist for southern Africa, Argentina, Falkland Islands, and pelagic waters (Baker 1985). Leeney et al. (2013) reported 12 strandings and 8 records of skeletal remains for Namibia since 1978. Most of the records are for Walvis Bay; strandings have only been reported during austral summer (November–March). The large number of juveniles suggests that the area may be a nursery ground (Leeney et al. 2013). Best (2007) reported records between 30°S and 40°S, including near the Central survey area. Bester and Ryan (2007) suggested that pygmy right whales occur in the Tristan da Cunha archipelago. One pygmy right whale was taken by whalers at 35°S and 8°W on 30 November 1970 (Budylenko et al. 1973 *in* Best et al. 2009). There are no OBIS records of pygmy right whales for the offshore waters of the proposed survey area, but 10 records exist off southwestern Africa (OBIS 2019). Pygmy right whales could be seen in any of the proposed project area at the time of the surveys, in particular in the Gough, Tristan, and Central survey areas.

Blue Whale (*Balaenoptera musculus*)

The blue whale has a cosmopolitan distribution, but tends to be mostly pelagic, only occurring nearshore to feed and possibly breed (Jefferson et al. 2015). It is most often found in cool, productive waters where upwelling occurs (Reilly and Thayer 1990). 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). Seamounts and other deep ocean structures may be important habitat for blue whales (Lesage et al. 2016). 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). Whereas *B. m. intermedia* (true blue whale) occurs in the Antarctic, *B. m. brevicauda* (pygmy blue whale) inhabits the subantarctic zone (Sears and Perrin 2018). The Antarctic blue whale is typically found south of 55°S during summer, although some do not migrate (Branch et al. 2007a).

An extensive data review and analysis by Branch et al. (2007a) showed that blue whales are essentially absent from the central regions of major ocean basins, including the South Atlantic. Blue whales were captured by the thousands off Angola, Namibia, and South Africa between 1908 and 1967 (Branch et al. 2007a; Figueiredo and Weir 2014), including several catches near the proposed project area during 1958–1973 (including in November and December) and a few sightings off South Africa. However, whales were nearly extirpated in this region, and sightings are now rare (Branch et al. 2007a). At least four records exist for Angola; all sightings were made in 2012, with at least one sighting in July, two in August, and one in October (Figueiredo and Weir 2014). Sightings were also made off Namibia in 2014 from seismic vessels (Brownell et al. 2016). Waters off Namibia may serve as a possible wintering and possible breeding ground for Antarctic blue whales (Best 1998, 2007; Thomisch et al. 2017). Antarctic blue whale calls were detected on acoustic recorders that were deployed northwest of Walvis Ridge (just to the north of the Valdivia Bank survey area) from November 2011 through May 2013 during all months except during September and October, indicating that not all whales migrate to higher latitudes during the summer (Thomisch et al. 2017). Most blue whales in southeastern Africa are expected to be Antarctic blue whales; however, ~4% may be pygmy blue whales (Branch et al. 2007b, 2008). In fact, pygmy blue whale vocalizations were detected off northern Angola in October 2008; these calls were attributed to the Sri Lanka population (Cerchio et al. 2010). One offshore sighting of a blue whale was made at 13.4°S, 26.8°W and the other at 15.9°S, 4.6°W (Branch et al. 2007a; OBIS 2019). The occurrence of blue whales in the Tristan da Cunha archipelago also seems likely (Bester and Ryan 2007). There are ~1845 blue whale records for the South Atlantic in the OBIS database; however, no records occur within the proposed project area (OBIS 2019). Blue whales could be encountered during the proposed surveys, in particular in the Valdivia Bank survey area.

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 is 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 the summer; they are 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 and not all populations follow this simple pattern (Jefferson 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).

In the Southern Hemisphere, fin whales are typically distributed south of 50ºS in the austral summer, migrating northward to breed in the winter (Gambell 1985). Historical whaling data showed several catches for the Tristan da Cunha archipelago (Best et al. 2009), as well as off Namibia and southern Africa (Best 2007). Fin whales appear to be somewhat common in the Tristan da Cunha archipelago from October–December (Bester and Ryan 2007). According to Edwards et al. (2015), sightings have been made south of South Africa from December–February; they did not report any sightings or acoustic detections near the proposed project area. Several fin whales sightings and strandings have been reported for Namibia in the last decade (NDP unpublished data *in* Pisces Environmental Services 2017). Fin whale calls were detected on acoustic recorders that were deployed northwest of Walvis Ridge from November 2011 through May 2013 during the months of November, January, and June through August, indicating that the waters off Namibia serve as wintering grounds (Thomisch et al. 2017). Similarly, Best (2007) also suggested that waters off Namibia may be wintering grounds.

Several sightings were made off western South Africa during November 2009; one sighting was reported near 30°S and 2°E (near the proposed Tristan survey area), and several other sightings were made near 35°S and 11°E (Shirshov Institute n.d.). Two sightings were made during seismic surveys off the coast of northern Angola between 2004 and 2009 (Weir 2011). Forty fin whales were seen during a transatlantic voyage along 20°S during August 1943 between 5° and 25°W (Wheeler 1946 *in* Best 2007). A group of two fin whales was sighted near Trindade Island, at 20.5°S, 29.3°W, on 31 August 2010 (Wedekin et al. 2014). A fin whale sighting was also made southeast of the survey areas at ~41°S, 15°W (Scheidat et al. 2011). There are ~2570 fin whale records in the OBIS database for the South Atlantic; no records occur within the proposed project area (OBIS 2019). Fin whales could be encountered during the proposed project area during their migration to more southerly latitudes.

Sei Whale (*Balaenoptera borealis*)

The sei whale occurs in all ocean basins (Horwood 2018), predominantly inhabiting deep water throughout its range (Acevedo et al. 2017). It undertakes seasonal migrations to feed in sub-polar latitudes during summer, returning to lower latitudes during winter to calve (Horwood 2018). In the Southern Hemisphere, sei whales typically concentrate between the Subtropical and Antarctic convergences during the summer (Horwood 2018) between 40ºS and 50ºS; larger, older whales typically travel into the northern Antarctic zone while smaller, younger individuals remain in the lower latitudes (Acevedo et al. 2017). Best (2007) showed summer concentrations between 30ºS and 50ºS, including near the three proposed survey areas (Central, Tristan, Gough) in the Guyot Province of Walvis Ridge. Waters off northern Namibia may serve as wintering grounds (Best 2007).

A sighting of a mother and calf were made off Namibia in March 2012, and one stranding was reported in July 2013 (NDP unpublished data *in* Pisces Environmental Services 2017). One sighting was made during seismic surveys off the coast of northern Angola between 2004 and 2009 (Weir 2011). A group of 2–4 sei whales was seen near St. Helena during April 2011 (Clingham et al. 2013). Although the occurrence of sei whales is likely in the Tristan da Cunha archipelago (Bester and Ryan 2007), there have been no recent records of sei whales in the region; however, sei whale catches were made here in the 1960s (Best et al. 2009). Sei whales were also taken off southern Africa during the 1960s, with some catches reported just to the southeast of the proposed survey area; catches were made during the May–July northward migration as well as during the August–October southward migration (Best and Lockyer 2002). In the OBIS database, there are 40 sei whale records for the South Atlantic; the closest records were reported at 33.3°S, 8.0°W and 35.1°S, 6.4°W (OBIS 2019). Sei whales could be encountered in any of the proposed survey areas at the time of the surveys, in particular in the Gough, Tristan, and Central survey areas.

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 (Jefferson et al. 2015). 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 (Kato and Perrin 2018), but analyses have shown that it prefers water <20.6°C in the eastern tropical Atlantic (Weir et al. 2012). Seasonal movements have been recorded towards the Equator in winter and offshore in summer (Kato and Perrin 2018). It is frequently observed in biologically productive areas such as continental shelf breaks (Davis et al. 2002) and regions subjected to coastal upwelling (Gallardo et al. 1983; Siciliano et al. 2004). Central oceanic waters of the South Atlantic, including the proposed project area, are considered part of its secondary range (Jefferson et al. 2015).

In southern Africa, there are likely three populations of Bryde's whales — an inshore population, a pelagic population of the Southeast Atlantic stock, and the Southwest Indian Ocean stock (Best 2001). The Southeast Atlantic stock ranges from the equator to ~34°S and migrates north in the fall and south during the spring, with most animals occurring off Namibia during the austral summer (Best 2001). Numerous sightings have been made off Gabon (Weir 2011), Angola (Weir 2010, 2011), and South Africa (Findlay et al. 1992), including in deep slope waters. Strandings have also been reported along the Namibian coast (Pisces Environmental Services 2017). Bryde's whale was sighted in the offshore waters of the South Atlantic during a cruise from Spain to South Africa in November 2009, near 22°S, 6°W (Shirshov Institut n.d.). In the OBIS database, there are 12 records off the coast of South Africa (OBIS 2019). Bryde's whales are not expected to occur in the Libra Massif survey area. However, they could be encountered in the rest of the proposed project area, in particular the eastern portions of the Valdivia Bank survey area.

Common Minke Whale (*Balaenoptera acutorostrata*)

The common minke whale has a cosmopolitan distribution ranging from the tropics and subtropics to the ice edge in both hemispheres (Jefferson et al. 2015). A smaller form (unnamed subspecies) of the common minke whale, known as the dwarf minke whale, occurs in the Southern Hemisphere, where its distribution overlaps with that of the Antarctic minke whale (*B. bonaerensis*) during summer (Perrin et al. 2018). The dwarf minke whale is generally found in shallower coastal waters and over the shelf in regions where it overlaps with *B. bonaerensis* (Perrin et al. 2018). The range of the dwarf minke whale is thought to extend as far south as 65°S (Jefferson et al. 2015) and as far north as 2°S in the Atlantic off South America, where it can be found nearly year-round (Perrin et al. 2018). It is known to occur off South Africa during autumn and winter (Perrin et al. 2018), but has not been reported for the waters off Angola or Namibia (Best 2007). It is likely to occur in the waters of the Tristan da Cunha archipelago (Bester and Ryan 2007). There are 36 records for the South Atlantic in the OBIS database, including records off South America and along the coast of Namibia and South Africa; there are no records in the proposed project area (OBIS 2019). Dwarf minke whales could be encountered in the proposed project area at the time of the surveys.

Antarctic Minke Whale (*Balaenoptera bonaerensis*)

The Antarctic minke whale has a circumpolar distribution in coastal and offshore areas of the Southern Hemisphere from ~7°S to the ice edge (Jefferson et al. 2015). It is found between 60°S and the ice edge during the austral summer; in the austral winter, it is mainly found at mid-latitude breeding grounds, including off western South Africa and northeastern Brazil, where it is primarily oceanic, occurring beyond the shelf break (Perrin et al. 2018). Antarctic minke whale densities are highest near pack ice edges, although they are also found amongst pack ice (Williams et al. 2014), where they feed almost entirely on krill (Tamura and Konishi 2009).

In the Southeast Atlantic, Antarctic minke whales have been reported for the waters of South Africa, Namibia, and Angola (Best 2007). Antarctic minke whale calls were detected on acoustic recorders that were deployed northwest of Walvis Ridge from November 2011 through May 2013 during the months of November, December, January, and June through August, indicating that not all whales migrate to higher latitudes during the summer (Thomisch et al. 2017). Sightings have also been made along the coast of Namibia, in particular during summer (NPD unpublished data *in* Pisces Environmental Services 2017). Antarctic minke whales are also likely to occur in the Tristan da Cunha archipelago (Bester and Ryan 2007). Two groups totaling seven whales were sighted at 36.4°S, 8.5°W on 7 October 1988 (Best et al. 2009). A sighting of two whales was made off Brazil during an August–September 2010 survey from Vitória, at ~20°S, 40°W, to Trindade and Martim Vaz islands; the whales were seen in association with a group of rough-toothed dolphins near 19.1°S, 35.1°W on 21 August (Wedekin et al. 2014). There are five OBIS records for the South Atlantic, including along the coast of South America and South Africa; there are no records for the proposed project area (OBIS 2019). Antarctic minke whales could be encountered in the proposed project area at the time of the surveys.

Humpback Whale (*Megaptera novaeangliae*)

The humpback whale is found in all ocean basins (Clapham 2018). Based on recent genetic data, there could be three subspecies, occurring in the North Pacific, North Atlantic, and Southern Hemisphere (Jackson et al. 2014). The humpback whale 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; NOAA 2019). Although considered to be mainly a coastal species, it often traverses deep pelagic areas while migrating (Baker et al. 1998; Garrigue et al. 2002; Zerbini et al. 2011).

In the Southern Hemisphere, humpback whales migrate annually from summer foraging areas in the Antarctic to breeding grounds in tropical seas (Clapham 2018). The IWC recognizes seven breeding populations in the Southern Hemisphere that are linked to six foraging areas in the Antarctic (Clapham 2018). Two of the breeding grounds are in the South Atlantic, off Brazil and West Africa (Engel and Martin 2009). Bettridge et al. (2015) identified humpback whales at these breeding locations as the Brazil and Gabon/Southwest Africa DPSs. Breeding stock 'A' consists of whales that occur between ~5°S and 23°S in the coastal waters off Brazil (e.g., Andriolo et al. 2010; Kershaw et al. 2017). The southeastern Atlantic breeding stock 'B' occurs off western Africa (Rosenbaum et al. 2009; Carvalho et al. 2011). Migrations, song similarity, and genetic studies indicate some interchange between Breeding Stock 'A' and 'B' (Rosenbaum et al. 2009; Kershaw et al. 2017). Similarities in humpback whale songs have been demonstrated between Brazil and Gabon (Darling and Sousa-Lima 2005). Genetic data also show relatively high effective migration rates between western and eastern Africa (Rosenbaum et al. 2009). Based on photo-identification work, one female humpback whale traveled from Brazil to Madagascar, a distance of >9800 km (Stevick et al. 2011). Deoxyribonucleic acid (DNA) sampling showed evidence of a male humpback having traveled from western Africa to Madagascar (Pomilla and Rosenbaum 2005).

There may be two breeding substocks in Gabon/Southwest Africa, including individuals in the main breeding area in the Gulf of Guinea and those animals migrating past Namibia and South Africa (Rosenbaum et al. 2009; Barendse et al. 2010a; Branch 2011; Carvalho et al. 2011). Migration rates are relatively high between populations within the southeastern Atlantic (Rosenbaum et al. 2009). However, Barendse et al. (2010a) reported no matches between individuals sighted in Namibia and South Africa based on a comparison of tail flukes. In addition, wintering humpbacks have also been reported on the continental shelf of northwest Africa, which may represent the northernmost humpback whales that are known to winter in the Gulf of Guinea (Van Waerebeek et al. 2013). Feeding areas for this stock include Bouvet Island (Rosenbaum et al. 2014) and waters of the Antarctic Peninsula (Barendse et al. 2010b).

Humpbacks have been seen on breeding grounds around São Tomé in the Gulf of Guinea from August through November; off Gabon, whales occur from late June–December (Carvalho et al. 2011). The west coast of South Africa might not be a 'typical' migration corridor, as humpbacks are also known to feed in the area; they are known to occur in the region during the northward migration (July–August), the southward migration (October–November), and into February (Barendse et al. 2010b; Carvalho et al. 2011; Seakamela et al. 2015). The highest sighting rates in the area occurred during mid-spring through summer (Barendse et al. 2010b). Off Namibia, the main peak of occurrence is during winter (July), with another peak during spring (September); however, this area is unlikely to be a breeding area (Elwen et al. 2014).

Elwen et al. (2014) suggested that humpbacks are migrating northward past Namibia during winter and migrate closer to shore during a southward migration during spring/summer. Humpback whale calls were detected on acoustic recorders that were deployed northwest of Walvis Ridge from November 2011 through May 2013 during the months of November, December, January, and May through August, indicating that not all whales migrate to higher latitudes during the summer (Thomisch et al. 2017). Based on whales that were satellite-tagged in Gabon in winter 2002, migration routes southward include offshore waters along Walvis Ridge (Rosenbaum et al. 2014). Hundreds of sightings have been made during seismic surveys off the coast of Angola between 2004 and 2009, including in deep slope water; most sightings were reported during winter and spring (Weir 2011). Best et al. (1999) reported some sightings off the coast of Angola during November 1995. Humpback whale acoustic detections were made in the area from June through December 2008 (Cerchio et al. 2014).

Humpbacks occur occasionally around the Tristan da Cunha archipelago (Bester and Ryan 2007). Three records exist for Tristan waters, all south of 37°S (Best et al. 2009). Humpback whales have also been sighted off St. Helena (MacLeod and Bennett 2007; Clingham et al. 2013). Numerous humpbacks were detected visually and acoustically during a survey off Brazil from Vitória at ~20°S, 40°W, to Trindade and Martim Vaz islands during August–September 2010 (Wedekin et al. 2014). One adult humpback was seen on 31 August near Trindade Island, at 20.5°S, 29.3°W in a water depth of 150 m, but no acoustic detections were made east of 35°W (Wedekin et al. 2014). Numerous sightings were also made near Trindade Island during July–August 2007 and before that date (Siciliano et al. 2012). For the South Atlantic, the OBIS database shows over 700 records for the South Atlantic, including along the coast of South America and western Africa, and in offshore waters of the central Atlantic (OBIS 2019). The closest sightings to the proposed survey areas in the southeastern Atlantic occur near the Gough survey area at 33.8°S, 2.1°E and 32.5°S, 3.8°E (OBIS 2019). The waters of the proposed project area are considered part of the humpback's secondary range (Jefferson et al. 2015). However, humpback whales could be encountered at the time of the proposed surveys, in particular in the Valdivia Bank survey area.

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 according to an unknown schedule (Whitehead 2018). In the eastern tropical Atlantic, sperm whales were shown to prefer habitat with sea surface temperatures >23.6°C (Weir et al. 2012).

Whaling data from the South Atlantic indicate that sperm whales may be migratory off South Africa, with peak abundances reported in the region during autumn and late winter/spring (Best 2007). The waters of northern Namibia and Angola were also historical whaling grounds (Best 2007; Weir 2019). Sperm whales were the most frequently sighted cetacean during seismic surveys off the coast of northern Angola between 2004 and 2009; hundreds of sightings were made off Angola and a few sightings were reported off Gabon (Weir 2011). Sperm whales have also been sighted off South Africa during surveys of the Southern Ocean (Van Waerebeek et al. 2010). In addition, a sighting was made at 30.1°S, 14.3°E (Clingham et al. 2013). Bester and Ryan (2007) reported that sperm whales might be common in the Tristan da Cunha archipelago. Catches of sperm whales in the 19th century were made in Tristan waters between October and January (Townsend 1935 *in* Best et al. 2009), and catches also occurred there in the 1960s (Best et al. 2009). One group was seen at St. Helena during July 2009 (Clingham et al. 2013). There are ~3080 records of sperm whales for the South Atlantic in the OBIS database, including nearshore waters of South American and Africa and offshore waters (OBIS 2019). Most (3069) records are from historical catch data, which include captures within the proposed project area (OBIS 2019). Sperm whales could be encountered in the proposed project area at the time of the surveys.

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

Dwarf and pygmy sperm whales are distributed throughout tropical and temperate waters of the Atlantic, Pacific and Indian oceans, but their precise distributions are unknown because much of what we know of the species comes from strandings (McAlpine 2018). They 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). The two species are often difficult to distinguish from one another when sighted (McAlpine 2018).

Both *Kogia* species are sighted 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). Stomach content analyses from stranded whales further support this distribution (McAlpine 2018). Recent data indicate that both *Kogia* species feed in the water column and on/near the seabed, likely using echolocation to search for prey (McAlpine 2018). Several studies have suggested that pygmy sperm whales live and feed mostly beyond the continental shelf edge, whereas dwarf sperm whales tend to occur closer to shore, often over the continental shelf and slope (Rice 1998; Wang et al. 2002; MacLeod et al. 2004; McAlpine 2018). Barros et al. (1998), on the other hand, suggested that dwarf sperm whales could be more pelagic and dive deeper than pygmy sperm whales. It has also 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; McAlpine 2018). This idea is also supported by the distribution of strandings in South American waters (Muñoz-Hincapié et al. 1998; Moura et al. 2016).

Both species are known to occur in the South Atlantic, occurring as far south as northern Argentina in the west and South Africa in the east (Jefferson et al. 2015). There are 30 records of *Kogia* sp. for Namibia; most of these are strandings of pygmy sperm whales, but one live stranding of a dwarf sperm whale has also been reported (Elwen et al. 2013). Twenty-six sightings of dwarf sperm whales were made during seismic surveys off the coast Angola between 2004 and 2009 (Weir 2011). Findlay et al. (1992) reported numerous records of dwarf sperm whales for South Africa. *Kogia* sp. were sighted during surveys off St. Helena during August–October 2004 (Clingham et al. 2013). There are no records of *Kogia* sp. in the offshore waters of the proposed survey area (OBIS 2019). The only records in the OBIS database for the South Atlantic are for Africa; there are 57 records of *K. breviceps* and 22 records of *K. sima* exist for southwestern Africa (OBIS 2019). Both pygmy and dwarf sperm whales could be encountered in the proposed project area at the time of the surveys.

Arnoux's Beaked Whale (*Berardius arnuxii*)

Arnoux's beaked whale is distributed in deep, cold, temperate, and subpolar waters of the Southern Hemisphere, occurring between 24ºS and Antarctica (Thewissen 2018). Most records exist for southeastern South America, Falkland Islands, Antarctic Peninsula, South Africa, New Zealand, and southern Australia (MacLeod et al. 2006; Jefferson et al. 2015). One sighting was made south of Africa at ~40°S during surveys of the Southern Ocean (Van Waerebeek et al. 2010). Arnoux's beaked whales likely occur in the Tristan da Cunha archipelago (Bester and Ryan 2007). There are three OBIS records for the Southeast

Atlantic in South Africa and no records for the Southwest Atlantic (OBIS 2019). Based on information presented in Best (2007), it is more likely to be encountered in the southern Central, Gough, and Tristan survey areas than in the more northern survey area.

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). It is rarely observed at sea and is known mostly from strandings; it strands more commonly than any other beaked whale (Heyning 1989). 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).

In the South Atlantic, there are stranding records for Brazil, Uruguay, Argentina, Falkland Islands, Namibia, and South Africa (MacLeod et al. 2006; Otley et al. 2012; Bakara and Norman 2013; Fisch and Port 2013; Bortolotto et al. 2016; Riccialdelli et al. 2017). Sighting records exist for nearshore Brazil, South Africa, central South Atlantic, and Southern Ocean (Findlay et al. 1992; MacLeod et al. 2006; Prado et al. 2016), as well as for Gabon (Weir 2007) and Angola (Best 2007; Weir 2019). UNEP/CMS (2012) reported its presence in Namibia. Bester and Ryan (2007) suggested that Cuvier's beaked whales likely occur in the Tristan da Cunha archipelago. There are 11 OBIS records for the South Atlantic, including Brazil, Namibia, and South Africa; however, there are no records within or near the proposed project area (OBIS 2019). Cuvier's beaked whale could be encountered in the proposed project area at the time of the surveys.

Southern Bottlenose Whale (*Hyperoodon planifrons*)

The southern bottlenose whale is found throughout the Southern Hemisphere from 30°S to the ice edge, with most sightings reported between ~57°S and 70°S (Jefferson et al. 2015; Moors-Murphy 2018). It is apparently migratory, occurring in Antarctic waters during summer (Jefferson et al. 2015). Several sighting and stranding records exist for southeastern South America, Falkland Islands, South Georgia Island, southeastern Brazil, Argentina, South Africa, and numerous sightings have been reported for the Southern Ocean (Findlay et al. 1992; MacLeod et al. 2006; Santos and Figueiredo 2016; Riccialdelli et al. 2017). Southern bottlenose whales were sighted near 45°S and south of there during surveys of the Southern Ocean (Van Waerebeek et al. 2010). There are eight records in the OBIS database for the South Atlantic, including one in the central South Atlantic at 37.1°S, 12.3°W, as well as Brazil, Namibia, and South Africa (OBIS 2019). Based on limited information on its distributional range (Best 2007; Jefferson et al. 2015), the southern bottlenose whale is more likely to occur in the southern survey areas than the Valdivia Bank survey area.

Shepherd's Beaked Whale (*Tasmacetus shepherdi*)

Based on known records, it is likely that Shepherd's beaked whale has a circumpolar distribution in the cold temperate waters of the Southern Hemisphere, between 33–50ºS (Mead 2018). It is primarily known from strandings, most of which have been recorded in New Zealand and the Tristan da Cunha archipelago (Pitman et al. 2006; Mead 2018). The Tristan da Cunha archipelago has the second highest number of strandings (Mead 2018) and is thought to be a concentration area for Shepherd's beaked whales (Bester and Ryan 2007; Best et al. 2009). Pitman et al. (2006) and Best et al. (2009) reported six stranding records for Tristan da Cunha and possible sightings on the Tristan Plateau (2 sightings of 10 whales on 17 November 1985 near 37.3°S, 12.5°W) and Gough Island (one sighting of 4–5 animals). Another stranding of two whales on Tristan da Cunha occurred on 13 January 2012 (Best et al. 2014). Shepherd's beaked whales were sighted south of Africa during surveys of the Southern Ocean (Van Waerebeek et al. 2010). There are three records for the South Atlantic in the OBIS database, all southwest of South Africa

(OBIS 2019). Based on limited information on its distributional range (Best 2007; Jefferson et al. 2015), Shepherd's beaked whale is more likely to occur in the southern survey areas than the Valdivia Bank survey area.

Blainville's Beaked Whale (*Mesoplodon densirostris*)

Blainville's beaked whale is found in tropical and warm temperate waters of all oceans (Pitman 2018). It has the widest distribution throughout the world of all *Mesoplodon* species (Pitman 2018). In the South Atlantic, strandings have been reported for southern Brazil and South Africa (Findlay et al. 1992; Secchi and Zarzur 1999; MacLeod et al. 2006; Prado et al. 2016). A sighting was made during a boat survey off St. Helena in November 2007 (Clingham et al. 2013). There are 20 OBIS records for South Africa, but none for the offshore waters of the proposed project area (OBIS 2019). Based on limited information on its distributional range (Best 2007; Jefferson et al. 2015), Blainville's beaked whale could be encountered in the proposed project area.

Gray's Beaked Whale (*Mesoplodon grayi*)

Gray's beaked whale is thought to have a circumpolar distribution in temperate waters of the Southern Hemisphere (Pitman 2018). It primarily occurs in deep waters beyond the edge of the continental shelf (Jefferson et al. 2015). Some sightings have been made in very shallow water, usually of sick animals coming in to strand (Gales et al. 2002; Dalebout et al. 2004). There are numerous sighting records from Antarctic and sub-Antarctic waters (MacLeod et al. 2006); in summer months, Gray's beaked whales appear near the Antarctic Peninsula and along the shores of the continent (sometimes in the sea ice).

In the South Atlantic, several stranding records exist for Brazil, the southeast coast of South America, Falkland Islands, Namibia, and South Africa (Findlay et al. 1992; MacLeod et al. 2006; Otley 2012; Otley et al. 2012; Prado et al. 2016; Riccialdelli et al. 2017). Additionally, one sighting was reported off the southwestern tip of South Africa (MacLeod et al. 2006). A sighting was also made south of Arica near 45°S during surveys of the Southern Ocean (Van Waerebeek et al. 2010). UNEP/CMS (2012) reported their presence in Namibia. Gray's beaked whales likely occur in the Tristan da Cunha archipelago (Bester and Ryan 2007). However, there are no OBIS records for the offshore waters of the proposed project area, but there are records for Argentina and South Africa (OBIS 2019). Based on limited information on its distributional range (Best 2007; Jefferson et al. 2015). Gray's beaked whale is more likely to occur in the southern survey areas than the Valdivia Bank survey area.

Hector's Beaked Whale (*Mesoplodon hectori*)

Hector's beaked whale is thought to have a circumpolar distribution in temperate waters of the Southern Hemisphere (Pitman 2018). Like other Mesoplodonts, Hector's beaked whale likely inhabits deep waters (200–2000 m) in the open ocean or continental slopes (Pitman 2018). To date, Hector's beaked whales have only been identified from strandings and have not been observed in the wild (Pitman 2018). Based on the number of stranding records for the species, it appears to be relatively rare. Nonetheless, in the South Atlantic, strandings have been reported for southern Brazil, Argentina, Falkland Islands, and South Africa (MacLeod et al. 2006; Otley et al. 2012; Prado et al. 2016; Riccialdelli et al. 2017). However, there are no OBIS records for this species for the South Atlantic (OBIS 2019). Based on limited information on its distributional range (Best 2007; Jefferson et al. 2015). Hector's beaked whale is more likely to occur in the southern survey areas than the Valdivia Bank survey area.

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). Stranding records have been reported for Brazil and Ascension Island in the central South Atlantic (MacLeod et al. 2006). The southernmost stranding record was reported for São Paulo, Brazil, possibly expanding the known distributional range of this species southward (Santos et al. 2003). Although the distribution range of Gervais' beaked whale is not generally known to extend as far south as the proposed project area, this species might range as far south as Angola or northern Namibia in the South Atlantic (MacLeod et al. 2006; Best 2007; Jefferson et al. 2015). In fact, one stranding has been reported for Namibia (Bachara and Norman 2014). There are no OBIS records for the South Atlantic (OBIS 2019). Gervais' beaked whale could be encountered in the proposed project area at the time of the surveys.

True's Beaked Whale (*Mesoplodon mirus*)

True's beaked whale has a disjunct, antitropical distribution (Jefferson et al. 2015). In the Southern Hemisphere, it is known to occur in South Africa, South America, and Australia (Findlay et al. 1992; Souza et al. 2005; MacLeod and Mitchell 2006; MacLeod et al. 2006; Best et al. 2009). These areas may comprise three separate populations; the region of South Africa in the Indian Ocean is considered a key beaked whale area (MacLeod and Mitchell 2006). In the South Atlantic, True's beaked whale has stranded on Tristan da Cunha (Best et al. 2009). Based on stranding and sighting data, the proposed southern project area, including southern waters of Valdivia Bank survey area, is part of the possible range of True's beaked whale (MacLeod et al. 2006; Best 2007; Jefferson et al. 2015). There are 14 OBIS records for the South Atlantic, all for the off South Africa (OBIS 2019). True's beaked whale could be encountered in the proposed project area at the time of the surveys.

Strap-toothed Beaked Whale (*Mesoplodon layardii*)

The strap-toothed beaked whale is thought to have a circumpolar distribution in temperate and subantarctic waters of the Southern Hemisphere, mostly between 32° and 63°S (MacLeod et al. 2006; Jefferson et al. 2015). It may undertake limited migration to warmer waters during the austral winter (Pitman 2018). Strap-toothed beaked whales are thought to migrate northward from Antarctic and subantarctic latitudes during April–September (Sekiguchi et al. 1995).

In the South Atlantic, stranding records have been reported for Brazil, Uruguay, Argentina, Falkland Islands, South Georgia, Namibia, and South Africa (Findlay et al. 1992; Pinedo et al. 2002; MacLeod et al. 2006; Otley et al. 2012; Prado et al. 2016; Riccialdelli et al. 2017). In addition, sightings have been reported off the southern tip of Africa, near Bouvet Island, and in the Southern Ocean (Finlay et al. 1992; MacLeod et al. 2006). One sighting was made south of Africa during surveys of the Southern Ocean (Van Waerebeek et al. 2010). Bester and Ryan (2007) suggested that strap-toothed beaked whales likely occur in the Tristan da Cunha archipelago (Bester and Ryan 2007). There are 38 OBIS records for the South Atlantic, including for Argentina, Namibia, and South Africa; however, there are no records in the offshore waters of the proposed project area (OBIS 2019). Based on limited information on its distributional range (Best 2007; Jefferson et al. 2015), strap-toothed beaked whales are more likely to occur in the southern survey areas than the Valdivia Bank survey area.

Andrew's Beaked Whale (*Mesoplodon bowdoini*)

Andrew's beaked whale has a circumpolar distribution in temperate waters of the Southern Hemisphere (Baker 2001; Pitman 2018). It is known only from stranding records between 32°S and 55°S, with more than half of the strandings occurring in New Zealand (Jefferson et al. 2015). In the South Atlantic, Andrew's beaked whales have also stranded in the Tristan da Cunha archipelago, Falkland Islands, Argentina, and Uruguay (Baker 2001; Laporta et al. 2005; MacLeod et al. 2006; Best et al. 2009; Otley et al. 2012; Riccialdelli et al. 2017). There are no OBIS records for the South Atlantic (OBIS 2019). Based on limited information on its distributional range (Best 2007; Jefferson et al. 2015), Andrew's beaked whale is more likely to occur in the southern survey areas than the Valdivia Bank survey area.

Spade-toothed Beaked Whale (*Mesoplodon traversii)*

The spade-toothed beaked whale is the name proposed for the species formerly known as Bahamonde's beaked whale (*M. bahamondi*); genetic evidence has shown that it belongs to the species first identified by Gray in 1874 (Van Helden et al. 2002). The spade-toothed beaked whale is considered relatively rare and is known from only four records, three from New Zealand and one from Chile (Thompson et al. 2012). Although no records currently exist for the South Atlantic, the known records at similar latitudes suggest that the spade-toothed beaked whale could occur in the proposed project area.

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 southeastern Atlantic Ocean, there are records spanning from Gabon to South Africa (Jefferson et al. 2014). It appears to be relatively common off Angola; 75 sightings were made during seismic surveys off the coast of northern Angola between 2004 and 2009, including in deep slope waters (Weir 2011). Four sightings were also made off Gabon (Weir 2011). It was also sighted during surveys off southern Africa, and there are stranding records for Namibia (Findlay et al. 1992). There are 54 records for the South Atlantic in the OBIS database, including for Argentina, Namibia, and South Africa; however, there are no records in the proposed project area. Risso's dolphin could be encountered in the proposed survey areas at the time of the surveys.

Rough-toothed Dolphin (*Steno bredanensis*)

The rough-toothed dolphin is distributed worldwide in tropical and subtropical waters (Jefferson et al. 2015). It is generally seen in deep, oceanic water, although it is known to occur in coastal waters of Brazil (Jefferson et al. 2015; Cardoso et al. 2019). In the Southeast Atlantic, rough-toothed dolphins have been sighted off Namibia (Findlay et al. 1992), Gabon (de Boer 2010), and Angola (Weir 2007, 2010). Eighteen sightings were made during seismic surveys off the coast of northern Angola between 2004 and 2009, including in deep slope waters; one sighting was also made off Gabon (Weir 2011). Rough-toothed dolphins have also been sighted at St. Helena (MacLeod and Bennett 2007; Clingham et al. 2013), near the Central survey area at 32.5°S, 2.0°W (Peters 1876 *in* Best et al. 2009), and near 37°S, 15°E (Scheidat et al. 2011). One rough-toothed dolphin sighting was made during an August–September 2010 survey off Brazil from Vitória at ~20°S, 40°W to Trindade and Martim Vaz islands; the group of 30 individuals was seen in association with two minke whales at ~19.1°S, 35.1°W on 21 August (Wedekin et al. 2014). For the South Atlantic, there are 42 records of rough-toothed dolphin in the OBIS database, including off Brazil, central West Africa, and South Africa (OBIS 2019). Rough-toothed dolphins could be encountered in the proposed project area during the surveys.

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). Jefferson et al. (2015) reported central pelagic waters of the South Atlantic Ocean (within the proposed project area) as secondary range for the bottlenose dolphin. In the southeastern South Atlantic, common bottlenose dolphins occur off Gabon (de Boer 2010), Angola

(Weir 2007, 2010), Namibia (Findlay et al. 1992; Peddemors 1999), and South Africa (Findlay et al. 1992). Off Namibia, there is likely an inshore and an offshore ecotype (Peddemors 1999). Numerous sightings were made during seismic surveys off the coast of northern Angola between 2004 and 2009, including in deep slope waters; sightings were also made off Gabon (Weir 2011).

Three sightings of common bottlenose dolphins were made at Trindade Island during December 2009–February 2010 surveys; two sightings of 15 individuals were made during December and a single bottlenose dolphin was sighted on 23 February (Carvalho and Rossi-Santos 2011). Additionally, two sightings of common bottlenose dolphins were made during an August–September 2010 survey from Vitória at ~20°S, 40°W to Trindade and Martim Vaz islands; both groups were seen on 30 August at Trindade Island, near 20.5°S, 29.3°W (Wedekin et al. 2014). Common bottlenose dolphins have also been sighted near St. Helena (MacLeod and Bennett 2007; Clingham et al. 2013). There are 132 OBIS records for the western and eastern South Atlantic; however, there are no records in the offshore waters of the proposed project area (OBIS 2019). Common bottlenose dolphins could be encountered in the proposed project area during the surveys (Jefferson et al. 2015).

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 South Atlantic, pantropical spotted dolphins have been sighted off Brazil (Moreno et al. 2005), Gabon (de Boer 2010), Angola (Weir 2007, 2010), and St. Helena (MacLeod and Bennett 2007; Clingham et al. 2013). Four sightings were made during seismic surveys off the coast off northern Angola between 2004 and 2009, including in deep slope waters; and additional four sightings were made off Gabon (Weir 2011). Findlay et al (1992) reported sightings off the east coast of South Africa. In the OBIS database, there is one record for Brazil and one record for South Africa (OBIS 2019). Based on its distributional range (Best 2007; Jefferson et al. 2015), pantropical spotted dolphins could be encountered during the proposed surveys.

Atlantic Spotted Dolphin (*Stenella frontalis*)

The Atlantic spotted dolphin is distributed in tropical and warm temperate waters of the North Atlantic 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). Although its distributional range appears to be just to the north of the proposed project area (Best 2007; Jefferson et al. 2015), Culik (2004) reported its presence in Namibia. These dolphins were one of the most frequently sighted cetaceans during seismic surveys off the coast of northern Angola between 2004 and 2009, including in deep slope waters; about 100 sightings were made off Angola and several sightings were also made off Gabon (Weir 2011). For the South Atlantic, there is one record for Brazil in the OBIS database (OBIS 2019). Atlantic spotted dolphins could be encountered in the proposed project area during the surveys.

Spinner Dolphin (*Stenella longirostris*)

The spinner dolphin is pantropical in distribution, with a range nearly identical to that of the pantropical spotted dolphin, 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). Spinner dolphins are extremely gregarious, and usually form large schools in the open sea and small ones in coastal waters (Perrin and Gilpatrick 1994).

Its distributional range appears to be to the north of the proposed survey area in the South Atlantic (Best 2007; Jefferson et al. 2015). One group of three individuals was seen near the 1000-m isobath during seismic surveys off the coast of northern Angola between 2004 and 2009 (Weir 2011). There are two OBIS records for the South Atlantic: one sighting north of the Falkland Islands at 47.4°S, 54.2°W and another off Brazil (OBIS 2019). Based on distributional information (Best 2007; Jefferson et al. 2015), spinner dolphins could be encountered during the proposed surveys, most likely in the northern parts of the Valdivia Bank survey area.

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). 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). In the eastern Atlantic, they have been sighted as far south as Angola (Weir 2006; Weir et al. 2014). One sighting was made during seismic surveys off the coast of northern Angola between 2004 and 2009 (Weir 2011). Currently available information indicates that only the northern-most proposed project area might overlap with its distributional range (e.g., Fertl et al. 2003; Best 2007; Jefferson et al. 2015), although Weir et al. (2014) noted that it is unlikely that this species occurs farther south than Angola due to the cold Benguela Current there. There are no OBIS records for the South Atlantic (OBIS 2019). Based on distributional information (Best 2007; Jefferson et al. 2015), Clymene dolphins could be encountered in the northern parts of the Valdivia Bank survey area.

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. 1994; Jefferson et al. 2015). It occurs primarily in pelagic waters, but has been observed approaching shore where there is deep water close to the coast (Jefferson et al. 2015). In the South Atlantic, it is known to occur along the coast of South America, from Brazil to Argentina, and along the west coast of Africa (Jefferson et al. 2015). Sightings have been made on the west coast of South Africa (Findlay et al. 1992). Sixty-six sightings were made during seismic surveys off the coast of northern Angola between 2004 and 2009, including in deep slope waters (Weir 2011). There are ~60 OBIS records for the South Atlantic, including nearshore waters of Brazil, Uruguay, Argentina, Angola, and South Africa, and 19 records for offshore waters near 8.4°S, 24.4°W (OBIS 2019). Based on distributional information (Best 2007; Jefferson et al. 2015), striped dolphins could be encountered during the proposed surveys.

Short-beaked Common Dolphin (*Delphinus delphis*)

Although *D. delphis* and *D. capensis* (long-beaked common dolphin) are considered a single species by some (Perrin 2018c), here we still refer to *D. delphis* as the short-beaked common dolphin. It is found in tropical and warm temperate oceans around the world (Jefferson et al. 2015), ranging from ~60ºN to ~50ºS (Jefferson et al. 2015). It is the most abundant dolphin species in offshore areas of warm-temperate regions in the Atlantic and Pacific (Perrin 2018c). It can be found in oceanic and coastal habitats; it is common in coastal waters 200–300 m deep and is also associated with prominent underwater topography, such as seamounts (Evans 1994). In the eastern tropical Atlantic, it appears to prefer habitat with sea surface temperatures <22.1°C (Weir et al. 2012).

In the South Atlantic, the short-beaked common dolphin occurs along the coasts of South America and Africa (Perrin 2018c). Although according to Jefferson et al. (2015) and Perrin (2018c), its occurrence in central oceanic waters of the South Atlantic is uncertain, Best (2007) reported a few records between 30–41°S, 15°W–10°E. Sightings have also been reported along the coast of Namibia (Best 2007; NDP unpublished data *in* Pisces Environmental Services 2017). Sightings have been reported off the west coast of southern Africa during summer and winter, and there are stranding records for Namibia (Findlay et al. 1992). About 100 sightings of *Delphinus* sp. were made during seismic surveys off the coast of northern Angola between 2004 and 2009, including in deep slope waters; sightings were also made off Gabon (Weir 2011). For the South Atlantic, there are seven OBIS records for waters off Argentina and nearly 80 records for southwestern Africa, including Namibia and South Africa (OBIS 2019). Short-beaked common dolphins could be encountered in the proposed project area at the time of the surveys.

Fraser's Dolphin (*Lagenodelphis hosei*)

Fraser's dolphin is a tropical oceanic species generally distributed between 30°N and 30°S that generally inhabits deeper, offshore water (Dolar 2018). Strandings in more temperate waters, such as in Uruguay, are likely extralimital (Dolar 2018). Three sightings were made during seismic surveys off the coast of northern Angola between 2004 and 2009, all in water deeper than 1000 m; one sighting was made in the Gulf of Guinea (Weir et al. 2008; Weir 2011). Fraser's dolphin has also been sighted off the east coast of South Africa (Findlay et al. 1992). There are 24 OBIS records for the South Atlantic, all along the coast of South America (OBIS 2019). Based on its distribution (Jefferson et al. 2015), Fraser's dolphin could be encountered during the proposed surveys, but is more likely to be seen in the northern portions of the Valdivia Bank survey area than elsewhere.

Dusky Dolphin (*Lagenorhynchus obscurus*)

The dusky dolphin occurs throughout the Southern Hemisphere, primarily over continental shelves and slopes and sometimes over deep water close to continents or islands (Van Waerebeek and Würsig 2018). Along the east coast of South America, it is present from ~36ºS to Southern Patagonia and the Falkland Islands (Otley 2012; Van Waerebeek and Würsig 2018). In the southeastern Atlantic, it occurs along the coast of Angola, Namibia, and South Africa, as well as Tristan da Cunha (Findlay et al. 1992; Culik 2004; Weir 2019). It appears to occur off the west coast of southern Africa year-round (Findlay et al. 1982). According to Jefferson et al. (2015), it is unlikely to occur in the deep waters of the proposed project area.

It has been observed in groups of 10 to 20 individuals preying on Cape horse mackerel off Namibia (Bernasconi et al. 2011), and it has been seen in mixed groups with southern right whale dolphins there (Culik 2004). It was sighted during spring surveys off west coast of South Africa during 2014 (Seakamala et al. 2015). It has also been reported near Gough Island; animals there likely make up a disjunct oceanic population rather than suggesting movement of individuals between South America and southern Africa (Cassens et al. 2005). There are ~150 OBIS records for the South Atlantic, but none occur within the proposed project area. The dusky dolphin is unlikely to be encountered in the proposed survey areas in the southeastern Atlantic, and is not expected to occur in the Libra Massif survey area.

Hourglass Dolphin (*Lagenorhynchus cruciger*)

The hourglass dolphin occurs in all parts of the Southern Ocean, with most sightings between ~45°S and 60°S (Cipriano 2018). However, some sightings have been made as far north as 33°S (Jefferson et al. 2015). Hourglass dolphins were sighted near 45°S and south of there during surveys of the Southern Ocean (Van Waerebeek et al. 2010). Although it is pelagic, it is also sighted near banks and islands (Cipriano 2018). There are ~45 records in the OBIS database for the Southwest Atlantic, but none within the Libra Massif survey area (OBIS 2019). Based on its known distributional range (Best 2007; Jefferson et al. 2015), it could occur in the southern-most portions of the proposed project area.

Southern Right Whale Dolphin (*Lissodelphis peronii*)

The southern right whale dolphin is distributed between the Subtropical and Antarctic convergences in the Southern Hemisphere, generally between ~30ºS and 65ºS (Jefferson et al. 2015; Lipsky and Brownell 2018). It is sighted most often in cool, offshore waters, although it is sometimes seen near shore where coastal waters are deep (Jefferson et al. 2015). Cold-water currents, such as the Malvinas current off Brazil, might also influence its distribution, extending its range northward (Lipsky and Brownell 2018). It is also known to occur off Namibia (Findlay et al. 1992; Culik 2004), where it has been seen out to the 1000-m isobath (Rose and Payne 1991); it is thought to occur in the region year-round (Rose and Payne 1991). However, Best (2007) did not report any sightings in the Valdivia Bank survey area. There are no records for the South Atlantic in the OBIS database (OBIS 2019). Bester and Ryan (2007) suggested that southern right whale dolphins might be visitors to the southern waters of the Tristan da Cunha archipelago. One was captured near Tristan da Cunha on 10 December 1847 at 37.1°S, 11.6°W (Cruickshank and Brown 1981 *in* Best et al. 2009). There are no records for the South Atlantic in the OBIS database (OBIS 2019). According its distribution range (Best 2007; Jefferson et al. 2015), southern right whale dolphins could occur in the proposed project area, although they are more likely to be encountered in the more southerly survey areas.

Killer Whale (*Orcinus orca*)

The killer whale is cosmopolitan and globally abundant; it has been observed in all oceans of the world (Ford 2018). It is very common in temperate waters but also occurs in tropical waters (Heyning and Dahlheim 1988) and inhabits coastal and offshore regions (Budylenko 1981). Based on sightings by whaling vessels between 1960 and 1979, killer whales are distributed throughout the South Atlantic (Budylenko 1981; Mikhalev et al. 1981). However, densities between 40° of latitude and the Equator are relatively low (Forney and Wade 2006). Mikhalev et al. (1981) noted that they appear to migrate from warmer waters during the winter to higher latitudes during the summer.

In the southeastern Atlantic, killer whales are known to occur off Gabon (de Boer 2010; Weir 2010), Angola (Weir 2007, 2010, 2011), as well as Namibia and South Africa (Findlay et al. 1992; Best 2007; Elwen and Leeney 2011). Sightings of killer whale pods of 1 to >100 individuals have been made near the proposed survey areas during November and December (Budylenko 1981; Mikhalev et al. 1981). Eighteen sightings were made during seismic surveys off northern Angola between 2004 and 2009, including in deep slope waters; one sighting was made off Gabon (Weir 2011). The number of sightings are thought to decrease north of Cape Town, South Africa, but sightings have been made year round, including in offshore waters (up to 600 km from shore), but not within the proposed project area (Rice and Saayman 1987). Killer whales are known to prey on longline catches in the waters off South Africa (Williams et al. 2009).

In the southwestern Atlantic, killer whales are relatively common off southern Brazil (Pinedo et al. (2002b). Killer whales are known to prey on longline catches in the waters off southern Brazil (Dalla Rosa and Secchi 2007) and Uruguay (Passadore et al. 2014, 2015). Predation events by killer whales or false killer whales in the Uruguayan longline fishery were recorded north of the Libra Massif survey area (Passadore et al. 2014, 2015). Killer whales occur in the Uruguayan fishing grounds throughout the year, but most frequently during autumn and winter and ~300–750 km from shore along the shelf break (Passadore et al. 2014). Sightings of killer whale pods of 1 to >100 individuals have been made near the Libra Massif survey area during November (Budylenko 1981; Mikhalev et al. 1981).

Killer whales are considered scarce in the Tristan da Cunha archipelago (Bester and Ryan 2007), but they have been sighted there during September and October (Best et al. 2009). They have also been recorded for waters near St. Helena (Clingham et al. 2013). One killer whale sighting was made during an August–September 2010 survey from Vitória at ~20°S, 40°W to Trindade and Martim Vaz islands; the pod was seen to the east of Vitória, near 20.5°S, 37.2°W, on 4 September (Wedekin et al. 2014). A sighting was made south of the proposed survey areas at ~45°S, 8°W (Scheidat et al. 2011). There are ~55 records of killer whales for the South Atlantic in the OBIS database, including records for offshore and nearshore waters of South America, as well as South Africa (OBIS 2019); however, there are no records near the proposed survey areas.

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

The short-finned pilot whale is found in tropical and warm temperate waters, and the long-finned pilot whale is distributed antitropically in cold temperate waters (Olson 2018). The ranges of the two species show little overlap (Olson 2018). Short-finned pilot whale distribution does not generally range south of 40°S (Jefferson et al. 2015). Long-finned pilot whales are geographically isolated and separated into two subspecies, *G. melas melas* and *G. melas edwardii* in the Northern and Southern Hemispheres, respectively (Olson 2018). In the eastern tropical Atlantic, short-finned pilot whales were shown to prefer deep-water habitats with sea surface temperatures >25.3°C (Weir et al. 2012).

Short-finned pilot whales were the most frequently sighted cetacean during seismic surveys off the coast of Angola between 2004 and 2009; more than 100 sightings were off Angola including in deep slope waters and several sightings were also reported off Gabon (Weir 2011). There are records of long-finned pilot whales for South Africa and Namibia (Findlay et al. 1992; Best 2007). Long-finned pilot whales are considered uncommon in Tristan waters (Bester and Ryan 2007); pilot whales have stranded on the islands of the Tristan da Cunha archipelago, although it is uncertain what species they were (Best et al. 2009). There is a single record of short-finned pilot whales in the Southwest Atlantic Ocean, but there are >100 long-finned pilot whale records for the waters off South America, Namibia, South Africa, and the central Atlantic Ocean (OBIS 2019). Based on their distributional ranges (Best 2007; Jefferson et al. 2015), short-finned pilot whales are more likely to occur in the Valdivia Bank survey area, whereas long-finned pilot whales are more likely to occur in the more southern survey areas.

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 not abundant anywhere (Carwardine 1995). The false killer whale 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).

The false killer whales occurs throughout the South Atlantic. In the southeast Atlantic Ocean, 13 sightings were made during seismic surveys off the coast of northern Angola between 2004 and 2009, all in water deeper than 1000 m (Weir 2011). Stranding records and sightings also exist for Namibia and South Africa (Findlay et al. 1992). They have also been recorded around St. Helena (Clingham et al. 2013). Predation events by killer whales or false killer whales in the Uruguayan longline fishery were recorded north of the Libra Massif survey area (Passadore et al. 2014, 2015). Although there are no OBIS records of false killer whales for the offshore waters of the proposed project area, there are 91 records for the South Atlantic, including offshore waters off South America and nearshore waters of Namibia and South Africa; however, there are no records near the proposed survey areas (OBIS 2019). Based on its distributional range (Best 2007; Jefferson et al. 2015), the false killer whale could be encountered in the proposed project areas.

Pygmy Killer Whale (*Feresa attenuata*)

The pygmy killer whale has a worldwide distribution in tropical and subtropical waters, generally not ranging south of 35°S (Jefferson et al. 2015). It is known to inhabit the warm waters of the Indian, Pacific, and Atlantic oceans (Jefferson et al. 2015). It can be found in nearshore areas where the water is deep and in offshore waters (Jefferson et al. 2015). In the southeast Atlantic, there are stranding records along the coast of southern Africa, including Namibia (Findlay et al. 1992). There is one stranding record for Brazil (Santos et al. 2010). There are seven OBIS records for the Southeast Atlantic Ocean, but no records for the offshore waters of the proposed survey areas (OBIS 2019). Based on its distributional range (Best 2007; Jefferson et al. 2015), the pygmy killer whale could be encountered in the proposed survey areas.

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). It occurs most often in deep offshore waters and occasionally in nearshore areas where the water is deep (Jefferson et al. 2015). Off the west coast of Africa, melon-headed whales have been recorded off Gabon (de Boer 2010; Weir 2011) and Angola (Weir 2007a, 2010, 2011). Four sightings were made during seismic surveys off the coast of northern Angola between 2004 and 2009, all in water deeper than 1000 m (Weir 2011). Extralimital record exists for South Africa (Peddemors 1999; Jefferson et al. 2015). There is one OBIS record for South Africa (OBIS 2019). Based on its distributional range (Best 2007; Jefferson et al. 2015), melon-headed whale could be encountered in the northern portion of the Valdivia Bank survey area.

Pinnipeds

Subantarctic Fur Seal (*Arctocephalus tropicalis*)

Subantarctic fur seals occur between 10°W and 170°E north of the Antarctic Polar Front in the Southern Ocean (Hofmeyr and Bester 2018). Breeding occurs on several islands, with Gough Island in the central South Atlantic accounting for about two thirds of pup production (Hofmeyr and Bester 2018). Breeding/pupping at Tristan da Cunha archipelago occurs during late spring/early summer (Bester and Ryan 2007). Pups are weaned at about 10 months but females leave their pups within a day of birth to make foraging trips that last for a few days and increase to a few weeks in duration (Hofmeyr and Bester 2018). Males leave breeding colonies in January and do not return until the following October. Foraging trips are generally several hundred kilometers and can be up to 2000 km (Hofmeyr and Bester 2018). A few pups are also born at Tristan da Cunha Island, and the subantarctic fur seal can also be found on Nightingale and Inaccessible islands (Hofmeyr et al. 1997).

Vagrant subantarctic fur seals have been reported in South Africa (Shaughnessy and Ross 1980). The at-sea distribution of subantarctic fur seals is poorly understood, although they are often seen in the waters between Tristan da Cunha and South Africa (Bester and Ryan 2007). There are 35 OBIS records for the South Atlantic, including in nearshore and offshore waters of South Africa, and 21 records at 40.3°S, 9.9°W; however, there are no records for the proposed project area (OBIS 2019).

Cape Fur Seal (*Arctocephalus pusillus pusillus*)

The Cape fur seal is endemic to the west coast of southern Africa, occurring from Algoa Bay, South Africa to Ilha dos Tigres, Angola (Kirkman et al. 2013). The population severely declined between the 17th and 19th century, due to sealing and guano collection on many of the breeding islands (Kirkman et al. 2007). However, the population recovered when sealing limits were imposed in the early 20th century, and the population is now estimated to number ~2 million individuals (Kirkman et al. 2007). There have also been two mass die-offs of Cape fur seals in Namibia that were related to poor environmental conditions and reduced prey (Roux et al. 2002 *in* Kirkman et al. 2007).

The Cape fur seal currently breeds at 40 colonies along the coast of South Africa, Namibia, and Angola, including on the mainland and nearshore islands (Kirkman et al. 2013). There have been several new breeding colonies established in recent years, as the population has shifted northward (Kirkman et al. 2013). More than half of the seal population occurs in Namibia (Wickens et al. 1991). High densities have been observed between 30 and 60 n.mi. from shore, with densities dropping farther offshore (Thomas and Schülein 1988). Cape fur seals typically forage over the shelf up to ~220 km offshore (Shaughnessy 1979), but they are known to travel distances up to 1970 km along the coast of South America (Oosthuizen 1991). Breeding occurs during November and December (Warneke and Shaughnessy 1985 *in* Kirkman and Arnould 2018). There are over 2000 OBIS records along the coasts of Namibia and South Africa, but no records for the offshore survey areas. As Cape fur seals typically remain over the shelf to forage and are breeding during the time of the survey, they are unlikely to be encountered in the offshore project area.

Crabeater Seal (*Lobodon carcinophagus*)

Crabeater seals have a circumpolar distribution off Antarctica and generally spend the entire year in the advancing and retreating pack ice; occasionally they are seen in the far southern areas of South America though this is uncommon (Bengtson and Stewart 2018). Vagrants are occasionally found as far north as Brazil (Oliveira et al. 2006). Telemetry studies show that crabeater seals are generally confined to the pack ice, but spend ~14% of their time in open water outside of the breeding season (reviewed in Southwell et al. 2012). During the breeding season crabeater seals were most likely to be present within 5° or less (~550 km) of the shelf break in the south, though non-breeding animals ranged further north. Pupping season peaks in mid- to late-October and adults are observed with their pubs as late as mid-December (Bengtson and Stewart 2018). There are two records of crabeater seals for South Africa in the OBIS database (OBIS 2019).

Leopard Seal (*Hydrurga leptonyx*)

The leopard seal has a circumpolar distribution around the Antarctic continent where it is solitary and widely dispersed (Rogers 2018). Leopard seals are top predators, consuming everything from krill and fish to penguins and other seals (e.g., Hall-Aspland and Rogers 2004; Hirukie et al. 1999). Pups are born during October to mid-November and weaned approximately one month later (Rogers 2018). Mating occurs in the water during December and January. There is one record for South Africa in the OBIS database (OBIS 2019).

Southern Elephant Seal (*Mirounga leonina*)

The southern elephant seal has a near circumpolar distribution in the Southern Hemisphere (Jefferson et al. 2015), with breeding sites located on islands throughout the subantarctic (Hindell 2018). In the South Atlantic, southern elephant seals breed at Patagonia, South Georgia, and other islands of the Scotia Arc, Falkland Islands, Bouvet Island, and Tristan da Cunha archipelago (Bester and Ryan 2007). Península Valdés, Argentina, is the sole continental South American large breeding colony, where tens of thousands of southern elephant seals congregate (Lewis et al. 2006). Breeding colonies are otherwise island-based, with the occasional exception of the Antarctic mainland (Hindell 2018).

Numbers on Tristan da Cunha have been low since southern elephant seals were hunted there (Bester and Ryan 2007). At Gough Island, the breeding season takes place during the austral spring; pups are born in October and start to disperse in December (Bester and Ryan 2007). Between 1973 and 1998, the number of births at Gough Island declined from 38 pups in 1975 to 11 in 1997 (Bester et al. 2001). Immature animals also haul out on Tristan da Cunha and Inaccessible islands (Bester and Ryan 2007).

When not breeding (September–October) or molting (November–April), southern elephant seals range throughout the Southern Ocean from areas north of the Antarctic Polar Front to the pack ice of the Antarctic, spending >80% of their time at sea each year, up to 90% of which is spent submerged while hunting, travelling and resting in water depths ≥200 m (Hindell 2018). Males generally feed in continental shelf waters, while females preferentially feed in ice-free Antarctic Polar Front waters or the marginal ice zone in accordance with winter ice expansion (Hindell 2018). Southern elephant seals tagged at South Georgia showed long-range movements from ~April through October into the open Southern Ocean and to the shelf of the Antarctic Peninsula (McConnell and Fedak 1996). One adult male that was sighted on Gough Island had previously been tagged at Marion Island in the Indian Ocean (Reisinger and Bester 2010). Vagrant southern elephant seals, mainly consisting of juvenile and subadult males, have been documented in Uruguay, Brazil, Argentina, Falkland Islands, and South Georgia (Lewis et al. 2006a; Oliveira et al. 2011; Mayorga et al. 2015). For the South Atlantic, there are more than 2000 OBIS records for the nearshore and offshore waters of South America and along the coasts of Namibia and South Africa (OBIS 2019). Most of the records (1793) are for waters of the Patagonian Large Marine Ecosystem (Campagna et al. 2006), but none occur within the proposed project area.

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.

SIO 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 South Atlantic Ocean during November–December 2019. The operations outlined in § I have the potential to take marine mammals by harassment. Sounds would be generated by the GI airguns used during the surveys, by echosounders, and by general vessel operations. "Takes" by harassment would potentially result when marine mammals near the activities are exposed to the pulsed sounds generated by the GI 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. No take by serious injury is expected, given the nature of the planned operations and the mitigation measures that are planned (see § XI, Mitigation Measures), and no lethal takes are expected. However, per NMFS requirement, small numbers of Level A takes are also being requested for the remote possibility of low-level physiological effects. Because of the characteristics of the proposed study and the proposed monitoring and mitigation measures, in addition to the general avoidance by marine mammals of loud sounds, Level A takes are considered highly unlikely.

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, and refer to recent literature that has become available since the PEIS was released in 2011. A more comprehensive review of the relevant background information appears in § 3.6.4.3, § 3.7.4.3, 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, and Appendix E of the PEIS.
- Finally, we estimate the numbers of marine mammals that could be affected by the proposed surveys in the South Atlantic Ocean during November–December 2019. This section includes a description of the rationale for the estimates of the potential numbers of harassment "takes" during the planned surveys, as called for in § VI.

Summary of Potential Effects of Airgun Sounds

As noted in the PEIS (§ 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). 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, but temporary threshold shift (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 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). Although the possibility cannot be entirely excluded, it is 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 encounter a survey while it is underway, 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 at a distance of 2000 km from the seismic source. Nieukirk et al. (2012) and Blackwell et al. (2013) 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). 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. Sills et al. (2017) reported that recorded airguns sounds masked the detection of low-frequency sounds by ringed and spotted seals, especially at the onset of the airgun pulse when signal amplitude was variable.

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'.

Behavioural reactions of marine mammals to sound are difficult to predict in the absence of site- and context-specific data (Ellison et al. 2018). 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). 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). Some studies have attempted modeling to assess consequences of effects from underwater noise at the population level (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. 2018). Various authors have noted that some marine mammals that show no obvious avoidance or behavioral changes may still be adversely affected by sound (e.g., Weilgart 2007; Wright et al. 2011; Gomez et al. 2016).

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.

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).

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 vessel; 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 humpback whales 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 array 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). Overall, the results showed that humpbacks were more likely to avoid active airgun arrays (of 20 and 140 in^3) within 3 km and at levels of at least 140 dB re 1 $\mu Pa^2 \cdot s$ (Dunlop et al. 2017a). Responses to ramp up and use of a 3130 in^3 array elicited greater behavioral changes in humpbacks when compared with small arrays (Dunlop et al. 2016c). Humpbacks reduced their southbound migration, or deviated from their path thereby avoiding the active array, when they were within 4 km of the active large airgun source, where received levels were >135 dB re 1 $\mu Pa^2 \cdot s$ (Dunlop et al. 2017b). These results are consistent with earlier studies (e.g., McCauley et al. 2000). However, some individuals did not show avoidance behaviors even at levels as high as 160 to 170 dB re 1 $\mu Pa^2 \cdot s$ (Dunlop et al. 2018).

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). 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).

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 $\mu Pa^2 \cdot s$. 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) or 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 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, preliminary data collected during a seismic program in 2015 showed some displacement of animals from the feeding area and responses to lower sound levels than expected (Gailey et al. 2017; Sychenko et al. 2017).

Gray whales in British Columbia 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 to 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. 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 protected species 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.

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). However, foraging behavior can be altered upon exposure to airgun sound (e.g., Miller et al. 2009) which, according to Farmer et al. (2018), could have significant consequences on individual fitness. 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). Preliminary data from the Gulf of Mexico show a correlation between reduced sperm whale acoustic activity during 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. 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 $\mu Pa^2 \cdot s$). 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 $\mu Pa_{0\text{-peak}}$. However, Kastelein et al. (2012a) 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. 2013a). 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 $\mu Pa^2 \cdot s$. 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 (in particular mid-frequency cetaceans), which tend to be less responsive than the more responsive cetaceans. NMFS is currently 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).

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 1994–2010 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, 2019; 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; Finneran 2012, 2015; Kastelein et al. 2012b,c; 2013b,c, 2014, 2015a, 2016a,b; Ketten 2012; Supin et al. 2016).

Recent data 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 $\mu Pa^2 \cdot s$ (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).

Recent 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) 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 $\mu Pa^2 \cdot s$, 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. 2017).

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;

NMFS 2016a). 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. 2012c, 2013b,c, 2014, 2015a) have indicated that received levels that elicit onset of TTS are lower in porpoises than in other odontocetes. Kastelein et al. (2012c) exposed a harbor porpoise to octave band noise centered at 4 kHz for extended periods. A 6-dB TTS occurred with SELs of 163 dB and 172 dB for low-intensity sound and medium-intensity sound, respectively; high-intensity sound caused a 9-dB TTS at a SEL of 175 dB. Kastelein et al. (2013b) exposed a harbor porpoise to a long, continuous 1.5-kHz tone, which induced a 14-dB TTS with a total SEL of 190 dB. 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 $L_{eq\text{-}fast}$ (rms average over the duration of the pulse) of 45 dB above the hearing threshold for behavioral responses (i.e., negative phonotaxis). According to Wensveen et al. (2014) and Tougaard et al. (2015), M-weighting, as used by Southall et al. (2007), might not be appropriate for the harbor porpoise. Thus, Wensveen et al. (2014) developed six auditory weighting functions for the harbor porpoise that could be useful in predicting TTS onset. Basing weighting functions on equal latency/loudness contours may be more appropriate than M-weighting for marine mammals (Mulsow et al. 2015; Southall et al. 2019). 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). Houser et al. (2017) and Tougaard and Beedholm (2019) provide a review of the development and application of auditory weighting functions, as well as recommendations for future work.

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. (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. 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). 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.

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. Similarly, 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. 372*ff*; 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).

The new noise exposure criteria for marine mammals that were recently released by NMFS (2016a, 2018a) 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 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).

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 (see § XI and § XIII). Also, many marine mammals and (to a limited degree) sea turtles 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. 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 stranding along Ireland’s coast increased with seismic surveys operating offshore (McGeady et al. 2016). 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 67 Marine Mammal Unusual Mortality Events (UME) in the U.S. (NMFS 2018b). In a hearing to examine the Bureau of Ocean Energy Management's 2017–2022 OCS Oil and Gas Leasing Program (http://www.energy.senate.gov/public/index.cfm/hearings-and-business-meetings?ID=110E5E8F-3A65-4BEC-9D25-5D843A0284D3), 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.

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, 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.

Possible Effects of Other Acoustic Sources

The Kongsberg EM300 MBES and a Knudsen 3260 SBP would be operated from the source vessel during the proposed surveys, but not during transits. Information about this equipment, or similar, was provided in § 2.2.3.1 of the PEIS. A review of the anticipated potential effects (or lack thereof) of MBESs and SBPs on marine mammals and sea turtles appears in § 3.4.4.3, § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS.

There has been some recent attention given to the effects of 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 (*Peponocephala electra*; Southall et al. 2013) off Madagascar. 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 is 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 similar to that used on R/V *Thompson*. 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).

There is no available information on marine mammal behavioral response to MBES sounds (Southall et al. 2013) or sea turtle responses to MBES systems. Much of the literature on marine mammal response to sonars relates to the types of sonars used in naval operations, including low-frequency, mid-frequency, and high-frequency active sonars (see review by Southall et al. 2016). However, the MBES sounds are quite different from naval sonars. Ping duration of the MBES is very short relative to naval sonars. Also, at any given location, an individual marine mammal would be in the beam of the MBES for much less time given the generally downward orientation of the beam and its narrow fore-aft beamwidth; naval sonars often use near-horizontally-directed sound. In addition, naval sonars have higher duty cycles. These factors would all reduce the sound energy received from the MBES relative to that from naval sonars.

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).

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).

This new information presented here is in agreement with the assessment presented in § 3.6.7, 3.7.7, and 3.8.7 of the PEIS that operation of MBESs and SBPs is 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 *Thompson* could affect marine animals in the proposed project area. Houghton et al. (2015) proposed that vessel speed is the most important predictor of received noise levels. 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); low levels of high-frequency sound from vessels has been shown to elicit responses in harbor porpoise (Dyndo et al. 2015). Increased levels of ship noise have been shown to affect foraging by porpoise (Teilmann et al. 2015) and humpback whales (Blair et al. 2016).

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). 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). 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 behaviour (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). 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).

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 project area 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). 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).

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.

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. 2017). 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 § 3.6.4.4 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. However, McKenna et al. (2015) noted the potential absence of lateral avoidance demonstrated by blue whales and perhaps other large whale species to vessels (McKenna et al. 2015). The PEIS concluded that the risk of collision of seismic vessels or towed/deployed equipment with marine mammals exists but is 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. During the proposed cruise, most (~70%) of the seismic survey effort is expected to occur at a speed of ~9 km/h, and ~30% is expected to occur at 15 km/h; typical cruise speed when not operating airguns would be ~22 km/h. The number of seismic survey km and cruise speed are low relative to other fast-moving vessels in the area. There has been no history of marine mammal vessel strikes with any of the vessels in the U.S. academic research fleet in 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. As required by NMFS, Level A takes have been requested; given the very small EZs and the proposed mitigation measures to be applied, 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 B and Level A sound levels and present estimates of the numbers of marine mammals that could be affected during the proposed seismic surveys. The estimates are based on consideration of the number of marine mammals that could be disturbed appreciably by the seismic surveys in the South Atlantic Ocean. The main sources of distributional and numerical data used in deriving the estimates are described in the next subsection and in Appendix B.

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 and SBP 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 "Take by Harassment"

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 a seismic survey. 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. Likewise, 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 preferred source of density data for the species that might be encountered in the proposed survey areas in the South Atlantic Ocean was Di Tullio et al. (2016). The rationale for using these data was that these surveys were conducted offshore along the continental slope at the same latitudes as the proposed seismic surveys and so come from a similar season, water depth category, and climatic region in the southern Atlantic Ocean. When data for species expected to occur in the proposed seismic survey areas were not available in Di Tullio et al. (2016), we used data from White et al. (2002) as calculated in LGL/NSF (2019) because they came from an area which was slightly south of the proposed project area but well north of the AECOM/NSF (2014) study area. An exception was made for the southern right whale, for which densities from AECOM/NSF (2014) were higher and thus more conservative. Next, we used data from AECOM/NSF (2014); although they come from an area south of the proposed project area, they were the next best data available for those species. For species not included in these sources, we used data from de Boer (2010), Garaffo et al. (2011), NOAA-SWFSC LOA (2013 *in* AECOM/NSF 2014), Wedekin et al. (2014), Bradford et al. (2017), and Mannocci et al. (2017). When densities were not directly available from the above studies, they were estimated using sightings and effort reported in those sources. Densities calculated from de Boer (2010) come from LGL/NSF (2016); densities from White et al. (2002), Garaffo et al. (2011), and Wedekin et al. (2014) are from LGL/NSF (2019). How densities were derived from these sources is explained in LGL/NSF (2016, 2019).

Table 4 shows estimated densities for cetacean and pinniped species that could occur in the proposed project area; data sources and density calculations are described in detail in Appendix B. There is uncertainty about the representativeness of the data and the assumptions used below. Thus, for some species, the densities derived from past surveys may not be representative of the densities that would be encountered during the proposed seismic surveys. However, the approach used here is based on the best available data. The calculated exposures that are based on these densities are best estimates for the proposed surveys.

The estimated numbers of individuals potentially exposed are based on the 160-dB re 1 μPa_{rms} criterion for all cetaceans and pinnipeds. It is assumed that marine mammals exposed to airgun sounds that strong could change their behavior sufficiently to be considered "taken by harassment". Table 4 shows the estimates of the number of marine mammals that potentially could be exposed to ≥160 dB re 1 μPa_{rms} during the seismic surveys in the South Atlantic Ocean if no animals moved away from the survey vessel. The *Requested Take Authorization* is given in the far-right column of Table 4. Except for species for which densities were unknown (pygmy right whale, Cape fur seal), we have included a *Requested Take Authorization* for marine mammals based on the calculations shown in Appendix C. For species with unknown densities and for those for which the estimated takes were smaller than the mean group size, *Requested Take Authorization*s were increased to mean group size (see footnotes in Table 4).

It should be noted that the following estimates of exposures assume that the proposed surveys would be completed; in fact, the calculated takes have been increased by 25% (see below). Thus, the following estimates of the numbers of marine mammals potentially exposed to Level B sounds ≥160 dB re 1 μPa_{rms} are precautionary and probably overestimate the actual numbers of marine mammals that could be involved.

TABLE 4. Densities and estimates of the possible numbers of individuals that could be exposed to Level B and Level A thresholds for various hearing groups during the proposed seismic surveys in the South Atlantic Ocean. Species in italics are listed as endangered under the ESA.

Species	Estimated Density[1] (#/km^2)	Calculated Take, NMFS Daily Method[2]		Level A + Level B as % of Population[5]	Requested Take Authorization[6]
		Level B[3]	Level A[4]		
LF Cetaceans					
Southern right whale	*0.007965*	*41*	*0*	*1.3*	***41***
Pygmy right whale	N.A.	N.A.	N.A.	N.A.	**2**[7]
Blue whale	*0.000051*	*0*	*0*	*<0.1*	***3***[8]
Fin whale	*0.000356*	*2*	*0*	*<0.1*	***4***[8]
Sei whale	*0.000086*	*0*	*0*	*<0.1*	***3***[8]
Bryde's whale	0.000439	2	0	<0.1	**20**[7]
Common (dwarf) minke whale	0.077896	400	4	0.1	**404**
Antarctic minke whale	0.077896	400	4	0.1	**404**
Humpback whale	0.000310	2	0	0	**20**[7]
MF Cetaceans					
Sperm whale	*0.005975*	*31*	*0*	*0.3*	***31***
Arnoux's beaked whale	0.011379	59	0	<0.1	**59**
Cuvier's beaked whale	0.000548	3	0	<0.1	**3**
Southern bottlenose whale	0.007906	41	0	<0.1	**41**
Shepherd's beaked whale	0.009269	48	0	N.A.	**48**
Blainville's beaked whale	0.000053	0	0	N.A.	**7**[8]
Gray's beaked whale	0.001885	10	0	<0.1	**10**
Hector's beaked whale	0.000212	1	0	N.A.	**2**[8]
Gervais' beaked whale	0.001323	7	0	N.A.	**7**
True's beaked whale	0.000053	0	0	N.A.	**2**[8]
Strap-toothed beaked whale	0.000582	3	0	<0.1	**3**
Andrew's beaked whale	0.000159	1	0	N.A.	**2**[8]
Spade-toothed beaked whale	0.000053	0	0	N.A.	**2**[8]
Risso's dolphin	0.010657	55	0	0.3	**78**[8]
Rough-toothed dolphin	0.005954	31	0	N.A.	**55**[8]
Common bottlenose dolphin	0.040308	209	0	0.3	**209**
Pantropical spotted dolphin	0.003767	20	0	0.6	**104**[8]
Atlantic spotted dolphin	0.213721	1108	0	2.5	**1108**
Spinner dolphin	0.040720	211	0	N.A.	**315**[8]
Clymene dolphin	0.006800	35	0	N.A.	**35**
Striped dolphin	0.004089	21	0	<0.1	**110**[7]
Short-beaked common dolphin	0.717166	3714	4	5.3	**3718**
Fraser's dolphin	0.021040	109	0	N.A.	**283**[8]
Dusky dolphin	0.012867	67	0	0.9	**67**
Southern right whale dolphin	0.006827	35	0	N.A.	**35**
Killer whale	0.000266	1	0	<0.1	**5**[8]
Short-finned pilot whale	0.002085	11	0	<0.1	**41**[8]
Long-finned pilot whale	0.021379	111	0	0.1	**111**
False killer whale	0.000882	5	0	N.A.	**19**[8]
Pygmy killer whale	0.000321	2	0	N.A.	**26**[8]
Melon-headed whale	0.003540	18	0	N.A.	**170**[8]
HF Cetaceans					
Pygmy sperm whale	0.003418	17	1	N.A.	**18**
Dwarf sperm whale	0.002582	12	1	N.A.	**13**
Hourglass dolphin	0.011122	54	4	<0.1	**58**

Species	Estimated Density[1] (#/km²)	Calculated Take, NMFS Daily Method[2]		Level A + Level B as % of Population[5]	Requested Take Authorization[6]
		Level B[3]	Level A[4]		
Otariids					
Subantarctic fur seal	0.00274	14	0	<0.1	**14**
Cape fur seal	N.A.	N.A.	N.A.	N.A.	**20[9]**
Phocids					
Crabeater seal	0.00649	34	0	<0.1	**34**
Leopard seal	0.00162	8	0	<0.1	**8**
Southern elephant seal	0.00155	8	0	<0.1	**8**

Species in italics are listed under the ESA as endangered. N.A. (-) is not available

1 See text and Appendix B for density sources.

2 Take using NMFS daily method for calculating ensonified area: estimated density multiplied by the daily ensonified area to levels ≥160 dB re 1 μPa_{rms} on one selected day multiplied by the number of survey days, times 1.25 (see Appendix C); daily ensonified area = full 160-dB area minus ensonified area for the appropriate PTS threshold.

3 Level B takes, based on the 160-dB criterion, excluding exposures to sound levels equivalent to PTS thresholds.

4 Level A takes if there were no mitigation measures.

5 Requested Level A and Level B takes (used by NMFS as proxy for number of individuals exposed) expressed as % of population (see Table 3).

6 Requested take authorization is Level A plus Level B calculated takes, unless otherwise indicated.

7 Requested take authorization (Level B only) increased to maximum group size from Jefferson et al. (2015).

8 Requested take authorization (Level B only) increased to mean group size from Weir (2001), Bradford et al. (2017), or Di Tullio et al. (2016), whichever is larger.

9 Requested take authorization (Level B only) increased to 20 individuals, as no densities available.

Consideration should be given to the hypothesis that delphinids are less responsive to airgun sounds than are mysticetes, as referenced in both the PEIS and §4.1.1.1 of this document. 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). It has become evident that the context of an exposure of a marine mammal to sound can affect the animal's initial response to the sound (NMFS 2013).

Potential Number of Marine Mammals Exposed

The number of marine mammals that could be exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} (Level B) for marine mammals on one or more occasions have been estimated using a method required 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 trackline(s) that could be surveyed on one day during the 5-kt surveys (~120 n.mi. or 222 km per day) and 8-kt surveys (192 n.mi. or 356 km per day) with a proportion occurring in water depth ranges (intermediate and deep) that is roughly similar to that of the entire survey.

The area expected to be ensonified on that one day was determined by entering the planned survey lines into a MapInfo GIS, using the GIS to identify the relevant areas by "drawing" the applicable 160-dB and PTS threshold buffers around each seismic line. The ensonified areas were then multiplied by the number of survey days (10 and 4 days for 5-kt and 8-kt surveys, respectively) and increased by 25% (see Appendix C for more details). These values for the 5- and 8-kt surveys were then added to provide a value for the total survey. 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 *Thompson* approaches.

The estimate of the number of cetaceans that could be exposed to seismic sounds with received levels ≥160 dB re 1 µPa$_{rms}$ in the proposed project area is 6915 (Table 4). That total includes 74 cetaceans listed under the ESA: 31 sperm whales, 41 southern right whales, and 2 fin whales, representing 0.3%, 1.3%, and <0.1% of their regional populations, respectively. A total of 173 beaked whales could be exposed. Most (99%) of the cetaceans potentially exposed would be MF cetaceans, including estimates of 3714 short-beaked common dolphins and 1108 Atlantic spotted dolphins. Most (65%) of the HF cetaceans exposed to ≥160 dB re 1 µPa$_{rms}$ would be hourglass dolphins. In addition, ~64 pinnipeds could be exposed, more than half of which would be crabeater seals.

Conclusions

The proposed seismic project would involve towing a very small source, a pair of 45-in^3 GI airguns, that 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, 3.7.7, and 3.8.7, the PEIS concluded that outside the Gulf of Alaska, airgun operations with implementation of the proposed monitoring and mitigation measures could result in a small number of Level B behavioral effects in some cetaceans and pinnipeds, that Level A effects were unlikely, and that operations were unlikely to adversely affect ESA-listed species. However, NMFS requires the calculation and request of potential Level A takes (following a different methodology than used in the PEIS). For several past 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; however, NMFS expected neither mortality nor serious injury of marine mammals to result from the surveys (e.g, NMFS 2015, 2016b,c, NMFS 2017a,b). Level A takes are considered highly unlikely, as predicted Level A EZs are small, and mitigation measures would further reduce the chances of, if not eliminate, any such takes.

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 A and/or B harassment are low percentages of the regional population sizes (Table 4). The calculated take estimates are likely overestimates of the actual number of animals that would be exposed to and would react to the seismic sounds. 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 NSF-funded seismic surveys carried out by vessels in the U.S. academic research fleet, PSOs and other crew members have not observed any 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 the *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 the *Langseth* along the U.S. east coast in August–September 2014, only three unidentified dolphins were observed within the predicted 160-dB zone and potentially taken, representing <0.03% of the 11,367 authorized takes (RPS 2014b). Furthermore, as defined, all animals exposed to sound levels >160 dB are Level B 'takes' whether or not a behavioral response occurred. The 160-dB zone, which is based on predicted sound levels, is thought to be conservative; thus, not all animals detected within this zone would be expected to have been exposed to actual sound levels >160 dB.

VIII. ANTICIPATED IMPACT ON SUBSISTENCE

The anticipated impact of the activity on the availability of the species or stocks of marine mammals for subsistence uses. (This issue is only applicable in Alaska.)

The proposed action would not occur in the Alaska region or have the potential to impact the ability of Alaska Natives to conduct subsistence hunts. Therefore, the proposed action would not constitute an unmitigable adverse impact on the availability of marine mammals for subsistence uses.

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 (crustaceans and cephalopods), 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 activity is 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 as much as a few kilometers by the planned activity.

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.

Marine mammals and sea turtles are known to occur in the proposed project area. To minimize the likelihood that impacts would occur to the species and stocks, GI airgun operations would be conducted in accordance with regulations by NMFS under the MMPA and the ESA, including obtaining permission for incidental harassment or incidental 'take' of marine mammals and other endangered species.

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 NSF-funded 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 activity begins during the planning phase. Several factors were considered during the planning phase of the proposed activity, including

Energy Source**.—**Part of the considerations for the proposed surveys was to evaluate what source level was necessary to meet the research objectives. It was decided that the scientific objectives could be met using a low-energy source consisting of two 45-in^3 GI guns (total volume of 90 in^3) at a tow depth of ~2–4 m. The SIO portable MCS system's energy source level is one of the smallest source levels used by the science community for conducting seismic research.

Survey Timing**.—**The PIs worked with SIO, UW, and NSF to identify potential times to carry out the survey, taking into consideration key factors such as environmental conditions (e.g., the seasonal presence of marine mammals), weather conditions, equipment, and optimal timing for other proposed research cruises. Except for some baleen whales, most marine mammal species are expected to occur in the area year-round, so altering the timing of the proposed project likely would result in no net benefits for those species.

Mitigation Zones**.—**During the planning phase, mitigation zones for the proposed seismic surveys were not derived from the farfield signature but calculated based on modeling by L-DEO for both the EZ for Level A takes and safety zones (160 dB re 1µPa$_{rms}$) for Level B takes. The background information and methodology for this are provided in Appendix A. Table 1 shows the distances at which the 160- and 175-dB re 1µPa$_{rms}$ sound levels are expected to be received for the two 45-in^3 GI airguns. The 160-dB level is the behavioral disturbance criterion that is used to estimate anticipated Level B takes for marine mammals; a 175-dB level is used by NMFS to determine behavioral disturbance for sea turtles. NMFS guidance for assessing the effects of anthropogenic sound on marine mammal hearing (NMFS 2016a, 2018a) established new thresholds for PTS onset or Level A Harassment (injury), for marine mammal species. The distances to the PTS thresholds for the various marine mammal hearing groups are provided in Table 2.

The NSF/USGS PEIS defined a low-energy source as any towed acoustic source whose received level is ≤180 dB re 1 µPa$_{rms}$ (the Level A threshold under the former NMFS acoustic guidance) at 100 m, including any single or any two GI airguns and a single pair of clustered airguns with individual volumes of ≤250 in^3. In § 2.4.2 of the PEIS, Alternative B (the Preferred Alternative) conservatively applied a 100-EZ for all low-energy acoustic sources in water depths >100 m. Consistent with the PEIS, that approach is used here for the pair of 45-in^3 GI airguns in all water depths. The 100-m EZ would also be used as the EZ for sea turtles and diving ESA-listed seabirds. If marine mammals, diving ESA-listed seabirds, or sea turtles are detected in or about to enter the appropriate EZ, the airguns would be shut down immediately. Enforcement of mitigation zones via shut downs would be implemented in the Operational Phase, as noted below. A fixed 160-dB "Safety Zone" was not defined for the same suite of low-energy sources in the NSF/USGS PEIS.

Mitigation During Operations

Mitigation measures that would be adopted include (1) vessel speed or course alteration, provided that doing so would not compromise operational safety requirements, (2) GI-airgun shut down within EZs, and (3) ramp-up procedures. Although power-down procedures are often standard operating practice for seismic surveys, they would not be used here because powering down from two airguns to one airgun would make only a small difference in the EZs—probably not enough to allow continued one-airgun operations if a mammal or turtle came within the safety radius for two airguns.

Speed or Course Alteration

If a marine mammal or sea turtle is detected outside the EZ, based on its position and the relative motion, is likely to enter the EZ, the vessel's speed and/or direct course could be changed. This would be done if operationally practicable while minimizing the effect on the planned science objectives. The activities and movements of the marine mammal or sea turtle (relative to the seismic vessel) would then be closely monitored to determine whether the animal is approaching the applicable EZ. If the animal appears likely to enter the EZ, further mitigative actions would be taken, i.e., either further course alterations or a shut down of the seismic source. Typically, during seismic operations, the source vessel is unable to change speed or course and one or more alternative mitigation measures (see below) would need to be implemented.

Shut-down Procedures

If a marine mammal or turtle is detected outside the EZ but is likely to enter the EZ, and if the vessel's speed and/or course cannot be changed to avoid having the animal enter the EZ, the GI airguns would be shut down before the animal is within the EZ. Likewise, if a mammal or turtle is already within the EZ when first detected, the GI airguns would be shut down immediately. The operating airguns would also be shut down in the event an ESA-listed seabird were observed diving or foraging within the designated EZ. Following a shut down, seismic activity would not resume until the marine mammal or turtle has cleared the EZ, or until the PSO is confident that the animal has left the vicinity of the vessel. The animal would be considered to have cleared the EZ zone if

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

Ramp-up Procedures

A ramp-up procedure would be followed when the pair of GI airguns begins operating after a specified period without GI airgun operations. It is proposed that, for the present survey, this period would be 15 min. Ramp up would not occur if a marine mammal or sea turtle has not cleared the EZ as described earlier. Ramp up would begin with one GI airgun 45 in^3, and the second GI airgun would be added after 5 min. During ramp up, the PSOs would monitor the EZ, and if marine mammals or turtles are sighted, a shut down would be implemented as though the full array were operational.

If the EZ has not been visible for at least 30 min prior to the start of operations in either daylight or nighttime, ramp up would not commence. If one GI airgun has operated, ramp up to full power would be permissible at night or in poor visibility, on the assumption that marine mammals and turtles would be alerted to the approaching seismic vessel by the sounds from the single GI airgun and could move away if they choose. A ramp up from a shut down may occur at night, but only where the safety radius is small enough to be visible. Ramp up of the GI airguns would not be initiated if a sea turtle or marine mammal is sighted within or near the applicable EZ during day or night.

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 activity would take place in the South Atlantic Ocean, and no activities would take place in or near a 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...

SIO 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 anticipated monitoring requirements of the IHA. SIO's proposed Monitoring Plan is described below. SIO 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. SIO 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

PSO observations would take place during daytime GI airgun operations and nighttime start ups of the airguns. GI airgun operations would be suspended when marine mammals, turtles, or diving ESA-listed seabirds 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 and turtles near the seismic vessel for at least 30 min prior to the planned start of airgun operations. When feasible, PSOs would also make observations during daytime periods when the seismic system is not operating for comparison of animal abundance and behavior. PSOs would also watch for any potential impacts of the acoustic sources on fish.

Three PSOs would be appointed by SIO, with NMFS Office of Protected Resources concurrence. One dedicated PSO would monitor the EZ during all daytime seismic operations. PSOs would normally work in shifts of 4-hour duration or less. The vessel crew would also be instructed to assist in detecting marine mammals and turtles.

R/V *Thompson* is a suitable platform from which PSOs would watch for marine mammals, ESA-listed seabirds, and turtles. Standard equipment for marine mammal observers would be 7 x 50 reticle binoculars and optical range finders. At night, night-vision equipment would be available. The observers would be in communication with ship's officers on the bridge and scientists in the vessel's operations laboratory, so they can advise promptly of the need for avoidance maneuvers or seismic source shut down.

PSO Data and Documentation

PSOs would record data to estimate the numbers of marine mammals, turtles, and diving ESA-listed seabirds 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 marine mammals potentially 'taken' by harassment (as defined in the MMPA). They would also provide information needed to order a power down or shut down of the airguns when a marine mammal, sea turtle, or diving ESA-listed seabird 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 (GI 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, turtles, and diving ESA-listed seabirds in the area where the seismic study is conducted.
4. Information to compare the distance and distribution of marine mammals, turtles, and diving ESA-listed seabirds relative to the source vessel at times with and without seismic activity.
5. Data on the behavior and movement patterns of marine mammals and turtles seen at times with and without seismic activity.
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, ESA-listed seabirds, and turtles near the operations. The report would provide full documentation of methods, results, and interpretation pertaining to all monitoring. The 90-day report would summarize the dates and locations of seismic operations, all marine mammal, turtle, and diving ESA-listed seabird sightings (dates, times, locations, activities, associated seismic survey activities), and any observations of fish potentially affected by the sound sources. 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.

SIO and NSF would coordinate the planned marine mammal monitoring program associated with the seismic survey with other parties that may have interest in this area. NMFS's interative map (accessed during preparation of this IHA applicaton) did not identify any other nearby planned or authorized activities in or near the proposed action area. SIO and NSF would coordinate with applicable U.S. agencies (e.g., NMFS), and would comply with their requirements.

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List of Appendices

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 both the exclusion zones (EZ) for Level A takes and safety zones (160 dB re 1µPa$_{rms}$) for Level B takes. 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 airguns, for the two 45-in^3 GI airguns. 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).

For deep and intermediate-water cases, the field measurements cannot be used readily to derive mitigation radii, as at those 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 (~2000 m) for marine mammals. 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 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 two 45-in^3 GI guns at a tow depth of 2–4 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 airgun array with 2-m (Fig. A-1) and 8-m (Fig. A-2) airgun separation. 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).

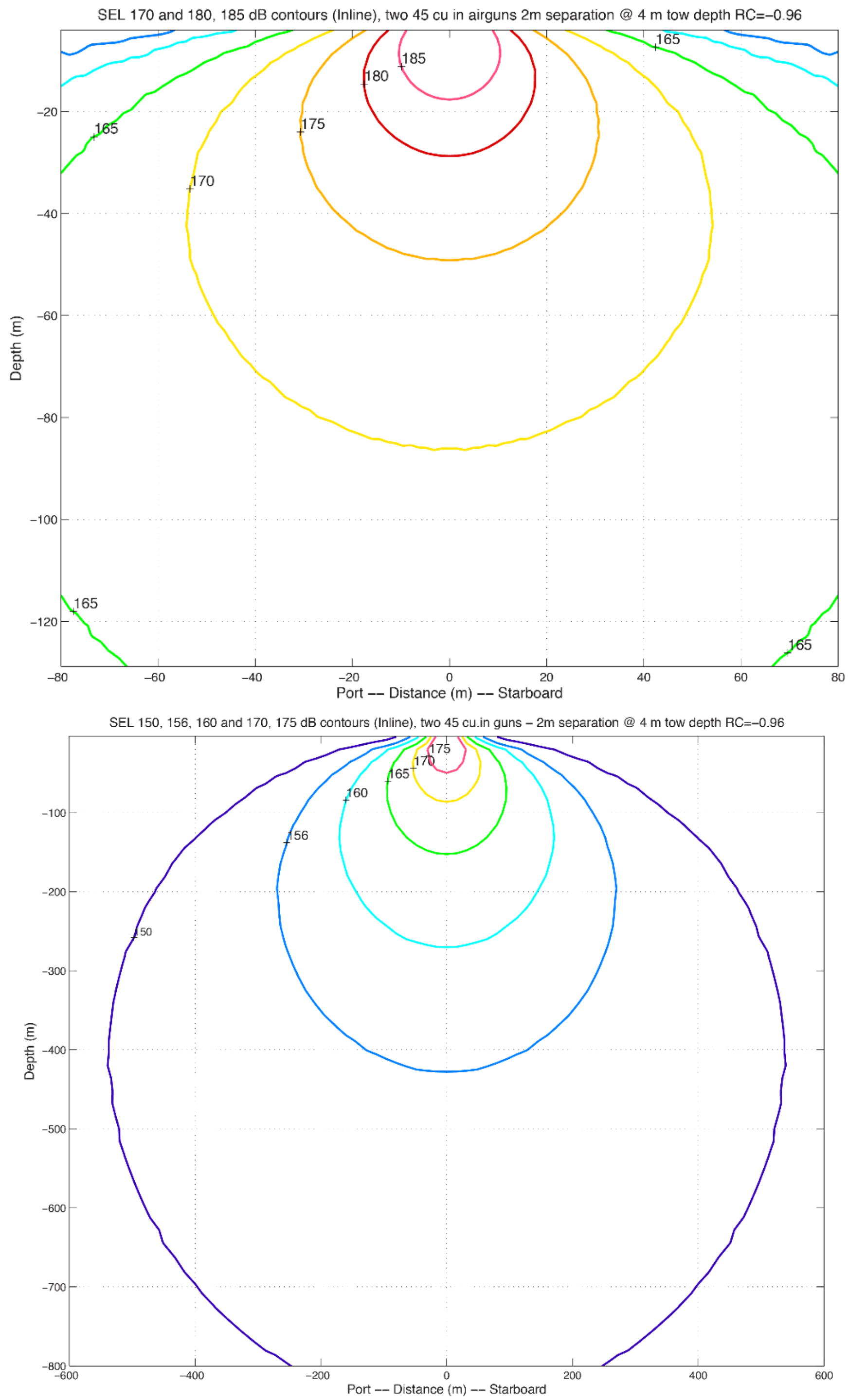

FIGURE A-1. Modeled deep-water received sound exposure levels (SELs) from the two 45-in³ GI guns, with a 2-m gun separation, planned for use during the proposed surveys in the South Atlantic Ocean at a 4-m tow depth. Received rms levels (SPLs) are expected to be ~10 dB higher. The radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.

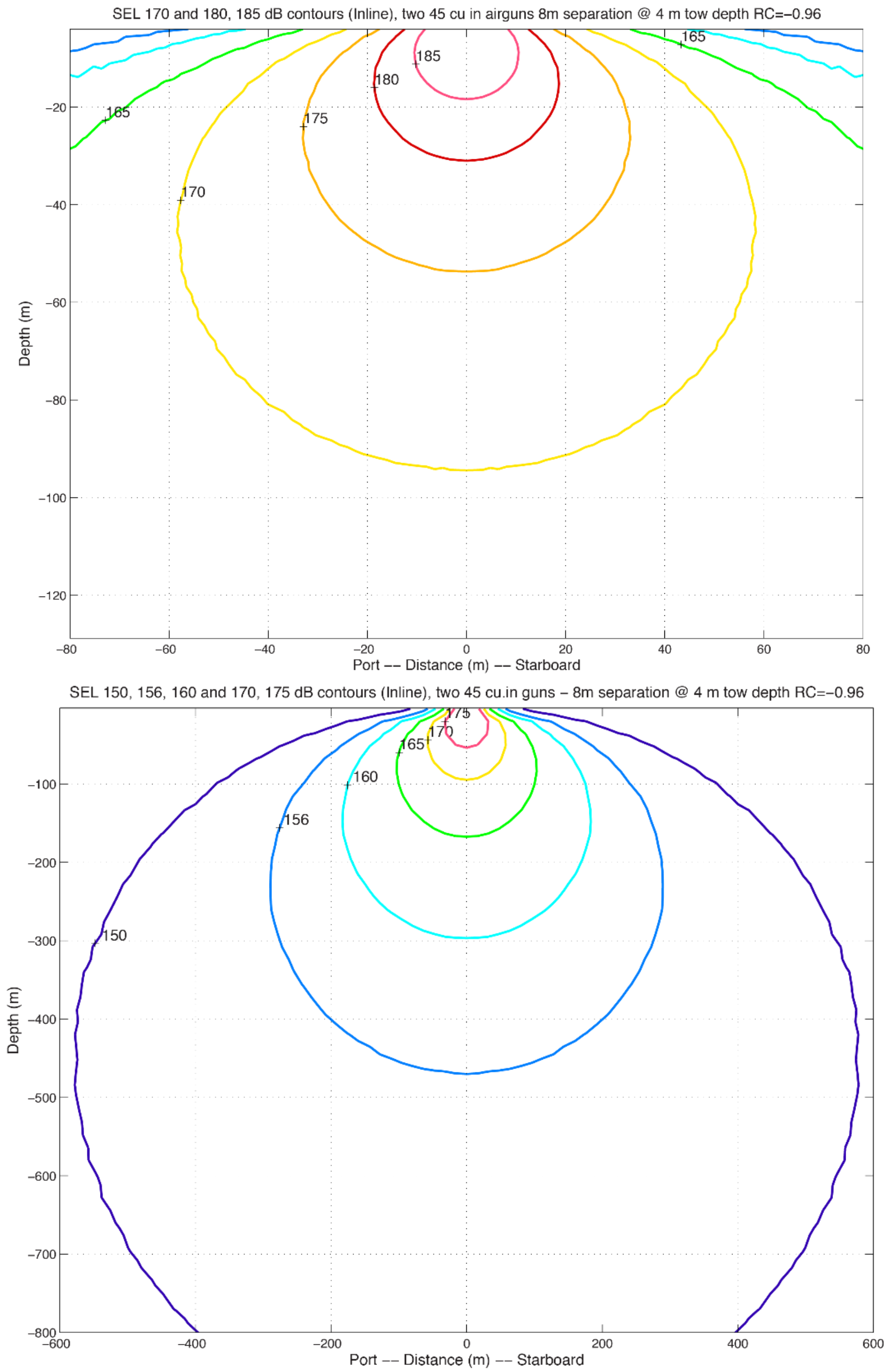

FIGURE A-2. Modeled deep-water received sound exposure levels (SELs) from the two 45-in^3 GI guns, with an 8-m gun separation, planned for use during the proposed surveys in the South Atlantic Ocean at a 4-m tow depth. Received rms levels (SPLs) are expected to be ~10 dB higher. The radius to the 150-dB 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 shows the distances at which the 160- and 175-dB re 1µPa$_{rms}$ sound exposure levels (SEL)[2], are expected to be received for the two different airgun configurations at the maximum 4-m tow depth at various depth categories. The 160-dB level is the behavioral disturbance criterion that is used to estimate anticipated Level B takes for marine mammals; a 175-dB level is used by NMFS, as well as the U.S. Navy (USN 2017), to determine behavioral disturbance for sea 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 level[3] have confirmed that the L-DEO model generated conservative EZs, resulting in significantly larger EZs than required by the National Marine Fisheries Service (NMFS).

In July 2016, the National Oceanic and Atmospheric Administration's (NOAA) NMFS released new 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). Onset of PTS was assumed to be 15 dB or 6 dB higher when considering SEL$_{cum}$ and SPL$_{flat}$, respectively. For impulsive sounds, such airgun pulses, the new guidance incorporates marine mammal auditory weighting functions (Fig. A-3) 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). As required by NMFS (2016, 2018), the largest distance of the dual criteria (SEL$_{cum}$ or Peak SPL$_{flat}$) would be used as the EZ and for calculating takes. Here, for the 2-m gun separation configuration, SEL$_{cum}$ is used for LF cetaceans, and Peak SPL$_{flat}$ is used for all other hearing groups; Peak SPL$_{flat}$ is used for all hearing groups for the 8-m gun separation configuration. The new guidance did not alter the current threshold, 160 dB re 1µPa$_{rms}$, for Level B harassment (behavior).

[2] SEL (measured in dB re 1 µPa^2 · s) is a measure of the received energy in the pulse and represents the SPL that would be measured if the pulse energy were spread evenly across a 1-s period. Because actual seismic pulses are less than 1 s in duration in most situations, this means that the SEL value for a given pulse is usually lower than the SPL calculated for the actual duration of the pulse. In this EA, we assume that rms pressure levels of received seismic pulses would be 10 dB higher than the SEL values predicted by L-DEO's model.

[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).

TABLE A-1. Level B. Predicted distances to the 160 dB re 1 μPa$_{rms}$ and 175-dB sound levels that could be received from two 45-in^3 GI guns (at a tow depth of 4 m) that would be used during the seismic surveys in the South Atlantic Ocean during November–December 2019 (model results provided by L-DEO). The 160-dB criterion applies to all marine mammals; the 175-dB criterion applies to sea turtles.

Airgun Configuration	Water Depth (m)	Predicted Distances (m) to Various Received Sound Levels	
		160 dB re 1 μPa$_{rms}$	**175 dB re 1 μPa$_{rms}$**
Two 45-in^3 GI guns / 2-m gun separation	>1000	539[1]	95[1]
	100-1000	809[2]	143[2]
Two 45-in^3 GI guns / 8-m gun separation	>1000	578[1]	103[1]
	100-1000	867[2]	155[2]

[1] Distance is based on L-DEO model results.
[2] Distance is based on L-DEO model results with a 1.5 × correction factor between deep and intermediate water depths.

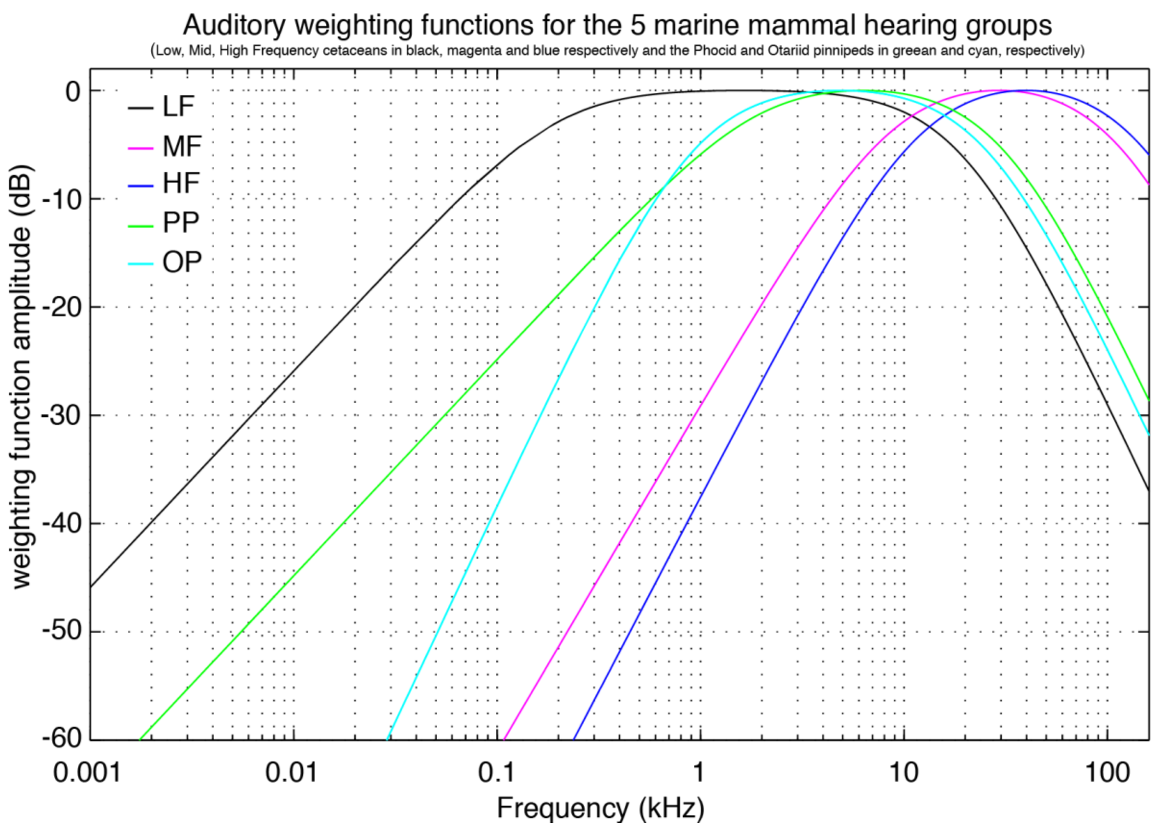

FIGURE A-3. Auditory weighting functions from NMFS technical guidance.

Since release of the new technical guidance by NMFS (2016, 2018), Southall et al. (2019) provided updated scientific recommendations regarding noise exposure criteria. These are similar to those presented by NMFS (2016, 2018) and Finneran (2016), but include all marine mammals and a re-classification of hearing groups.

The SEL_{cum} for the 2-GI airgun 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 (right) 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 interactions of the two airguns that occur near the source center and is calculated as a point source (single airgun), the modified farfield signature is a more appropriate measure of the sound source level for large arrays. For this smaller array, the modified farfield changes will be correspondingly smaller as well, but we use this method for consistency across all array sizes.

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 default values and calculating individual adjustment factors (dB) 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 (duty cycle and speed) after Sivle et al. (2014). The methodology (input) for calculating the distances to the SEL_{cum} PTS thresholds (Level A) for the airgun array is shown in Table A-2.

For the LF cetaceans, during operations with the airgun array that has the 2-m airgun separation configuration, 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; the maximum 183 dB SEL_{cum} isopleth was located at 15.38 m from the source. We then ran the modeling for a single shot with the LF cetacean weighting function applied to the full spectrum; the maximum 183 dB SEL_{cum} isopleth was located at 7.20 m from the source. The difference between 15.38 m and 7.20 m gives an adjustment factor of 6.59 dB assuming a propagation of $20\log_{10}$(Radial distance) (Table A-3). The adjustment factor for LF cetaceans during operations with the array configuration that has 8-m airgun separation is 8.26 dB (Table A-3).

TABLE A-2. SEL_{cum} Methodology Parameters (Sivle et al. 2014)†.

Airgun Configuration	Source Velocity (meters/second)	1/Repetition rate^ (seconds)
Two 45-in^3 GI guns / 2-m gun separation	2.5722	9.7192
Two 45-in^3 GI guns / 8-m gun separation	4.1156	12.1490

† Methodology assumes propagation of 20logR. ^ Time between onset of successive pulses. Activity duration (time) independent. The source velocity and 1/Repetition rate were used as inputs to the NMFS User Spreadsheet.

TABLE A-3. Table showing the results for one single SEL source level modeling for the two different airgun array configurations without and with applying weighting function to the five 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 (dB)				
	183	**185**	**155**	**185**	**203**
Two 45-in^3 GI guns / 2-m gun separation					
Distance (m) (no weighting function)	15.3852	12.3810	409.3403	12.3810	1.6535
Modified Farfield SEL	206.7421	206.8551	207.2417	206.8551	207.3681
Distance (m) (with weighting function)	7.202	N/A	N/A	N/A	N/A
Adjustment (dB)	- 6.59	N/A	N/A	N/A	N/A
Two 45-in^3 GI guns / 8-m gun separation					
Distance (m) (no weighting function)	15.9209	12.2241	427.0022	12.2241	N/A (<1m)
Modified Farfield SEL	207.0394	206.7443	207.6086	206.7443	203
Distance (m) (with weighting function)	6.145	N/A	N/A	N/A	N/A
Adjustment (dB)	- 8.26	N/A	N/A	N/A	N/A

N.A. means not applicable or not available.

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).

For the different airgun array configurations, the results for single shot SEL source level modeling are shown in Table A-3. The weighting function calculations, thresholds for SEL_{cum}, and the distances to the PTS thresholds are shown in Table A-4 for the 2-m airgun separation configuration, and in Table A-5 for the 8-m airgun separation configuration. Figure A-4 shows the impact of weighting functions by hearing group for the 2- and 8-m airgun separation configurations. For the 2-m airgun separation configuration, Figures A-5 and A-6 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups, and Figure A-7 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans. For the 8-m airgun separation configuration, Figures A-8 and A-9 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups, and Figure A-10 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans.

The thresholds for Peak SPL_{flat} for the two airgun array configurations, as well as the distances to the PTS thresholds, are shown in Table A-6. Figures A-11 and A-12 and Figures A-13 and A-14 show the modeled received sound levels to the Peak SPL_{flat} thresholds, for a single shot, without applying a high-pass filter, for the 2-m and 8-m airgun separation configurations, respectively.

The NSF/USGS PEIS defined a low-energy source as any towed acoustic source whose received level is ≤180 dB re 1 μPa_{rms} (the Level A threshold under the former NMFS acoustic guidance) at 100 m, including any single or any two GI airguns and a single pair of clustered airguns with individual volumes of ≤250 in^3. In § 2.4.2 of the PEIS, Alternative B (the Preferred Alternative) conservatively applied a 100-m EZ for all low-energy acoustic sources in water depths >100 m. Consistent with the PEIS, that approach would be used here for the pair of 45-in^3 GI airguns for all water depths. The 100-m EZ would also be used as the EZ for sea turtles, although current guidance by NMFS suggests a Level A criterion of 195 dB re 1 μPa_{rms} or an EZ of 10–11 m in deep water for the airgun array (see Fig. A-1 and A-2). If marine mammals or sea turtles are detected in or about to enter the EZ, the airguns would be shut down immediately. Enforcement of mitigation zones via shut downs would be implemented in the Operational Phase, as noted below. A fixed 160-dB “Safety Zone” was not defined for the same suite of low-energy sources in the NSF/USGS PEIS; therefore, L-DEO model results are used here to determine the 160-dB radius for the pair of 45-in^3 GI airguns (see Table A-1).

Enforcement of mitigation zones via shut downs would be implemented in the Operational Phase, as noted below. The Draft EA has been prepared in accordance with the current NOAA acoustic practices, and the procedures are based on best practices noted by Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013a), Wright (2014), and Wright and Cosentino (2015).

TABLE A-4. NMFS User Spreadsheet. Results for single shot SEL source level modeling for the two GI guns, in the 2-m airgun separation configuration, with weighting function calculations for the SEL_{cum} criteria, as well as resulting isopleths to thresholds for various hearing groups.

STEP 1: GENERAL PROJECT INFORMATION	
PROJECT TITLE	R/V Thompson
PROJECT/SOURCE INFORMATION Please include any assumptions	Two 45 cu.in. GI-guns with 2 m separation @ 4-m tow depth
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)[¥]	N/A	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.

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)	2.57222
1/Repetition rate^ (seconds)	9.7192

†Methodology assumes propagation of 20 log R; Activity duration (time) independent

^Time between onset of successive pulses.

Modified farfield SEL	206.7421	206.8551	207.2417	206.8551	207.3681
Source Factor	4.85936E+19	4.98746E+19	5.45179E+19	4.98746E+19	5.6128E+19

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
SEL_{cum} Threshold	183	185	155	185	203
PTS SEL_{cum} Isopleth to threshold (meters)	6.5	0.0	0.0	0.1	0.0

WEIGHTING FUNCTION CALCULATIONS

Weighting Function Parameters	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	
a	1	1.6	1.8	1	2	
b	2	2	2	2	2	
f_1	0.2	8.8	12	1.9	0.94	
f_2	19	110	140	30	25	
C	0.13	1.2	1.36	0.75	0.64	
Adjustment (dB)†	-6.59	-54.54	-63.64	-24.57	-30.30	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 $20\log_{10}$ (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 4A).

TABLE A-5. NMFS User Spreadsheet. Results for single shot SEL source level modeling for the two GI guns, in the 8-m airgun separation configuration, with weighting function calculations for the SEL_{cum} criteria, as well as resulting isopleths to thresholds for various hearing groups.

STEP 1: GENERAL PROJECT INFORMATION	
PROJECT TITLE	R/V Thompson
PROJECT/SOURCE INFORMATION	Two 45 cu.in. GI-guns with 8-m separation @ 4-m tow depth
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)[¥]	N/A	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.

F2: ALTERNATIVE METHOD[†] TO CALCULATE PK and SEL_{cum} (SINGLE STRIKE/SHOT/PULSE EQUIVALENT)

SEL_{cum}

Source Velocity (meters/second)	4.1156
1/Repetition rate^ (seconds)	12.1490

†Methodology assumes propagation of 20 log R; Activity duration (time) independent

^Time between onset of successive pulses.

Modified farfield SEL	207.0394	206.7443	207.6086	206.7443	203
Source Factor	4.16293E+19	3.88946E+19	4.74591E+19	3.88946E+19	1.64233E+19

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
SEL_{cum} Threshold	183	185	155	185	203
PTS SEL_{cum} Isopleth to threshold (meters)	2.4	0.0	0.0	0.0	0.0

WEIGHTING FUNCTION CALCULATIONS

Weighting Function Parameters	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	
a	1	1.6	1.8	1	2	
b	2	2	2	2	2	
f_1	0.2	8.8	12	1.9	0.94	
f_2	19	110	140	30	25	
C	0.13	1.2	1.36	0.75	0.64	
Adjustment (dB)†	-8.26	-55.38	-64.50	-25.13	-31.19	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 $20\log_{10}$ (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 4B).

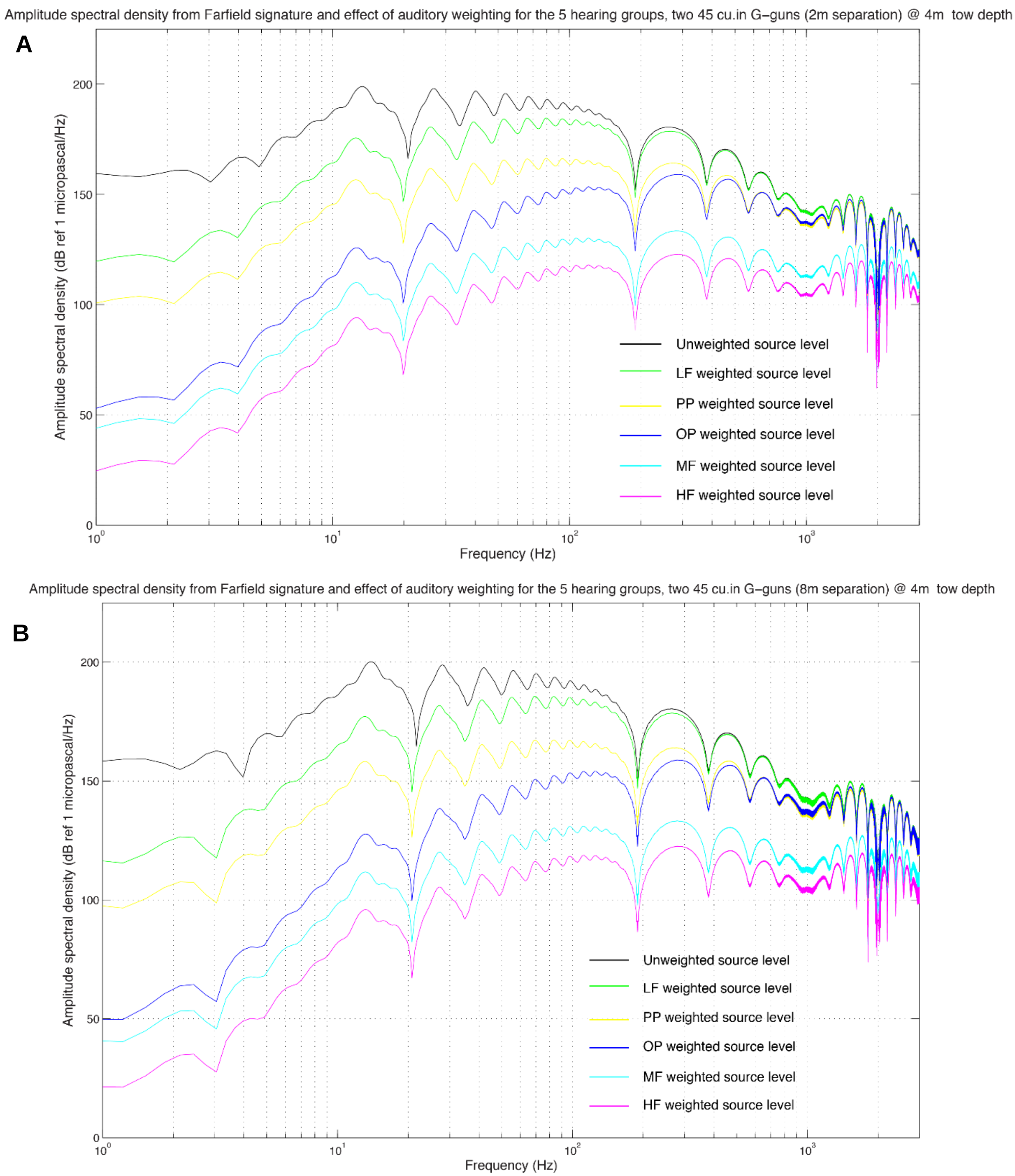

FIGURE A-4. Modeled amplitude spectral density of the two GI guns farfield signature for the (A) 2-m airgun separation and (B) 8-m airgun separation configurations. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid 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.

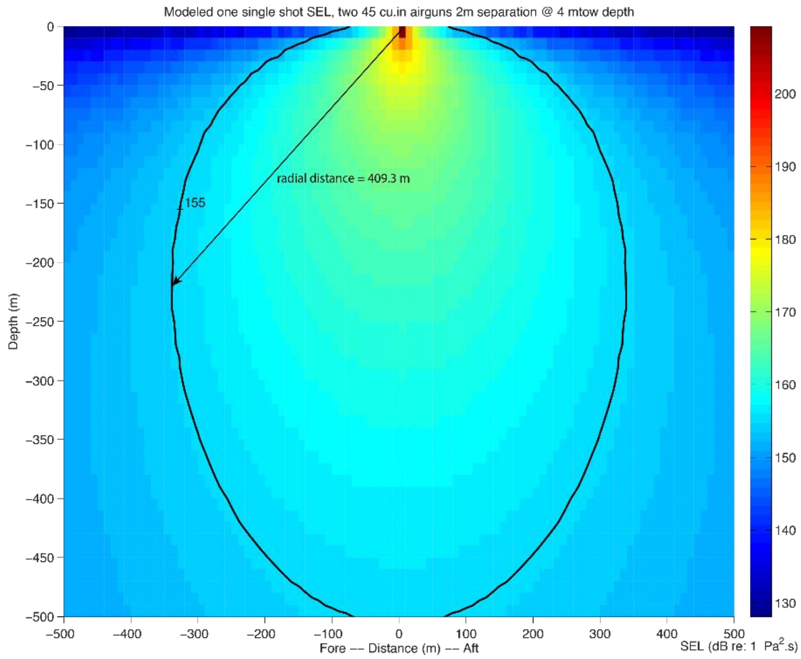

FIGURE A-5. Modeled received sound levels (SELs) in deep water from the two 45 in³ GI guns, with 2-m gun separation, at a 4-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth.

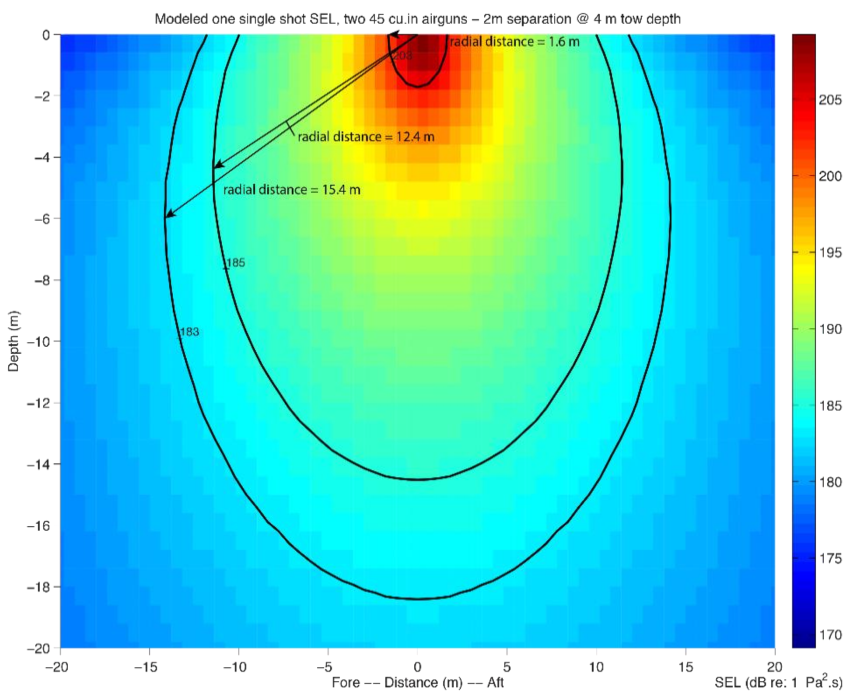

FIGURE A-6. Modeled received sound levels (SELs) in deep water from the two 45 in³ GI guns, with 2-m gun separation, at a 4-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183-, 185-, and 203-dB SEL isopleths.

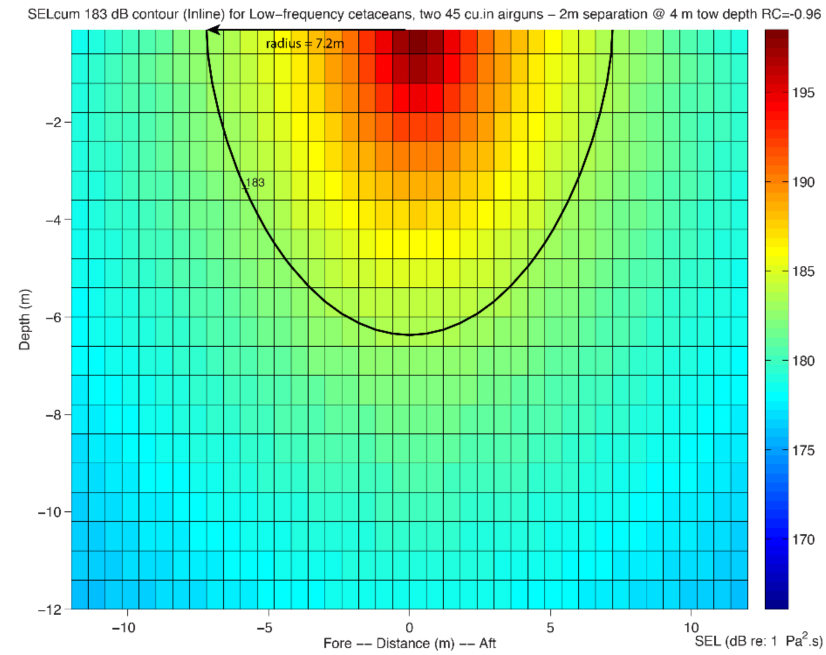

FIGURE A-7. Modeled received sound exposure levels (SELs) from the two 45 in^3 GI guns, with a 2-m airgun separation, at a 4-m tow depth, after applying the auditory weighting function for the LF cetaceans following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one shot. The difference in radial distances between Fig. A-6 and this figure allows us to estimate the adjustment in dB.

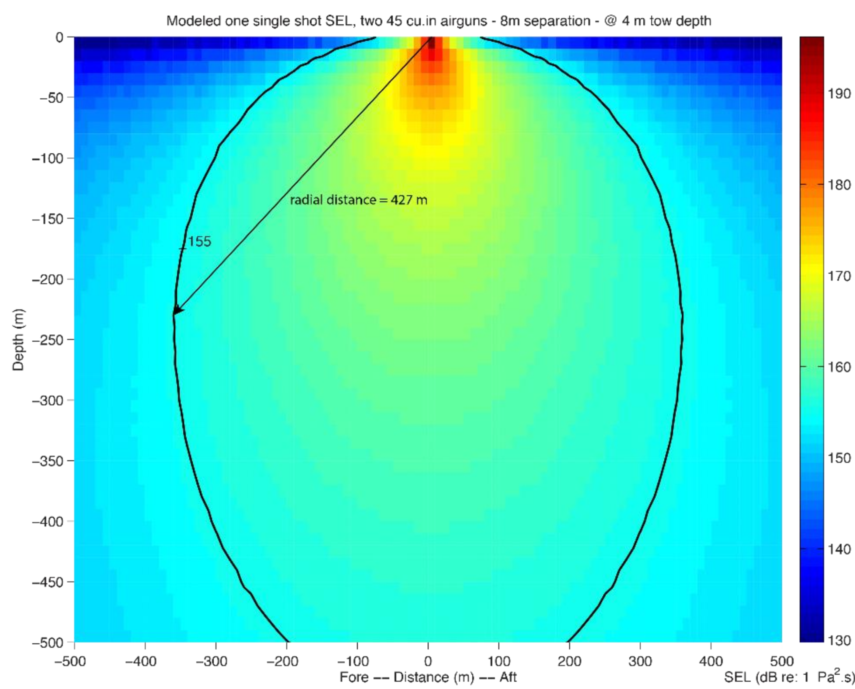

FIGURE A-8. Modeled received sound levels (SELs) in deep water from the two 45 in^3 GI airguns, with 8-m airgun separation, at a 4-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth.

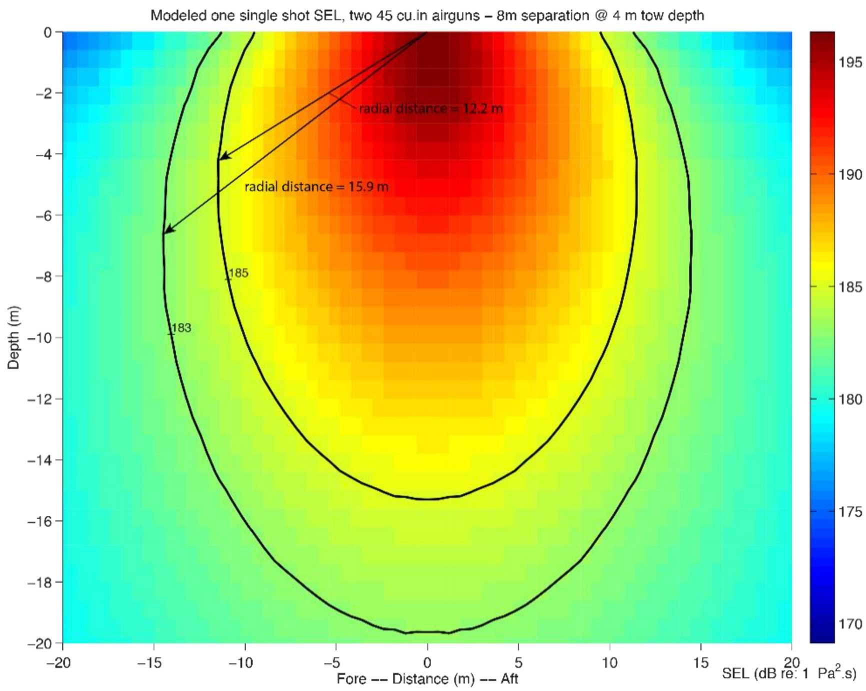

FIGURE A-9. Modeled received sound levels (SELs) in deep water from the two 45 in³ GI airguns, with 8-m airgun separation, at a 4-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183-, 185-, and 203-dB SEL isopleths.

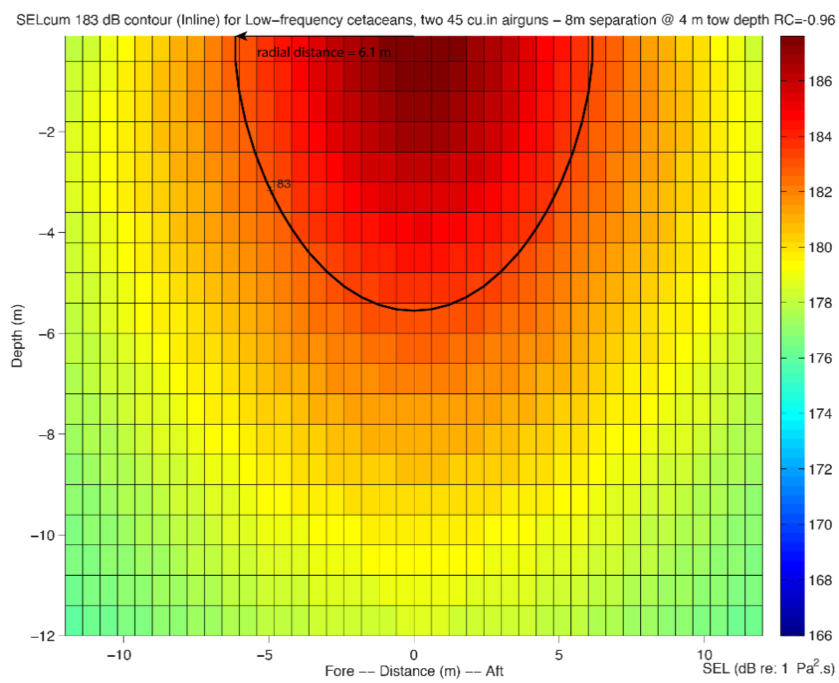

FIGURE A-10. Modeled received sound exposure levels (SELs) from the two 45 in³ GI airguns, with an 8-m airgun separation, at a 4-m tow depth, after applying the auditory weighting function for the LF cetaceans following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one shot. The difference in radial distances between Fig. A-9 and this figure allows us to estimate the adjustment in dB.

TABLE A-6. NMFS Level A acoustic thresholds (Peak SPL_{flat}) for impulsive sources for marine mammals and predicted distances to Level A thresholds for various marine mammal hearing groups that could be received from the different airgun configurations during the proposed seismic surveys in the South Atlantic Ocean.

	Hearing Group				
	Low-Frequency Cetaceans	**Mid-Frequency Cetaceans**	**High-Frequency Cetaceans**	**Phocid Pinnipeds**	**Otariid Pinnipeds**
PK Threshold (dB)	**219**	**230**	**202**	**218**	**232**
Two 45-in^3 GI guns / 2-m gun separation					
Modified PK Farfield	232.7862	229.8245	232.9136*	232.8230	225.6248
Radius to Threshold (m)	4.89	0.98	34.62	5.51	0.48
Two 45-in^3 GI guns / 8-m gun separation					
Modified PK Farfield	228.7710	N/A	233.0119*	230.0845	N/A
Radius to Threshold (m)	3.08	N/A	34.84	4.02	N/A

N.A. means not applicable or not available.

[1] Using radial distance (35.13 m and 35.53 m for the 2- and 8-m airgun separation configurations, respectively); for other hearing groups, radius and radial distance are the same.

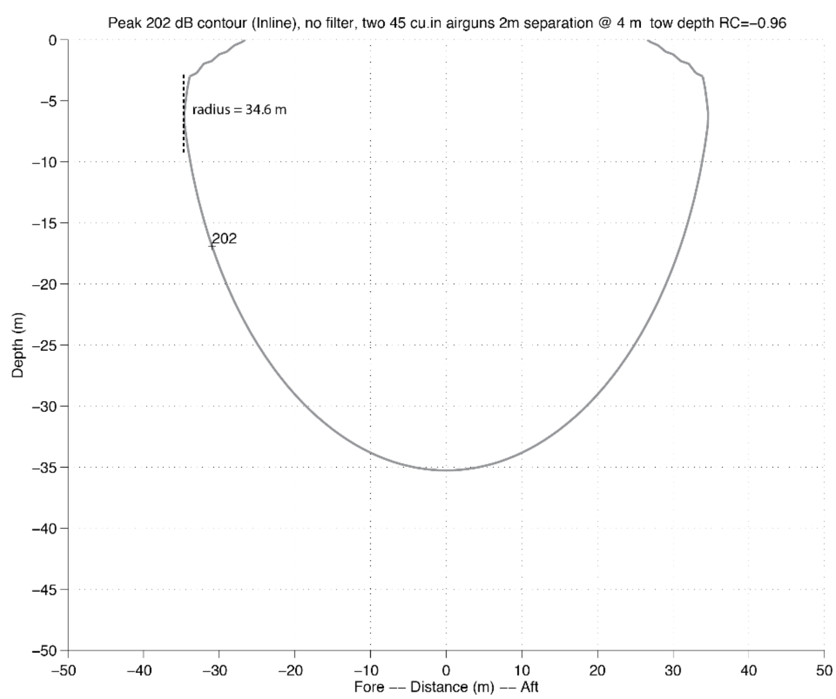

FIGURE A-11. Modeled deep-water received Peak SPL from two 45-in^3 GI guns, in a 2-m gun separation configuration, at a 4-m tow depth. The plot provides the radial distance and radius from the source geometrical center to the 202-dB Peak isopleth.

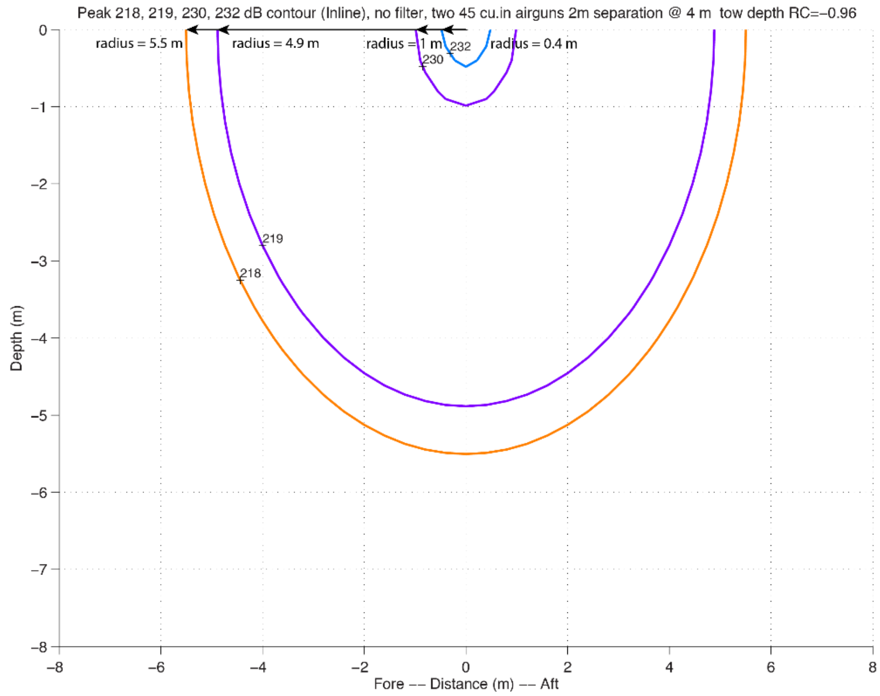

FIGURE A-12. Modeled deep-water received Peak SPL from two 45-in^3 GI airguns, with a 2-m airgun separation configuration, at a 4-m tow depth. The plot provides the radial distances (radii) from the source geometrical center to the 218-, 219-, 230-, and 232-dB Peak isopleths.

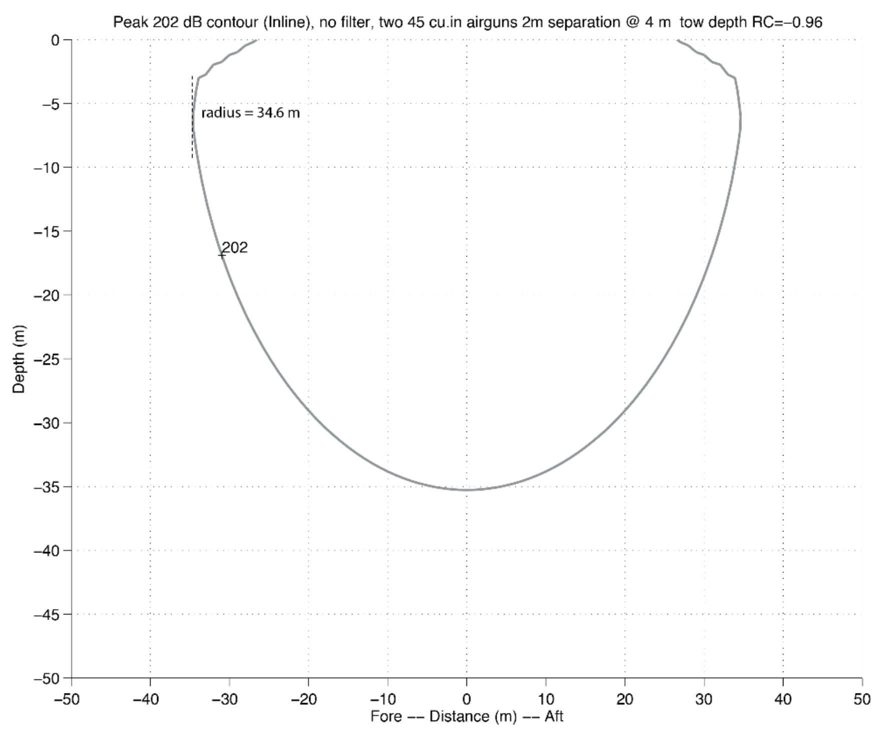

FIGURE A-13. Modeled deep-water received Peak SPL from two 45-in^3 GI airguns, in an 8-m airgun separation configuration, at a 4-m tow depth. The plot provides the radial distance and radius from the source geometrical center to the 202-dB Peak isopleth.

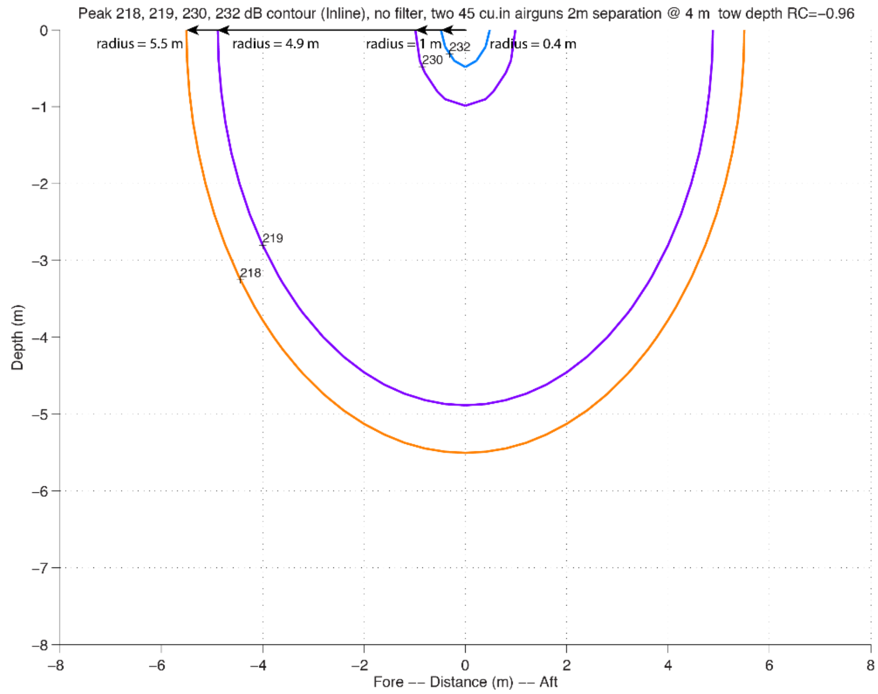

FIGURE A-14. Modeled deep-water received Peak SPL from two 45-in^3 GI airguns, with an 8-m airgun separation configuration, at a 4-m tow depth. The plot provides the radial distances (radii) from the source geometrical center to the 218-, 219-, 230-, and 232-dB Peak isopleths.

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APPENDIX B: MARINE MAMMAL DENSITIES

The preferred source of density data for the species that might be encountered in the proposed survey areas in the South Atlantic Ocean was Di Tullio et al. (2016). The rationale for using these data was that these surveys were conducted offshore along the continental slope at the same latitudes as the proposed seismic surveys and so come from a similar season, water depth category, and climatic region in the southern Atlantic Ocean. When data for species expected to occur in the proposed seismic survey areas were not available in Di Tullio et al. (2016), we used data from White et al. (2002) as calculated in LGL/NSF (2019) because they came from an area which was slightly south of the proposed project area but well north of the AECOM/NSF (2014) study area. An exception was made for the southern right whale, for which densities from AECOM/NSF (2014) were higher and thus more conservative. Next, we used data from AECOM/NSF (2014); although they come from an area south of the proposed project area, they were the next best data available for those species. For species not included in these sources, we used data from de Boer (2010), Garaffo et al. (2011), NOAA-SWFSC LOA (2013 *in* AECOM/NSF 2014), Wedekin et al. (2014), Bradford et al. (2017), and Mannocci et al. (2017). When densities were not directly available from the above studies, they were estimated using sightings and effort reported in those sources. Densities calculated from de Boer (2010) come from LGL/NSF (2016); densities from White et al. (2002), Garaffo et al. (2011), and Wedekin et al. (2014) are from LGL/NSF (2019). How densities were derived from these sources is explained in LGL /NSF (2016, 2019). Methods used from newer data sources to estimate animal abundance when direct estimates of density were not available are described below.

1. Di Tullio et al. (2016) conducted vessel-based surveys during austral spring and fall of 2009–2015 at the same latitude along South America as the proposed surveys off Southwest Africa. Surveys were conducted along the continental slope which is a similar habitat as would be covered by the proposed seismic surveys. They provide summaries of their survey data for the northern and southern parts of their survey area, and we included data from both areas to estimate densities for the proposed surveys. Their summaries included number of sightings for each species, mean pod size, and survey effort.

2. Mannocci et al. (2017) modelled densities of *Kogia* spp. in the Northwest Atlantic Ocean. An average density for offshore areas south of 40°N is 0.0060 animals/1000 km^2. We prorated the density for *Kogia* spp. according to the number of carcasses examined by Findlay et al. (1992) along the coast of southern Africa to estimate densities for pygmy and dwarf sperm whales.

Densities from the Di Tullio et al. (2016) study were calculated using the number of sightings, mean group size, and the survey effort (in km) given in the paper. They were entered into the distance formula (1) from Barlow (2003) to calculate the density using the correction factors given in Bradford et al. (2017), or for species not present in Bradford et al. (2017), in Barlow (2016) for vessel-based surveys.

(1) $\text{Density} = [n \times s \times f(0)] / [2L \times g(0)]$

Where n is the number of sightings, s is the mean group size, and L is the number of km of survey effort.

When species could not be determined during the survey, but the sightings were identified to genus (i.e., *Kogia*, minke, and beaked whales), we calculated the density for all animals in that genus and prorated the density for the genus to densities for the individual species based on data on relative occurrence of each species in stranding records (Findlay et al. 1992; Otley et al. 2012). Unidentified whales, small cetaceans, unidentified dolphins, etc., were prorated based on the number of sightings for each identified species and added to the density for individual species that would be included in the particular unidentified category.

Table B-1 gives the sources of the data for estimation of density for each species with the sources of correction factors used. It also includes a brief explanation of the rationale for using upward or downward changes in the density because it had been obtained for areas outside of the proposed project area. For example, the density for southern right whales was obtained from AECOM/NSF (2014) for the summer feeding areas south of the proposed project area. During the proposed survey period, whales would primarily be in the southern feeding areas but any that might be encountered would be migrating from wintering areas in and adjacent to the proposed survey areas to summer feeding grounds areas south of there.

TABLE B-1. Sources of density data used.

Species	Reported Density (#/km²)	Adjustment	Density Used (#/km²)	Density References	Comment
Mysticetes					
South Atlantic right whale	0.007965		0.007965	AECOM/NSF (2014)	Density based on White et al. (2002) seemed too low.
Pygmy right whale	N.A.		N.A.		No density available.
Blue whale	0.000051		0.000051	AECOM/NSF (2014)	
Fin whale	0.000356		0.000356	Di Tullio et al. (2016)	
Sei whale	0.000086		0.000086	Di Tullio et al. (2016)	
Bryde's whale	0.000439		0.000439	Di Tullio et al. (2016)	
Common minke whale	0.155792	0.5	0.077896	AECOM/NSF (2014)	Density prorated based on equal numbers of both species.
Antarctic minke whale	0.155792	0.5	0.077896	AECOM/NSF (2014)	Density prorated based on equal numbers of both species.
Humpback whale	0.000310		0.000310	Di Tullio et al. (2016)	
Odontocetes					
Sperm whale	0.005975		0.005975	Di Tullio et al. (2016)	
Pygmy sperm whale	0.006000	0.57	0.003418	Mannocci et al. (2017)	For *Kogia* spp. - prorated by carcasses examined in Findlay et al. (1992)
Dwarf sperm whale	0.006000	0.43	0.002582	Mannocci et al. (2017)	For *Kogia* spp. - prorated by carcasses examined in Findlay et al. (1992)
Arnoux's beaked whale	0.011379		0.011379	AECOM/NSF (2014)	
Cuvier's beaked whale	0.000548		0.000548	AECOM/NSF (2014)	
Southern bottlenose whale	0.007906		0.007906	White et al. (2002)	
Shepherd's beaked whale	0.009269		0.009269	79 FR60811	
Blainville's beaked whale	0.001323	0.04	0.000053	White et al. (2002)	Based on number of sightings and effort; adjustment based on stranding data in Otley et al. (2012)
Gray's beaked whale	0.001885		0.001885	AECOM/NSF (2014)	
Hector's beaked whale	0.001323	0.16	0.000212	White et al. (2002)	Based on number of sightings and effort; adjustment based on stranding daata in Otley et al. (2012)
Gervais' beaked whale	0.001323		0.001323	White et al. (2002)	Assumed same density as other rare beaked whales; based on number of sightngs and effort in White et al. (2002) and adjusted for number of strandings in Otley et al. (2012)
True's beaked whale	0.001323	0.04	0.000053	White et al. (2002)	Based on number of sightings and effort; adjustment based on stranding data in Otley et al. (2012)
Strap-toothed beaked whale	0.001323	0.44	0.000582	White et al. (2002)	Based on number of sightings and effort; adjustment based on stranding data in Otley et al. (2012)
Andrew's beaked whale	0.001323	0.12	0.000159	White et al. (2002)	Based on number of sightings and effort; adjustment based on stranding data in Otley et al. (2012)
Spade-toothed beaked whale	0.001323	0.04	0.000053	White et al. (2002)	Based on number of sightings and effort; adjustment based on stranding data in Otley et al. (2012)
Risso's dolphin	0.010657		0.010657	Di Tullio et al. (2016)	
Rough-toothed dolphin	0.005954		0.005954	Wedekin et al. 2014	1 sighting of 30 individuals, 1300 km, assumed 5 km horizontal detection area, assumed g*(0)* =0.2
Common bottlenose dolphin	0.040308		0.040308	Di Tullio et al. (2016)	
Pantropical spotted dolphin	0.003767		0.003767	de Boer (2010)	1 sighting, 60 individuals, 4109 km, assumed 5 km horizontal detection area, assumed g*(0)* =0.2
Atlantic spotted dolphin	0.213721		0.213721	Di Tullio et al. (2016)	
Spinner dolphin	0.040720		0.040720	Di Tullio et al. (2016)	
Clymene dolphin	0.006800		0.006800	Di Tullio et al. (2016)	
Striped dolphin	0.004089		0.004089	Di Tullio et al. (2016)	
Short-beaked common dolphin	0.717166		0.717166	Garaffo et al. (2011)	
Fraser's dolphin	0.021040		0.021040	Bradford et al. (2017)	Same distance above equator as Namibia is below the equator, but from Pacific
Dusky dolphin	0.128668	0.1	0.012867	Garaffo et al. (2011)	Downgraded to 10% of density, as unlikely to occur so far offshore
Hourglass dolphin	0.111223	0.1	0.011122	White et al. (2002)	Based on number of sightings and effort; downgraded to 10% of density, as likely to be rare in project area.
Southern right whale dolphin	0.006827		0.006827	White et al. (2002)	Based on number of sightings and effort
Killer whale	0.000266		0.000266	Di Tullio et al. (2016)	
Short-finned pilot whale	0.002085		0.002085	de Boer (2010)	2 sightings, 11 individuals, 4109 km, assumed 5 km horizontal detection area, assumed g*(0)* =0.2
Long-finned pilot whale	0.021379		0.021379	Di Tullio et al. (2016)	
False killer whale	0.000882		0.000882	Di Tullio et al. (2016)	
Pygmy killer whale	0.000321		0.000321	Di Tullio et al. (2016)	
Melon-headed whale	0.003540		0.003540	Bradford et al. (2017)	Same distance above equator as Namibia is below the equator, but from Pacific.
Pinnipeds					
Subantarctic fur seal	0.027362	0.1	0.002736	White et al. (2002)	Based on number of sightings and effort, but downgraded to 10% of density as likely to be rare in area.
Cape fur seal	N.A.		N.A.		Density not available for offshore waters, but unlikely to occur there.
Crabeater seal	0.648650	0.01	0.006487	NOAA-SWFSC LOA (2013)*; density/100	
Leopard seal	0.016220	0.1	0.001622	NOAA-SWFSC LOA (2013)*; density/10	
Southern elephant seal	0.001548		0.001548	White et al. (2002)	Based on number of sightings and effort

* density as cited in AECOM/NSF (2014). N.A. is not available.

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APPENDIX C: MARINE MAMMAL TAKE CALCULATIONS

Species	Reported Density (#/km^2)	Correction Factor	Estimated Density (#/km^2)	Population Size	Hearing Group	Level B Ensonified Area km^2 (160 dB)	Level A Ensonified Area km^2	Total Takes	Level B Takes	Level A Takes	% of Population	Requested Level B Take Authorization
Mysticetes												
South Atlantic right whale	0.007965		0.007965	3300	LF	5184	47	41	41	0	1.3	**41**
Pygmy right whale	N.A.		N.A.	N.A.	LF	5184	47	N.A.	N.A.	N.A.	N.A.	**2**
Blue whale	0.000051		0.000051	2300	LF	5184	47	0	0	0	<0.1	**3**
Fin whale	0.000356		0.000356	15000	LF	5184	47	2	2	0	<0.1	**4**
Sei whale	0.000086		0.000086	10000	LF	5184	47	0	0	0	<0.1	**3**
Bryde's whale	0.000439		0.000439	48109	LF	5184	47	2	2	0	<0.1	**20**
Common minke whale	0.077896		0.077896	515000	LF	5184	47	404	400	4	0.1	**404**
Antarctic minke whale	0.077896		0.077896	515000	LF	5184	47	404	400	4	0.1	**404**
Humpback whale	0.000310		0.000310	42000	LF	5184	47	2	2	0	0.0	**20**
Odontocetes												
Sperm whale	0.005975		0.005975	12069	MF	5184	6	31	31	0	0.3	**31**
Pygmy sperm whale	0.006000	0.57	0.003418	N.A.	HF	5184	316	18	17	1	N.A.	**18**
Dwarf sperm whale	0.006000	0.43	0.002582	N.A.	HF	5184	316	13	13	1	N.A.	**13**
Arnoux's beaked whale	0.011379		0.011379	599300	MF	5184	6	59	59	0	<0.1	**59**
Cuvier's beaked whale	0.000548		0.000548	599300	MF	5184	6	3	3	0	<0.1	**3**
Southern bottlenose whale	0.007906		0.007906	599300	MF	5184	6	41	41	0	<0.1	**41**
Shepherd's beaked whale	0.009269		0.009269	N.A.	MF	5184	6	48	48	0	N.A.	**48**
Blainville's beaked whale	0.001323	0.04	0.000053	N.A.	MF	5184	6	0	0	0	N.A.	**7**
Gray's beaked whale	0.001885		0.001885	599300	MF	5184	6	10	10	0	<0.1	**10**
Hector's beaked whale	0.001323	0.16	0.000212	N.A.	MF	5184	6	1	1	0	N.A.	**2**
Gervais' beaked whale	0.001323		0.001323	N.A.	MF	5184	6	7	7	0	N.A.	**7**
True's beaked whale	0.001323	0.04	0.000053	N.A.	MF	5184	6	0	0	0	N.A.	**2**
Strap-toothed beaked whale	0.001323	0.44	0.000582	599300	MF	5184	6	3	3	0	<0.1	**3**
Andrew's beaked whale	0.001323	0.12	0.000159	N.A.	MF	5184	6	1	1	0	N.A.	**2**
Spade-toothed beaked whale	0.001323	0.04	0.000053	N.A.	MF	5184	6	0	0	0	N.A.	**2**
Risso's dolphin	0.010657		0.010657	18250	MF	5184	6	55	55	0	0.3	**78**
Rough-toothed dolphin	0.005954		0.005954	N.A.	MF	5184	6	31	31	0	N.A.	**55**
Common bottlenose dolphin	0.040308		0.040308	77532	MF	5184	6	209	209	0	0.3	**209**
Pantropical spotted dolphin	0.003767		0.003767	3333	MF	5184	6	20	20	0	0.6	**104**
Atlantic spotted dolphin	0.213721		0.213721	44715	MF	5184	6	1108	1108	0	2.5	**1108**
Spinner dolphin	0.040720		0.040720	N.A.	MF	5184	6	211	211	0	N.A.	**315**
Clymene dolphin	0.006800		0.006800	N.A.	MF	5184	6	35	35	0	N.A.	**35**
Striped dolphin	0.004089		0.004089	54807	MF	5184	6	21	21	0	<0.1	**110**
Short-beaked common dolphin	0.717166		0.717166	70184	MF	5184	6	3718	3714	4	5.3	**3718**
Fraser's dolphin	0.021040		0.021040	N.A.	MF	5184	6	109	109	0	N.A.	**283**
Dusky dolphin	0.128668	0.10	0.012867	7252	MF	5184	6	67	67	0	0.9	**67**
Hourglass dolphin	0.111223	0.10	0.011122	150000	HF	5184	316	58	54	4	<0.1	**58**
Southern right whale dolphin	0.006827		0.006827	N.A.	MF	5184	6	35	35	0	N.A.	**35**
Killer whale	0.000266		0.000266	25000	MF	5184	6	1	1	0	<0.1	**5**
Short-finned pilot whale	0.002085		0.002085	200000	MF	5184	6	11	11	0	<0.1	**41**
Long-finned pilot whale	0.021379		0.021379	200000	MF	5184	6	111	111	0	0.1	**111**
False killer whale	0.000882		0.000882	N.A.	MF	5184	6	5	5	0	N.A.	**35**
Pygmy killer whale	0.000321		0.000321	N.A.	MF	5184	6	2	2	0	N.A.	**26**
Melon-headed whale	0.003540		0.003540	N.A.	MF	5184	6	18	18	0	N.A.	**170**
Pinnipeds												
Subantarctic fur seal	0.027362	0.10	0.002736	400000	OW	5184	3	14	14	0	<0.1	**14**
Cape fur seal	N.A.		N.A.	2000000	OW	5184	3	N.A.	N.A.	N.A.	N.A.	**20**
Crabeater seal	0.648650	0.01	0.006487	5000000	PW	5184	45	34	34	0	<0.1	**34**
Leopard seal	0.016220	0.10	0.001622	222000	PW	5184	45	8	8	0	<0.1	**8**
Southern elephant seal	0.001548	1.00	0.001548	750000	PW	5184	45	8	8	0	<0.1	**8**

APPENDIX D: ENSONIFIED AREAS FOR MARINE MAMMAL TAKE CALCULATIONS

Survey Type	Criteria	Daily Ensonified Area (km^2)	Total Survey Days	25% increase	Total Ensonified Area	Relevant Isopleth (m)
5-kt survey	160dB - all depths	245.98	10	1.25	3074.76	
5-kt survey	160 dB - intermediate	14.67	10	1.25	183.34	809
5-kt survey	160-dB - deep	231.31	10	1.25	2891.42	539
5-kt survey	LFCetacean - Level A	2.89	10	1.25	36.08	6.5
5-kt survey	MFCetacean - Level A	0.44	10	1.25	5.55	1
5-kt survey	HFCetacean - Level A	15.37	10	1.25	192.12	34.6
5-kt survey	Phocids - Level A	2.44	10	1.25	30.53	5.5
5-kt survey	Otariids - Level A	0.22	10	1.25	2.77	0.5
8-kt survey	160dB - all depths	421.83	4	1.25	2109.13	
8-kt survey	160 dB - intermediate	25.95	4	1.25	129.75	867
8-kt survey	160-dB - deep	395.88	4	1.25	1979.38	578
8-kt survey	LFCetacean - Level A	2.21	4	1.25	11.04	3.1
8-kt survey	MFCetacean - Level A	0	4	1.25	0	0
8-kt survey	HFCetacean - Level A	24.78	4	1.25	124	34.8
8-kt survey	Phocids - Level A	2.85	4	1.25	14.24	4
8-kt survey	Otariids - Level A	0	4	1.25	0	0

Criteria	Total Ensonified Area (km^2) (all survey days; all survey speeds)
160dB - all depths combined	5183.89
160 dB - intermediate water	313.09
160 dB - deep water	4870.80
LFCetacean - Level A	47.11
MFCetacean - Level A	5.55
HFCetacean - Level A	316.04
Phocids - Level A	44.77
Otariids - Level A	2.77