Request for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during Low-Energy Marine Geophysical Surveys by RVIB *Nathaniel B. Palmer* in the Ross Sea, Antarctica, Austral Summer 2022/2023

Submitted by

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to

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26 May 2020

LGL Report FA0244-2

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SUMMARY

The U.S. National Science Foundation (NSF) plans to support a research activity that would involve low-energy seismic surveys in the Ross Sea, Antarctica, during austral summer 2022/2023. The study would be conducted on the United States Antarctic Program (USAP) research vessel (R/V)/ice breaker (IB) RVIB *Nathaniel B. Palmer* (NBP). Researchers from Louisiana State University, Texas A&M University, University of Texas at Austin, University of West Florida, and Dauphin Island Sea Lab, with funding from the U.S. National Science Foundation (NSF), propose to use up to two low-energy Generator-Injector (GI) airguns with a maximum discharge volume of ~210 in^3 to conduct the surveys in the Ross Sea. The proposed seismic surveys would take place within the Antarctic Treaty area in depths ranging from ~150 to 1100 m. NSF on behalf of itself, Louisiana State University, Texas A&M University, University of Texas at Austin, University of West Florida, and Dauphin Island Sea Lab, 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 survey area in the Ross Sea. Under the U.S. Endangered Species Act (ESA), several of these species are listed as ***endangered***, including the blue, fin, sei, and sperm whales. NSF 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.

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

NSF plans to conduct low-energy seismic surveys in the Ross Sea from ~18 December 2022 to 18 January 2023. The Ross Bank survey would take place on the central Ross Sea continental shelf between ~75°–77.7°S and 171°E–173°W, and the Drygalski Trough survey would occur between ~74°–76.7°S and 163.6°E–170°E (Fig. 1). The proposed seismic surveys would occur within the Antarctic Treaty area in water depths ranging from ~150 to 1100 m. No survey effort would occur in shallow water <100 m deep; and very little, if any, is expected to occur in deep water >1000 m. Representative survey tracklines are shown in Figure 1; however, the actual survey effort could occur anywhere within the outlined survey areas as shown in Figure 1. Some deviation in actual tracklines could be necessary for reasons such as ice cover, science drivers, poor data quality, inclement weather, or mechanical issues with the research vessel and/or equipment. In particular, for the Drygalski Trough survey, the primary target site is shown, but seismic lines may have to be acquired north of the Drygalski Ice Tongue if ice conditions preclude seismic operations in the southern portion of the survey area.

During the Ross Bank survey, Principal Investigator (PI) Dr. P.J. Bart from Louisiana State University proposes to conduct low-energy seismic surveys and coring to test the hypothesis that the Ross Ice Shelf (RIS) was formerly pinned on the Ross Bank in the recent geologic past. The goal of the Ross Bay survey is to determine if, how, when, and why the RIS unpinned from Ross Bank in the recent geologic past, to assess to what degree that event caused a re-organization of ice sheet and ice shelf flow towards its current configuration. A regional grid of seismic data with companion multibeam echosounder (MBES) and sub-bottom profiler (SBP) data are needed to place the existing and new observations within a regional stratigraphic framework. This stratigraphic framework would allow a more targeted coring effort in the future that is fully informed by subglacial erosion and/or depositional features and subsurface thickness changes. Sedimentary changes in key cores (from the bank crest and adjacent basins) should provide a detailed record of the time-transgressive environmental changes associated with ice shelf unpinning from Ross Bank (i.e., from subglacial to sub-ice-shelf to the current open-marine setting). From the sedimentary boundaries in these cores, targeted sampling can be designed to generate a radiocarbon chronology of environmental changes at Ross Bank and an adjacent trough (i.e., Pennell and Glomar Challenger Basins).

Principal Investigator (PI) Dr. R. Coffin (Texas A&M University), along with co-PIs Drs. N. Bangs (University of Texas), I. Pecher (Texas A&M University), W. Jeffreys (University of West Florida), and B. Reese (Dauphin Island Sea Lab), propose to conduct low-energy seismic surveys along the Drygalski Trough to examine the gas hydrate contribution to the Ross Sea carbon budget. The Drygalski Trough survey would examine the warming and carbon cycling of the ephemeral reservoir of carbon at the extensive bottom ocean layer–sediment interface of the Ross Sea. This large carbon reserve appears to be sealed in the form of gas hydrate and is a thermogenic carbon source and carbon storage in deep sediment hydrates. The warming and ice melting coupled with high thermogenic gas hydrate loadings suggest the Ross Sea is an essential environment to determine contributions of current day and potential future methane, petroleum, and glacial carbon to shallow sediment and water column carbon cycles.

The procedures to be used for the seismic surveys would be similar to those used during previous NSF-funded research seismic surveys and would use conventional seismic methodology. To achieve the program goals, both the Ross Bank and Drygalski Trough surveys would use RVIB NBP to acquire low-energy, high-resolution multi-channel seismic (MCS) profiles in the Ross Sea. The Drygalski

Trough survey would also use Ocean Bottom Seismometers (OBSs) to acquire long offset reflection and refraction data to improve the assessment of methane hydrate. Marine technicians would deploy up to two GI airguns as an energy source, with a maximum discharge volume of ~210 in^3, from RVIB NBP. The GI airguns would be towed ~2.4 m apart, at a speed of 4.5 kt and a depth of 1–4 m. The receiving system would consist of one hydrophone streamer up to 800-m in length; during the Drygalski Trough survey, OBSs would be used in addition to the streamer. As the airguns are towed along the survey lines, the solid-state (solid flexible polymer made from extruded polyurethane, not gel or oil filled) hydrophone streamer would receive the returning acoustic signals and transfer the data to the on-board processing system, and the OBSs would receive and store the returning acoustic signals internally for later analysis. If sea-ice conditions permit, a multi-channel digital streamer would be used to improve signal-to-noise ratio by digital data processing; if ice is present, a single-channel digital steamer would be employed.

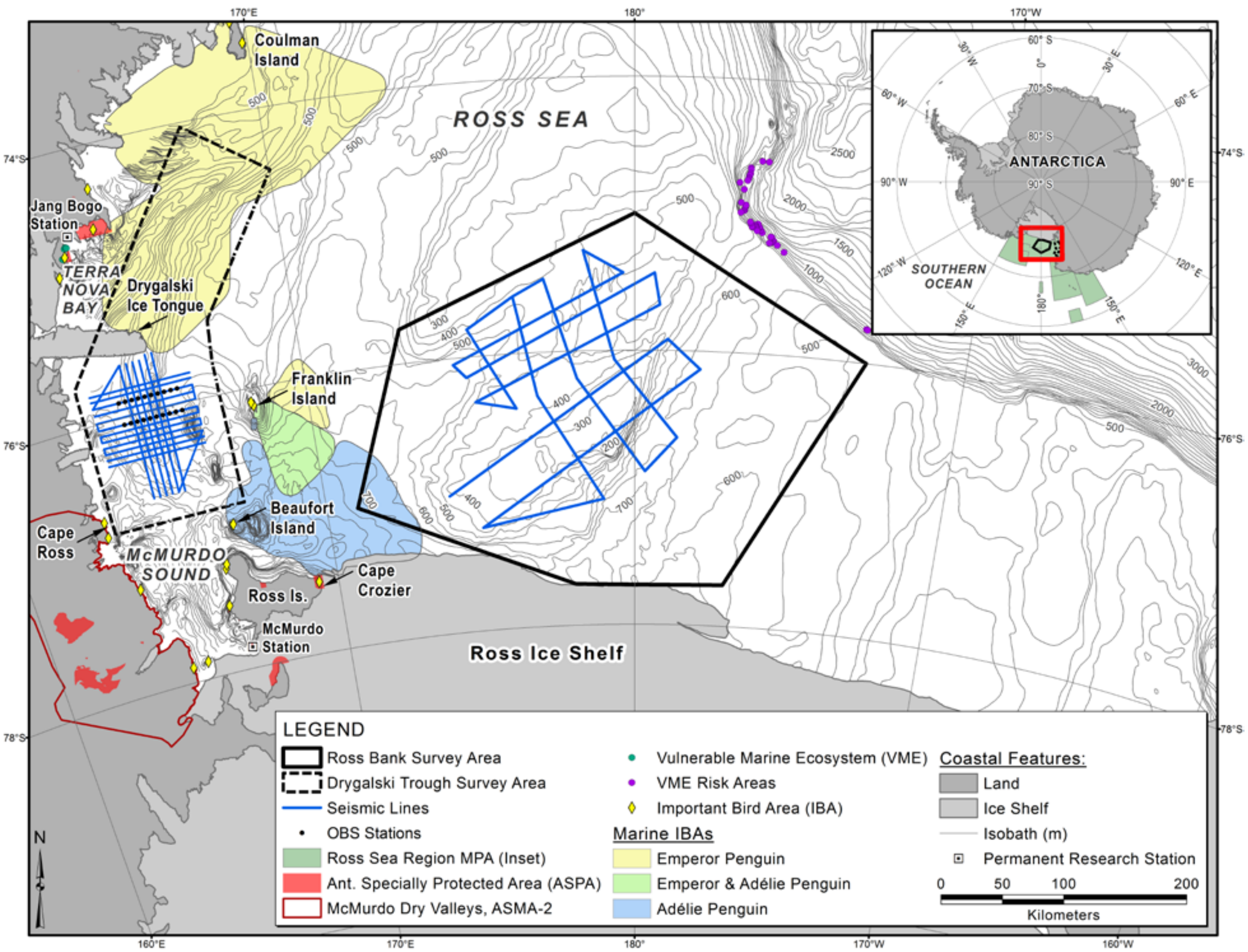

FIGURE 1. Location Survey areas for the proposed low-energy seismic surveys in the Ross Sea during austral summer 2022/2023, showing representative transect lines and the protected areas. Ant. = Antarctic. ASMA = Antarctic Specially Managed Area. IBA = Important Bird Area. Sources: Davey (2013), CCAMLR (2017), Handley et al. (2021), and British Antarctic Survey (2022).

Seismic acquisition is proposed to begin with a standard sea trial to determine which configuration and mode of GI airgun(s) provide the best reflection signals, which depends on sea-state and subsurface conditions. A maximum of two GI airguns would be used. Four GI configurations (each using one or two GI airguns) would be tested during the sea trial, including:

- Configuration 1: 50 in^3 Harmonic Mode configured as 25 in^3 Generator + 25 Injector in^3
- Configuration 2: 90 in^3 Harmonic Mode configured as 45 in^3 Generator + 45 Injector in^3
- Configuration 3: 150 in^3 True-GI Mode configured as 45 in^3 Generator + 105 Injector in^3
- Configuration 4: 210 in^3 Harmonic Mode configured as 105 in^3 Generator + 105 Injector in^3

During the Ross Bank survey, ~1920 km of seismic data would be collected, and during the Drygalski Trough survey, ~1800 km of seismic acquisition would occur, for a total of 3720 line km. Although representative lines for the two surveys are depicted in Figure 1, the line locations are preliminary and could be refined in light of information from data collected during the study and ice conditions within the survey areas. Most, if not all survey effort would occur in intermediate water ~150 to 1000 m deep; however, there could be some survey effort in water >1000 m if seismic operations occur north of the Drygalski Ice Tongue in the Drygalski Trough survey area. 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% of effort has been added for those additional operations. The airguns would be operated as efficiently as possible to meet science objectives, therefore, this could be 24/7 for multiple days.

Hull-mounted MBESs, SBP, and Acoustic Doppler Current Profilers (ADCPs) would also be operated from RVIB NBP continuously throughout the seismic surveys. All planned activities would be conducted by Louisiana State University, Texas A&M University, University of Texas at Austin, University of West Florida, and Dauphin Island Sea Lab, 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

RVIB NBP has a length of 93.9 m, beam of 18.3 m, and draft of 6.8 m. It has four Caterpillar Model 3608 diesel engines (each at 3300 brake horsepower (bhp) at 900 rpm) and a water jet, azimuthing bow thruster. Electrical power is provided by four Caterpillar 3512, 1050-kW diesel generators. An operation speed of ~8.3 km/h (~4.5 kt) would be used during seismic acquisition. When not towing seismic survey gear, NBP has a maximum speed of 26.9 km/h (14.5 kt), but cruises at an average speed of 18.7 km/h (10.1 kt). It has a normal operating range of 27,780 km (~15,000 n.mi.) or ~70 to 75 days.

Owner:	Offshore Vessel Services LLC
Operator:	Galliano Marine Service LLC
Chartered:	NSF
Flag:	United States of America
Date Built:	1992
Gross Tonnage:	5600 metric tons (6174 GT)
Accommodation Capacity:	22 crew and 39 scientists

NBP would also serve as the platform from which vessel-based protected species visual observers (PSVOs) would watch for marine species before and during airgun operations.

Airgun Description

RVIB NBP would tow up to two GI airguns and one streamer containing hydrophones. The generator chamber of each GI gun, the one responsible for introducing the sound pulse into the ocean, would be

25–105 in^3. The injector chamber (25–105 in^3) injects air into the previously generated bubble to maintain its shape and does not introduce more sound into the water. The GI airgun(s) would be towed at a depth of 1–4 m, 25–120 m behind the vessel, depending on ice conditions and other factors. Seismic pulses would be emitted at intervals of ~5–13 s (or 11–30 m) from the GI airgun(s).

GI Airgun Specifications

Energy Source:	Two GI airguns of 105 in^3 each
Gun positions used:	Inline airguns spaced ~2.4 m apart
Towing depth of energy source:	1–4 m
Source output (2.4-m gun separation)*:	0-peak is 233.8 dB re 1 μPa; peak-peak is 239.6 dB re 1 μPa
Air discharge volume:	~210 in^3 (maximum volume to be used)
Dominant frequency components:	0–188 Hz
Gun volumes at each position (in^3):	105, 105
Firing pressure:	2000 psi
Pulse duration:	0.113 s

*Source output downward for two 105 in^3 GI airguns based on a conservative tow depth of 4 m. Source level is based on filtered farfield signature, using signatures filtered with DFS V out-256 Hz 72 dB/octave. Smaller sources could be used but are not detailed here.

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 ~5º. 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.

Mitigation zones for the proposed seismic surveys were not derived from the farfield signature but calculated based on modeling by L-DEO for the 160 dB re 1µPa$_{rms}$ threshold 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 up to 2 GI airguns at a tow depth of ~1–4 m. L-DEO model results are used to determine the 160-dB$_{rms}$ radius for the largest airgun array configuration that could be used (two 105 in^3 GI airguns, with a total discharge volume of 210 in^3) in deep water (>1000 m) down to a maximum water depth of 2000 m, as animals are generally not anticipated to dive below 2000 m (Costa and Williams 1999). The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor of 1.5.

Table 1 shows the distances at which the 160-dB re 1µPa$_{rms}$ sound level is expected to be received for the 2-GI airgun configuration (totaling 210 in^3) at a 4-m tow depth. Levels and distances for this configuration would be used in the ensuing analysis, as it has the greatest energy output of the proposed configurations; this is therefore the most conservative approach. The 160-dB level is the behavioral disturbance criterion that is used to estimate anticipated Level B takes for marine mammals.

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 the literature. A measured received sound pressure level (SPL) of 160 dB re 1 μPa_{rms} in the farfield would typically correspond to ~170 dB re 1 μPa_{p} or 176–178 dB re 1 $\mu Pa_{p\text{-}p}$, as measured for the same pulse received at the same location (Greene 1997; McCauley et al. 1998, 2000). The exact 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 source.

Ocean Bottom Seismometer Description

During the Drygalski Trough survey, two deployments of 10 OBSs would occur along two different seismic refraction lines (see Fig. 1 for representative lines). Following refraction shooting of one line, OBSs on that line would be recovered, serviced, and redeployed on a subsequent refraction line. The spacing of OBSs on the initial refraction line would be 5 km apart, but OBSs could be deployed as close together as every 500 m on the subsequent refraction line. The University of Texas at Austin Geopro OBSs have a height of 46 cm, a diameter of 51 cm, and a weight ~30 kg; the steel anchor is 100 cm x 100 cm x 8 cm high and weighs ~24 kg. All OBSs would be recovered at the end of the surveys. To retrieve the OBSs, the instrument is released via an acoustic release system to float to the surface from the wire and/or anchor, which are not retrieved.

Description of Operations

The proposed surveys would involve one source vessel, RVIB NBP, which would tow up to two GI airguns as an energy source, with a maximum discharge volume of ~210 in^3 at a depth of 1–4 m and a streamer up to 800-m in length containing hydrophones along predetermined lines. As the GI airguns are towed along the survey lines, the solid-state hydrophone streamer would receive the returning acoustic signals and transfer the data to the on-board processing system, and the OBSs would receive and store the returning acoustic signals internally for later analysis.

During the Ross Bank survey, ~1920 km of seismic data would be collected, and during the Drygalski Trough survey, ~1800 km of seismic acquisition would occur, for a total of 3720 line km. Although representative lines for the two surveys are depicted in Figure 1, the line locations are preliminary and could be refined in light of information from data collected during the study and ice conditions within the survey areas. Most, if not all survey effort would occur in intermediate water ~150 to 1000 m deep; however, there could be some survey effort in water >1000 m if seismic operations occur north of the Drygalski Ice Tongue in the Drygalski Trough survey area.

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

TABLE 1. Level B. Predicted distances to the 160 dB re 1 μPa$_{rms}$ sound level that could be received from two 105-in^3 GI guns (separated by 2.4 m, at a tow depth of 4 m) that would be used during the seismic surveys in the Ross Sea during austral summer 2022/2023 (model results provided by L-DEO).

Airgun Configuration	Water Depth (m)	Predicted Distances (m)
Two 105-in^3 GI guns	>1000[1]	726[2]
	100-1000	1089[3]

[1] No survey effort would occur in water <100 m and not likely in >1000 m; threshold distances for the >1000 m water depth is included for illustrative purposes only.

[2] Distance is based on L-DEO model results.

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

Additional acoustical data acquisition systems would be operated during the Proposed Action at any time to meet scientific objectives. The ocean floor would be mapped with an MBES, SBP, and/or ADCP. These sources 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 (PEIS; NSF and USGS 2011), further detailed below, and in the associated Draft Initial Environmental Evaluation (IEE) submitted to NMFS for these surveys.

***Single Beam Echosounder (Knudsen 3260)*.—**The hull-mounted compressed high-intensity radiated pulse (CHIRP) echosounder is operated at 12 kHz for bottom-tracking purposes or at 3.5 kHz in the SBP mode. The echosounder emits energy in a 30° beam from the bottom of the ship and has a sound level of 224 dB$_{rms}$ re 1 μPa at 1 m.

***Multibeam Echosounder (Kongsberg EM122)*.—**The hull-mounted, multibeam echosounder operates at a frequency of 12 kHz, has an estimated maximum source energy level of 242 dB$_{rms}$ re 1μPa, and emits a very narrow (< 2°) beam fore to aft and 150° in cross-track. The multibeam system emits a series of nine consecutive 15 ms pulses.

***Acoustic Doppler Current Profiler (ADCP) (Teledyne RDI VM-150)*.—**The hull-mounted ADCP operates at a frequency of 150 kHz, with an estimated acoustic output level at the source of 223.6 dB$_{rms}$ re 1μPa. Sound energy from the ADCP is emitted as a 30° conically shaped beam.

***ADCP (Ocean Surveyor OS-38)*.—**The characteristics of this backup, hull-mounted ADCP unit are similar to the Teledyne VM-150. The ADCP operates at a frequency of 150 kHz with an estimated acoustic output level at the source of 223.6 dB$_{rms}$ re 1μPa. Sound energy from the ADCP is emitted as a 30° conically-shaped beam.

***EK Biological Echosounder (Simrad ES200-7C, ES38B, ES-120-7C)*.—**This echosounder is a split-beam transducer with an estimated acoustic output level at the source of 183–185 dB re 1μPa. It emits a 7° beam and can operate at 38 kHz, 120 kHz, or 200 kHz.

***Acoustic Release*.—**To retrieve OBSs, an acoustic release transponder (pinger) is used to interrogate the instrument at a frequency of 8–11 kHz, and a response is received at a frequency of 7–15 kHz. The burn-wire release assembly is then activated, and the instrument is released to float to the surface from the wire and/or anchor which are not retrieved.

Icebreaking

Icebreaking activities are expected to be limited during the proposed surveys. The cruise dates were specifically chosen to avoid areas of heavy ice. The Ross Sea is generally clear of ice during December–February, because of the large Ross Sea Polynya that occurs in front of the RIS. Heavy ice conditions would hamper the proposed activities, as noise from icebreaking degrades the quality of the geophysical data to be acquired. If RVIB NBP would find itself in heavy ice conditions, it is unlikely that the airgun(s) and streamer could be towed, as this could damage the equipment and generate noise interference. The seismic surveys could take place in low ice conditions if RVIB NBP were able to generate an open path behind the vessel. RVIB NBP is not rated for breaking multi-year ice and generally avoids transiting through ice 2 years or older and more than 1 m thick. If sea ice were to be encountered during the surveys, RVIB NBP would likely proceed through one-year sea ice, and new, thin ice, but would follow leads wherever possible. Any time spent icebreaking would take away time from the proposed research activities, as the vessel would travel slower in ice-covered seas. Based on estimated transit to the survey areas, it is estimated that the RVIB NBP would break ice up to a distance of 500 km. Based on a ship speed of 5 kts under moderate ice conditions, this distance represents ~54 hrs of icebreaking (or 2.2 days). Transit through areas of primarily open water containing brash ice or pancake ice is not considered icebreaking for the purposes of this assessment. For recent NSF seismic surveys conducted in the Antarctic for which an IHA was sought, National Marine Fisheries Service (NMFS) required an assessment of and estimated takes for icebreaking activities; therefore, NSF has again included icebreaking information and analyses in this document (see Appendix).

Oceanographic Sampling

During the Drygalski Trough study, the researchers would also conduct opportunistic oceanographic sampling as time and scheduling allows, including conductivity, temperature and depth (CTD) measurements, box cores, and/or multi-cores. The main sampling would likely occur at ~five stations along one transect line. For sediments, six to nine sub-samples would be collected at each location. CTD profiles would be collected at discreet depth intervals decided through down-cast observation of CTD data.

All sampling activities would use standard oceanographic research techniques and methodologies. CTD, box cores, and multi-core equipment would all be lowered over the side (or stern) of the vessel and their own weight keeps standard oceanographic metal wire taut preventing opportunities for entanglement with marine species. As these types of sampling activities would have negligible to no impact on the surrounding environment, they are summarized briefly below but not discussed further.

Monitoring and Collecting Water Quality Samples.—Marine-based research frequently includes the measurement of water quality parameters and the collection of water samples. Typically, conductivity, temperature and depth (CTD) measurements may be made using an instrument attached to a wireline as a single cast or might be deployed from a frame (i.e., rosette) and equipped with a series of water samplers (e.g., Niskin) that can be activated individually at desired depths. Additional sensors may be installed on a rosette including dissolved oxygen and fluorescence sensors.

Coring.—Core samplers are open cylindrical or box-shaped devices that are inserted or driven into the sediment to sample sediment or benthic organisms. The depth a sampler penetrates the sediment is a function of the bottom type, the type of sampler, and its configuration (e.g., ballast weight). Depending on the seafloor composition, standard 3- or 6-m long core barrels (~6 inches in diameter) may be interconnected to collect a continuous core up to ~15 m long. A box corer consists of a stainless-steel box and weighted drive mechanism that is capable of collecting a sediment sample (50 x 50 x 75 cm) with negligible disturbance to the sampled material. Though limited by the size of the box, the depth that the corer penetrates the seafloor may be controlled by the speed at which the unit is lowered to the seafloor or the height above the seafloor at which the sampler is allowed to free fall.

Replicate sediment samples may be collected with a multi-corer, which allows researchers to collect multiple samples. The individual multiple core samples are collected in polycarbonate tubes which also capture the supernatant liquid to preserve sediment/water interface.

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 Ross Bank survey would take place on the central Ross Sea continental shelf between ~75°–77.7°S and 171°E–173°W, and the Drygalski Trough survey would occur between ~74°–76.7°S and 163.6°E–170°E; representative survey tracklines are shown in Figure 1. The proposed seismic surveys would occur within the Antarctic Treaty area in water depths ranging from ~150 to 1100 m. No survey effort would occur in shallow water <100 m deep; and very little, if any, is expected to occur in deep water >1000 m.

RVIB NBP would likely depart from Lyttelton, New Zealand, on ~18 December 2022, and would return to McMurdo Station, Antarctica, on ~18 January 2023, after the program is completed. However, given the significant logistics involved and remote locations of the proposed surveys, variation in the schedule is likely to occur but would remain within the austral summer timeframe. The cruise is expected to consist of 31 days at sea, including ~19 days of seismic operations, ~1 day of OBS deployment/recovery, and ~11 days (or ~4000 km) of transit. Some deviation in timing could also result from unforeseen events such as weather or logistical issues.

III. SPECIES AND NUMBERS OF MARINE MAMMALS IN AREA

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

Seventeen species of marine mammals could occur in the Ross Sea, including 5 mysticetes (baleen whales), 7 odontocetes (toothed whales) and 5 pinniped species (Table 2). Another seven species occur in the Sub-Antarctic but are unlikely to be encountered in the proposed survey areas, as they generally occur farther to the north. These species are not discussed further here but include: the southern right whale (*Eubalaena australis*), common (dwarf) minke whale (*Balaenoptera acutorostrata*), Cuvier's beaked (*Ziphius cavirostris*), Gray's beaked (*Mesoplodon grayi*), Hector's beaked (*Mesoplodon hectori*), and spade-toothed beaked (*Mesoplodon traversii*) whales, southern right whale dolphin (*Lissodelphis peronii*), and spectacled porpoise (*Phocoena dioptrica*). To avoid redundancy, we have included the required information about the species and (insofar as it is known) numbers of these species in § IV, below.

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

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

Sections III and IV are integrated here to minimize repetition. Four are listed as ***endangered*** under the ESA, including the blue, fin, sei, and sperm 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 survey areas. Waterhouse (2001) noted that seals are the most common marine mammal in the region. Ballard et al. (2012) reported that the main structuring factor of mesopredator distribution in the Ross Sea was horizontal partitioning among the shelf break, shelf and slope, and marginal ice zone of the pack ice. Sounds produced by Antarctic marine mammals were recently summarized by Erbe et al. (2017).

TABLE 2. The habitat, occurrence, population sizes, and conservation status of marine mammals that could occur in or near the proposed project area in the Ross Sea.

Species	Habitat	Occurrence in Ross Sea[1]	Abundance	US ESA[2]	IUCN[3]	CITES[4]
Mysticetes						
Fin whale	Coastal, pelagic	Uncommon	140,000 [5] 38,200 [6]	EN	VU	I
Blue whale	Coastal, pelagic	Rare	10,000-25,000 [5] 1,700 [7]	EN	EN	I
Sei whale	Pelagic	Rare	10,000 [8]	EN	EN	I
Antarctic minke whale	Coastal, pelagic	Common	Several 100,000 [5] 515,000 [9]	NL	NT	I
Humpback whale	Mainly nearshore and banks	Uncommon	90,000-100,000 [5] 80,000 [10] 42,000 [11]	NL	LC	I
Odontocetes						
Sperm whale	Usually pelagic and deep seas	Uncommon	360,000 [12] 12,069 [13]	EN	VU	I
Southern bottlenose whale	Pelagic	Common	599,300 [14]	NL	LC	I
Arnoux's beaked whale	Pelagic	Common	599,300 [14]	NL	LC	I
Strap-toothed beaked whale	Pelagic	Uncommon	599,300 [14]	NL	LC	II
Hourglass dolphin	Pelagic, ice edge	Rare	144,300 [15]	NL	LC	II
Killer whale	Widely distributed	Common	50,000 [16] 25,000 [17]	NL	DD	II
Long-finned pilot whale	Coastal, pelagic	Rare	200,000 [15]	NL	LC	II
Pinnipeds						
Crabeater seal	Coastal, pack ice	Common	5-10 million [18] 1.7 million [19]	NL	LC	NL
Leopard seal	Pack ice, sub-Antarctic islands	Common	220,000-440,000 [5, 20]	NL	LC	NL
Weddell seal	Fast ice, pack ice, sub-Antarctic islands	Common	1 million [5, 21]	NL	LC	NL
Ross seal	Pack ice, floes, pelagic	Common	250,000 [22]	NL	LC	NL
Southern elephant seal	Coastal, pelagic	Rare	750,000 [23]	NL	LC	II

N.A. means not available.

[1] Occurrence in area at the time of the proposed activities; based on professional opinion and available data.

[2] U.S. Endangered Species Act: EN = endangered, NL = not listed.

[3] International Union for the Conservation of Nature Red List of Threatened Species version 2021-3: EN = endangered; VU = vulnerable; NT = near threatened; LC = least concern; DD = data deficient.

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

[5] Worldwide (Jefferson et al. 2015).

[6] Antarctic (Aguilar and García-Vernet 2018).
[7] Antarctic (Branch et al. 2007).
[8] Southern Hemisphere, south of 30°C (IWC 1996).
[9] Southern Hemisphere (IWC 2022).
[10] Southern Hemisphere (Clapham 2018).
[11] Antarctic feeding area (IWC 2022).
[12] Worldwide (Whitehead 2002).
[13] Antarctic south of 60°S (Whitehead 2002).
[14] All beaked whales south of the Antarctic Convergence; mostly southern bottlenose whales (Kasamatsu and Joyce 1995)
[15] Kasamatsu and Joyce (1995).
[16] Minimum worldwide (Forney and Wade 2006).
[17] Minimum estimate for Southern Ocean (Branch and Butterworth 2001)
[18] Worldwide (Bengtson and Stewart 2018).
[19] Ross and Amundsen seas (Bengtson et al. 2011).
[20] Rogers et al. 2018.
[21] Hückstädt 2018a.
[22] Worldwide (Curtis et al. 2011 *in* Hückstädt 2018b).
[23] Total world population (Hindell et al. 2016).

Mysticetes

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). 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).

Most populations migrate seasonally between temperate waters, where mating and calving occur in winter, and polar waters where feeding occurs in the summer (Evans 1987). Although they are known to use the shelf edge as a migration route (Evans 1987), fin whales most commonly occur offshore but can also be found in coastal areas (Jefferson et al. 2015). 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).

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). Fin whales are generally absent from the ice limit in higher latitudes (Anguilar and García-Vernet 2018). Based on Edwards et al. (2015), densities in the Southern Ocean south of 60°S (including the northern part of the Ross Sea) are highest during December–February, with non-zero densities <0.003 whales/km^2. Pinkerton et al. (2010) assumed that ~200 fin whales use the Ross Sea during summer. Fin whale sightings have been reported for the Ross Sea by several authors (Nishiwaki et al. 1997; Matsuoka et al. 2006; Ainley et al. 2010; Baird and Mormede 2014; MacDiarmid and Stewart 2015), including adjacent to the Ross Bank and Drygalski Trough survey areas (Matsuoka and Hakamada 2020). During an NSF-funded seismic survey in the Ross Sea in January–February 2015, 13 sightings totaling 34 fin whales were made, including within the proposed survey areas (RPS 2015a). Ensor et al. (2003) reported sightings north of the Ross Sea during summer surveys in 2002–2003.

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). 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 subantarctic waters (Sears and Perrin 2018). There are discrete feeding stocks in the Southern Hemisphere, and six stocks have been identified (Sears and Perrin 2018).

The Antarctic blue whale is typically found south of 55°S during summer, although some individuals do not migrate (Branch et al. 2007). The blue whale is considered to be rare in the Southern Ocean; up to 360,000 blue whales were harvested in the Southern Hemisphere in the early 20th century (Sears and Perrin 2018). Ainley (2010) noted that they were extirpated from the Ross Sea shelf break front in the 1920s. Smith et al. (2012) estimated that 30 blue whales may occur in the Ross Sea. Several records were reported during surveys in the Ross Sea from 1987/88–2008/09, including sightings adjacent to the Drygalski Trough survey area and within the Ross Bank survey area (Matsuoka and Hakamada 2020). Sightings have also been reported for the northern Ross Sea between 1978 and 2005 (Kasamatsu et al. 1990; Nishiwaki et al. 1997; Matsuoka et al. 2006; Ainley et al. 2010) as well as during a 2008 survey (Baird and Mormede 2014). Acoustic detections were also made in the northeastern Ross Sea between 1996 to 2010 (Shabangu et al. 2018). Eight groups of 24 individuals were seen north of the Ross Sea during summer surveys in 2002–2003 (Ensor et al. 2003). No blue whales were seen during an NSF-funded seismic survey in the Ross Sea in January–February 2015 (RPS 2015a).

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 (between 40ºS and 50ºS) during the summer (Horwood 2018); larger, older whales typically travel into the northern Antarctic zone while smaller, younger individuals remain in the lower latitudes (Acevedo et al. 2017). Pinkerton et al. (2010) assumed that ~100 animals may occur in the Ross Sea. Ensor et al. (2003) reported no sightings south of 54°S during a summer survey of the Southern Ocean in 2002–2003, but Matsuoka and Hakamada (2020) reported several sightings north of the Ross Sea, between 60°S and 66°S. Similarly, no sei whales were seen during an NSF-funded seismic survey in the Ross Sea in January–February 2015 (RPS 2015a).

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 (Ainley et al. 2012; Williams et al. 2014), where they feed almost entirely on krill (Tamura and Konishi 2009). Murase et al. (2006, 2007) found that minke whale distribution was related to krill density in the Ross Sea, with the greatest number of pods in areas with a krill density of 1 g/m^2.

Minke whales were harvested heavily in the Southern Ocean during the 1970s and 1980s, with >13,000 harvested in the early 1980s; but the hunt ceased in 1986 under an IWC moratorium (Ainley 2002). However, Japanese whaling continued under scientific permit taking hundreds of minke whales in the Ross Sea since the late 1980s (Ainley 2002). During Japanese sighting surveys from 1976–2009, high encounter rates occurred in the Ross Sea (Kasamatsu et al. 1996; Matsuoka and Hakamada 2020), where minke whales are known to form feeding aggregations (Kasamatsu et al. 1998). Saino and Guglielmo (2000) reported a mean density of 0.13 whales/km^2 in the western Ross Sea. The minke whale is the most abundant species occupying the shelf waters in the Ross Sea (Waterhouse 2001; Smith et al. 2007). Approximately 6% of Antarctic minke whales occur in the Ross Sea (Ainley et al. 2010; Smith et al. 2012). The Ross Sea population was estimated at 14,300 by Ainley (2002) and 87,643 individuals by Matsuoka et al. (2009).

Ainley et al. (2017) reported that minke whales started to arrive in the southwestern Ross Sea in mid-November, with decreasing ice conditions. Ainley et al. (2010, 2012) and Ballard et al. (2012) reported sightings around the northwestern and northeastern periphery of the proposed Ross Bank survey area and within the Drygalski Trough survey area. Although minke whales have a high likelihood of occurrence in the Ross Sea (e.g., Ainley et al. 2012; Ropert-Coudert et al. 2014), habitat suitability for the proposed Ross Bank survey area in summer was modeled as relatively low, whereas higher habitat suitability was reported for the area around the Drygalski Ice Tongue (Ballard et al. 2012). However, minke whales were seen in the Ross Sea during surveys conducted between 1978 and 2009, including within the proposed survey areas (Kasamatsu et al. 1990; Baird and Mormede 2014; MacDiarmid and Stewart 2015; Matsuoka and Hakamada 2020). They were also detected acoustically in the Ross Sea in 2004 (Dolman et al. 2005). Minke whales were seen feeding (presumable on fish) in the southwestern Ross Sea (Lauriano et al. 2007). During an NSF-funded seismic survey in the Ross Sea in January–February 2015, 224 sightings totaling 1023 minke whales were made, including within the proposed survey areas and in McMurdo Sound (RPS 2015a). Ensor et al. (2003) reported numerous sightings north of the Ross Sea during summer surveys in 2002–2003.

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). 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 (Bettridge et al. 2015; Clapham 2018). Humpbacks that occur in the western Ross Sea (west of 170°W) are part of the Area V feeding stock (Schmitt et al. 2014); these individuals are from the Oceania DPS that breeds in French Polynesia, Cook Islands, and Tonga, and from the East Australia DPS (Schmitt et al. 2014; Bettridge et al. 2015).

Humpback densities are high north of the Ross Sea (Branch 2011; Matsuoka and Hakamada 2020), but not within it (Ropert-Coudert et al. 2014). Pinkerton et al. (2010) estimated that <5% (150 individuals) of the Southern Ocean population occurs in the Ross Sea in the austral summer. Humpback whales were seen in the northern Ross Sea during surveys conducted between 1987 and 2009 (Baird and Mormede 2014; MacDiarmid and Stewart 2015). However, none were seen in the Ross Sea during the IDCR/SOWER surveys from 1978/79 to 2004/05 (Branch 2011). During an NSF-funded seismic survey in the Ross Sea in January–February 2015, two sightings totaling six individuals were made east of the proposed survey areas (RPS 2015a). Acoustic detections were also made in the northeastern Ross Sea between 1996 to 2010 (Shabangu et al. 2018). Ensor et al. (2003) reported numerous humpback sightings and acoustic detections north of the Ross Sea during summer surveys in 2002–2003.

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). Few sperm whales are thought to occur in the Ross Sea (Smith et al. 2012), although Pinkerton et al. (2010) assumed that 800 sperm whales could be using the Ross Sea. Sperm whales generally do not occur south of ~73–74°S in the Ross Sea (Matsuoka et al. 1998; Ropert-Coudert et al. 2014). Nonetheless, sperm whales have been reported there by several authors (Kasamatsu et al. 1990; Baird and Mormede 2014; Matsuoka and Hakamada 2020). Ensor et al. (2003) reported numerous sightings and acoustic detections north of the Ross Sea during summer surveys in 2002–2003. No sperm whales were seen during an NSF-funded seismic survey in the Ross Sea in January–February 2015 (RPS 2015a).

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; Riccialdelli et al. 2017). The population size of southern bottlenose whales in the Ross Sea was assumed to be 500 by Pinkerton et al. (2010). Ropert-Coudert et al. (2014) reported their occurrence in the Ross Sea, and Kasamatsu et al. (1990) reported sightings between 1978 and 1988. Southern bottlenose whales were also sighted in the northern Ross Sea and north of there during surveys of the Southern Ocean by Van Waerebeek et al. (2010). Several unidentified beaked whales have also been reported in the Ross Sea, including in the Ross Bank survey area and near the Drygalski Trough survey area (Baird and Mormede 2014; MacDiarmid and Stewart 2015; Matsuoka and Hakamada 2020). Ensor et al. (2003) and Matsuoka and Hakamada (2020) reported numerous sightings of southern bottlenose whales north of the Ross Sea. No bottlenose whales were seen during an NSF-funded seismic survey in the Ross Sea in January–February 2015 (RPS 2015a).

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). Ainley et al. (2010) and Van Waerebeek et al. (2010), and Ropert-Coudert et al. (2014) reported their occurrence in the Ross Sea. Lauriano et al. (2011) reported two sightings of single individuals in Terra Nova Bay, western Ross Sea, during summer 2004 surveys. There may be 50 (Pinkerton et al. 2010) to 150 (Smith et al. 2012). Arnoux's beaked whales in the Ross Sea. No Arnoux's beaked whales were seen during an NSF-funded seismic survey in the Ross Sea in January–February 2015 (RPS 2015a).

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 is likely quite common in the Southern Ocean (Pitman 2018). 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). One group of three strap-toothed beaked whales was seen north of the Ross Sea, north of 65°S, during a 2002–2003 summer survey (Ensor et al. 2003). No strap-toothed beaked whales were seen during an NSF-funded seismic survey in the Ross Sea in January–February 2015 (RPS 2015a).

Hourglass Dolphin (*Lagenorhynchus cruciger*)

The hourglass dolphin occurs in 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, north of the Ross Sea, 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). Ensor et al. (2003) reported numerous sightings of hourglass dolphins north of the Ross Sea, north of 65°S, during a summer survey in 2002–2003. No hourglass dolphins were seen during an NSF-funded seismic survey in the Ross Sea in January–February 2015 (RPS 2015a).

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). Mikhalev et al. (1981) noted that it appears to migrate from warmer waters during the winter to higher latitudes during the summer. In the Antarctic, it commonly occurs up to the pack ice edge but may also find its way into ice-covered water (Ford 2018).

There are three ecotypes that occur in Antarctic waters: type A hunts marine mammals in open water, mainly seeking minke whales, type B hunt seals in loose pack ice, and type C feeds on fish in dense pack ice (Pitman and Ensor 2003); these types are likely different species (Morin et al. 2010; Pitman et al. 2017). Type D occurs in subantarctic waters and is also likely a separate species (Pitman et al. 2011). Type B travels widely to hunt its prey, whereas type C is more resident (Andrews et al. 2008). In fact, type Cs (Ross Sea killer whales) appear to have resident and transient groups in the Ross Sea (e.g., Ainley et al. 2017). In the Ross Sea, abundance has been estimated at 7500 individuals (Smith et al. 2007). Ainley et al. (2010) and Smith et al. (2012) estimated that ~50% of Ross Sea killer whales use the Ross Sea during summer foraging. Smith et al. (2012) reported 3350 type C killer whales and 70 type A/B killer whales in the Ross Sea. Pitman et al. (2017) reported only two ecotypes in the Ross Sea (types B and C), but Ainley et al. (2010) noted that type A could occur along the slope.

Ainley et al. (2017) reported that type C and B killer whales start to arrive in the southwestern Ross Sea in mid-November, with decreasing ice conditions, with type Bs arriving earlier than type Cs. Type C killer whales have been seen feeding (presumable on fish) in the southwestern Ross Sea (Lauriano et al. 2007), and type B and C killer whales were reported during summer 2004 surveys in Terra Nova Bay, western Ross Sea (Lauriano et al. 2011). Eiser et al. (2014) reported Type C and B in McMurdo Sound. Type C killer whales have also been detected acoustically in McMurdo Sound (Wellard et al. 2020). During an NSF-funded seismic survey in the Ross Sea in January–February 2015, 14 sightings totaling 254 killer whales were made, including within the survey areas and in McMurdo Sound (RPS 2015a). Saino and Guglielmo (2000) reported a mean density of 0.05 whales/km^2 in the western Ross Sea. However, numbers of type C killer whales have apparently decreased in the southwestern Ross Sea, because of changes in prey distribution (Antarctic toothfish) likely brought on by fishing pressures (Ainley et al. 2009a; Ainley and Ballard 2012). However, Pitman et al. (2018) suggested that the presence of a mega-iceberg at Ross Island may have also impeded killer whale movement, thereby affecting the population size; they estimated a population size of 470 distinct individuals in McMurdo Sound. Type B killer whale numbers have not changed in the southern Ross Sea, where they hunt Weddell seals and emperor penguins (Ainley and Ballard 2012).

Type C killer whale appears to favor the Ross Sea shelf and slope (Ballard et al. 2012). Sightings of type C killer whales within the proposed survey areas have been reported during summer (Andrews et al. 2008; Ballard et al. 2012). The habitat suitability in summer for type C killer whales in the proposed Ross Bank survey area was modeled as relatively high, whereas it was lower for the Drygalski Trough survey area (Ballard et al. 2012). Andrews et al. (2008) documented movement of a tagged type B killer whale to the west of the proposed study area. Aubrey et al. (1982) reported sightings of killer whales in the Ross Sea off Cape Adare and over Pennell Banks, and noted that killer whales were abundant off Ross Island. Killer whales were also reported in the Ross Sea by several other authors (e.g., Kasamatsu et al. 1990; Van Dam and Kooyman 2004; Van Waerebeek et al. 2010; Baird and Mormede 2014; Ropert-Coudert et al. 2014; Matsuoka and Hakamada 2020). Acoustic detections were also made in the northeastern Ross Sea between 1996 to 2010 (Shabangu et al. 2018). Ensor et al. (2003) reported numerous sightings and acoustic detections north of the Ross Sea during summer surveys in 2002–2003.

Long-finned Pilot Whale (*Globicephala melas*)

The long-finned pilot whale is distributed antitropically in cold temperate waters, including the Southern Ocean, whereas the short-finned pilot whale is found in tropical and warm temperate waters (Olson 2018). The ranges of the two species show little overlap (Olson 2018). 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 Southern Hemisphere, their range extends to the Antarctic Convergence and sometimes as far south as 68°S (Jefferson et al. 2015). Although generally not seen south of 68°S, long-finned pilot whales were reported in the Ross Sea during observations from longliners between 1997 and 2009 (Baird and Mormede 2014). During summer surveys in 2002–2003, several sightings were made north of the Ross Sea (Ensor et al. 2003). They were also reported north of the Ross Sea during surveys by Van Waerebeek et al. (2010). No pilot whales were seen during an NSF-funded seismic survey in the Ross Sea in January–February 2015 (RPS 2015a).

Pinnipeds

Crabeater Seal (*Lobodon carcinophagus*)

The crabeater seal has a circumpolar distribution off Antarctica and is the most abundant seal in the region, sometimes congregating in the hundreds (Bengtson and Stewart 2018). It generally spends the entire year in the advancing and retreating pack ice (Bengtson and Stewart 2018). However, outside of the breeding season, crabeater seals spend ~14% of their time in open water (reviewed in Southwell et al. 2012); they mainly forage on krill. During the breeding season, crabeater seals are most likely to be present within 5° or less (~550 km) of the shelf break; non-breeding animals range farther north (Southwell et al. 2012). Pupping season peaks in mid- to late-October, and adults are observed with their pups as late as mid-December (Bengtson and Stewart 2018).

Crabeater seals are most common in the pack ice of the northern Ross Sea (Waterhouse 2001). A population of ~204,000 has been estimated for the Ross Sea (Waterhouse 2001; Ainley 2002, 2010; Pinkerton and Bradford-Grieve 2010; Smith et al. 2012). Crabeater seals have been reported for the Ross Sea by several authors (Stirling 1969; Van Dam and Kooyman 2004; Bester and Stewart 2006; Baird and Mormede 2014; Ropert-Coudert et al. 2014). Crabeater seals have been sighted within the proposed survey areas (e.g., Saino and Guglielmo 2000; Ainley et al. 2010; Ballard et al. 2012), with greater habitat suitability in summer in the Drygalski Trough survey area than in the Ross Bank survey area (Ballard et al. 2012). Similarly, Bengtson et al. (2011) reported relatively low densities in the Ross Bank survey area, and higher densities in the Drygalski Trough survey area. Saino and Guglielmo (2000) showed increasing densities with increasing pack ice and distance from shore, with a mean density of 0.49 seals/km^2, in the western Ross Sea. In contrast, Bengtson et al. (2011) reported the highest density (1.3 seals/km^2) on the shelf at distances up to 200 km from the ice edge during surveys of the Ross and Amundsen seas. During an NSF-funded seismic survey in the Ross Sea in January–February 2015, nine sightings of 14 individuals were made (RPS 2015a).

Leopard Seal (*Hydrurga leptonyx*)

The leopard seal has a circumpolar distribution around the Antarctic continent where it is solitary and widely dispersed at low densities (Rogers 2018). It primarily occurs in pack ice, but when the sea ice extent is reduced, it can be found in coastal habitats (Meade et al. 2015). 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 ~ 1 month later (Rogers 2018). Mating occurs in the water during December and January. A population of ~8000 is thought to occur in the Ross Sea (Waterhouse 2001; Ainley 2002, 2010; Pinkerton and Bradford-Grieve 2010; Smith et al. 2012). Bengtson et al. (2011) reported an abundance of 15,000 leopard seals for the Ross and Amundsen seas. Densities were highest (0.024 seals/km^2) in water <3000 m deep and <100 km from the ice edge; very low densities were estimated for the southern portion of the Ross Bank survey area, with low densities in the rest of the survey area and in the Drygalski Trough survey area (Bengtson et al. 2011). Leopard seals have been documented to take Adélie penguins at several colonies in the Ross Sea, including Cape Crozier (south of the proposed survey areas), and in McMurdo Sound (Ainley et al. 2005). Leopard seals have been reported within and near the Drygalski Trough survey area, no sightings have been reported within the Ross Bank survey area (Stirling 1969; Ackley et al. 2003; Van Dam and Kooyman 2004; Bester and Stewart 2006; Ainley et al. 2010; Baird and Mormede 2014; Ropert-Coudert et al. 2014). No leopard seals were sighted during an NSF-funded seismic survey in the Ross Sea in January–February 2015 (RPS 2015a).

Weddell Seal (*Leptonychotes weddellii*)

The Weddell seal is the second most abundant species of Antarctic seal (Hückstädt 2018a). It occurs in the fast and pack ice around all of Antarctica, as well as on land along the coast, but is rarely found in ice-free water (Hückstädt 2018a). It occurs on the Ross Sea shelf and slope (Ballard et al. 21012). It is the most southerly breeding mammal in the world, occurring as far south as the RIS (Hückstädt 2018a). Unlike other Antarctic ice seals, Weddell seals form colonies (Cameron et al. 2007). There are numerous pupping locations throughout the western Ross Sea, including around Ross Island (Ainley et al. 2010). Juveniles tend to disperse widely, resulting in genetic diversity in the population (Hückstädt 2018a). Seals outfitted with tags in the western Ross Sea were documented to disperse hundreds of kilometers, making their way into the proposed survey areas (Ainley et al. 2010; Goetz 2015). However, some small colonies have been isolated from open water by ice sheets and therefore show inbreeding depression (Gelatt et al. 2010). Weddell seals primarily feed on fish. Pups are born from October through November and are weaned after ~6 to 8 weeks (Hückstädt 2018a). Paterson et al. (2015) suggested that the timing of reproduction by Weddell seals in Erebus Bay, McMurdo Sound, is coupled with periods of high productivity in Ross Bay. After the breeding season, the ice breaks down and seals disperse into the sea to forage for 1 to 2 months and return to ice or land to molt in January and February (Hückstädt 2018a).

Ainley et al. (2010) estimated that 50–72% of the South Pacific sector of Weddell seals occur in the Ross Sea. The population in the Ross Sea has been estimated between 32,000 and 50,000 individuals (e.g. Ainley 2002, 2010; Pinkerton and Bradford-Grieve 2010; Smith et al. 2012). Bengtson et al. (2011) estimated the population in the Ross and Amundsen seas at 330,000 seals. The highest densities (up to 0.173 seals/km^2) were observed in water <3000 m deep; densities in the proposed survey areas were estimated to be low (Bengtson et al. 2011). Populations at McMurdo Sound were permanently reduced by sealing in the 20th century (Ainley 2010). Sightings within the Ross Sea, including within the proposed survey areas, have been reported by several sources (Stirling 1969; Saino and Guglielmo 2000; Ackley et al. 2003; Van Dam and Kooyman 2004; Bester and Stewart 2006; Ainley et al. 2010; Ballard et al. 2012; Ropert-Coudert et al. 2014; Baird and Mormede 2014). Ballard et al. (2012) relatively low habitat suitability for Weddell seals in the majority of the Ross Bank survey area, with higher suitability in the easter portion of the Ross Bank survey area and within the Drygalski Trough survey area. During an NSF-funded seismic survey in the Ross Sea in January–February 2015, 17 sightings of Weddell seals were made, including within the proposed survey areas (RPS 2015a).

Ross Seal (*Ommatophoca rossii*)

The Ross seal is the least abundant Antarctic pinniped species (Hückstädt 2018b). It occurs throughout the Antarctic; in the spring and summer breeding period (October–December) and during the molt in late summer through fall (January–March), it occurs in the pack ice, but it forages in open water to the north during the remainder of the year (Hückstädt 2018b). It primarily feeds on cephalopods, mainly squid, but it also consumes fish and krill (Hückstädt 2018b). Pups are born in November and are weaned by ~1 month of age (Hückstädt 2018b).

The population in the Ross Sea may number 500 (Smith et al. 2012) to ~5000 individuals (Waterhouse 2001; Ainley 2010; Pinkerton and Bradford-Grieve 2010). According to surveys by Bester and Stewart (2006), Ross seals are relatively abundant in the Ross Sea. Based on surveys of the Ross and Amundsen seas, Bengtson et al. (2011) estimated an abundance of 22,600, with the highest density (0.032 seals/km^2) in deep water (>3000 m) within 200 km from the ice edge; low densities were estimated for the proposed survey areas. Ross seals were seen in the western (Stirling 1969) and eastern Ross Sea during surveys (Stirling 1969; Ackley et al. 2003; Bester and Stewart 2006). During an NSF-funded seismic survey in the Ross Sea in January–February 2015, two sightings of single Ross seals were made to the east of the Ross Bank survey area (RPS 2015a).

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). Breeding colonies are generally island-based, with the occasional exception of the Antarctic mainland (Hindell 2018). 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). Their occurrence in the Ross Sea is rare and only during the summer (Waterhouse 2001; Pinkerton and Bradford-Grieve 2010). The population size in the Ross Sea is estimated to number <100 individuals (Ainley 2010; Smith et al. 2012). Ropert-Coudert et al. (2014) reported one record in the Ross Sea, in McMurdo Sound. No southern elephant seals were seen during an NSF-funded seismic survey in the Ross Sea in January–February 2015 (RPS 2015a).

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.

NSF, on behalf of itself, Louisiana State University, Texas A&M University, University of Texas at Austin, University of West Florida, and Dauphin Island Sea Lab, 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 Ross Sea during December 2022–January 2023. 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 or lethal takes (Level A) is expected, given the nature of the planned operations, the mitigation measures that are planned (see § XI, MITIGATION MEASURES), in addition to the general avoidance by marine mammals of loud sound. Although Level A takes are not requested and will likely not be issued, *NOAA Fisheries Office of Protected Resources ESA Interagency Cooperation Division* has requested the predicted distances to the Level A threshold distances for previous similar activities, therefore for consistency, we are including this information in Appendix B.

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 Ross Sea during December 2022–January 2023. 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 (§ 3.4.4.3, § 3.6.4.3, § 3.7.4.3, § 3.8.4.3), the effects of sounds from airguns could include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and at least in theory, temporary or permanent hearing impairment, or non-auditory physical or physiological effects (e.g., Richardson et al. 1995; Gordon et al. 2004; Nowacek et al. 2007; Southall et al. 2007; Erbe 2012; Peng et al. 2015; Erbe et al. 2016; Kunc et al. 2016; National Academies of Sciences, Engineering, and Medicine 2017; Weilgart 2017). In some cases, a behavioral response to a sound can reduce the overall exposure to that sound (e.g., Finneran et al. 2015; Wensveen et al. 2015).

Permanent hearing impairment (permanent threshold shift [PTS]), in the unlikely event that it occurred, would constitute injury (Southall et al. 2007; Le Prell 2012). Physical damage to a mammal's hearing apparatus can occur if it is exposed to sound impulses that have very high peak pressures, especially if the impulses have very short rise times (e.g., Morell et al. 2017). However, the impulsive nature of sound is range-dependent, becoming less harmful over distance from the source (Hastie et al. 2019). Temporary threshold shift (TTS) is not considered an injury by some authors (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 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.

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 >130 dB re 1 $\mu Pa^2 \cdot s$ (Dunlop et al. 2017b, 2018). 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 160–170 dB re 1 $\mu Pa^2 \cdot s$ (Dunlop et al. 2018). Dunlop et al. (2020) found that humpback whales reduce their social interactions at greater distances and lower received levels than regulated by current mitigation practices.

In the Northwest Atlantic, sighting rates were significantly greater during non-seismic periods compared with periods when a full array was operating, and humpback whales were more likely to swim away and less likely to swim towards a vessel during seismic vs. non-seismic periods (Moulton and Holst 2010). In contrast, sightings of humpback whales from seismic vessels off the U.K. during 1994–2010 indicated that detection rates were similar during seismic and non-seismic periods, although sample sizes were small (Stone 2015). 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 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. However, Heide-Jørgensen et al. (2021) did report avoidance reaction at distances >11 km from an active seismic vessel, as well as an increase in travel speed and changes in direction at distances up to 24 km from a seismic source. No long-term effects were reported. Tervo et al. (2021) reported that narwhal buzzing rates decreased in response to concurrent ship noise and airgun pulses (being 50% at 12 km from ship), and that the whales discontinued to forage at 7–8 km from the vessel, and that exposure effects could still be detected >40 km from the vessel.

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

Most studies of *sperm whales* exposed to airgun sounds indicate that the sperm whale shows considerable tolerance of airgun pulses; in most cases the whales do not show strong avoidance (e.g., Stone and Tasker 2006; Moulton and Holst 2010). 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).

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; Tyack and Thomas 2019).

Pinnipeds.—Pinnipeds are not likely to show a strong avoidance reaction to an airgun array. Visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds and only slight (if any) changes in behavior. However, telemetry work has suggested that avoidance and other behavioral reactions may be stronger than evident to date from visual studies (Thompson et al. 1998). Observations from seismic vessels operating large arrays off the U.K. from 1994–2010 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 grey 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 in3 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. 2012a,b; 2013a,b, 2014, 2015a, 2016a,b, 2017, 2018, 2019a,b, 2020a,b,c,d,e,f, 2021a,b, 2022; Supin et al. 2016).

Studies have shown that the SEL required for TTS onset to occur increases with intermittent exposures, with some auditory recovery during silent periods between signals (Finneran et al. 2010b; Finneran and Schlundt 2011). Studies on bottlenose dolphins by Finneran et al. (2015) indicate that the potential for seismic surveys using airguns to cause auditory effects on dolphins could be lower than previously thought. Based on behavioral tests, no measurable TTS was detected in three bottlenose dolphins after exposure to 10 impulses from a seismic airgun with a cumulative SEL of up to ~195 dB re 1 $\mu Pa^2 \cdot s$ (Finneran et al. 2015; Schlundt et al. 2016). However, auditory evoked potential (AEP) measurements were more variable; one dolphin showed a small (9 dB) threshold shift at 8 kHz (Finneran et al. 2015; Schlundt et al. 2016).

Studies have also shown that the SEL necessary to elicit TTS can depend substantially on frequency, with susceptibility to TTS increasing with increasing frequency above 3 kHz (Finneran and Schlundt 2010, 2011; Finneran 2012). When beluga whales were exposed to fatiguing noise with sound levels of 165 dB re 1 µPa for durations of 1–30 min at frequencies of 11.2–90 kHz, the highest TTS with the longest recovery time was produced by the lower frequencies (11.2 and 22.5 kHz); TTS effects also gradually increased with prolonged exposure time (Popov et al. 2013). Additionally, Popov et al. (2015) demonstrated that the impacts of TTS include deterioration of signal discrimination. Kastelein et al. (2015b) 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. 2018; Finneran 2020; Kastelein et al. 2020g).

Initial evidence from exposures to non-pulses has also suggested that some pinnipeds (harbor seals in particular) incur TTS at somewhat lower received levels than do most small odontocetes exposed for similar durations (Kastak et al. 1999, 2005, 2008; Ketten et al. 2001; Kastelein et al. 2013a). Kastelein et al. (2012b) exposed two harbor seals to octave-band white noise centered at 4 kHz at three mean received SPLs of 124, 136, and 148 dB re 1 µPa; TTS >2.5 dB was induced at an SEL of 170 dB (136 dB SPL for 60 min), and the maximum TTS of 10 dB occurred after a 120-min exposure to 148 dB re 1 µPa or an SEL of 187 dB. Kastelein et al. (2013c) reported that a harbor seal unintentionally exposed to the same sound source with a mean received SPL of 163 dB re 1 µPa for 1 h induced a 44 dB TTS. A maximum TTS >45 dB was elicited from a harbor seal exposed to 32 kHz at 191 dB SEL (Kastelein et al. 2020c). For a harbor seal exposed to octave-band white noise centered at 4 kHz for 60 min with mean SPLs of

124–148 re 1 µPa, the onset of PTS would require a level of at least 22 dB above the TTS onset (Kastelein et al. 2013c). Harbor seals appear to be equally susceptible to incurring TTS when exposed to sounds from 2.5 to 40 kHz (Kastelein et al. 2020a,b), but at frequencies of 2 kHz or lower, a higher SEL was required to elicit the same TTS (Kastelein et al. 2020c). Harbor seals may be able to decrease their exposure to underwater sound by swimming just below the surface where sound levels are typically lower than at depth (Kastelein et al. 2018). Reichmuth et al. (2016) exposed captive spotted and ringed seals to single airgun pulses with SELs of 165–181 dB and SPLs (peak to peak) of 190–207 re 1 µPa; no low-frequency TTS was observed. Similarly, no TTS was measured when a bearded seal was exposed to a single airgun pulse with an unweighted SEL of 185 dB and an SPL of 207 dB; however, TTS was elicited at 400 Hz when exposed to four to ten consecutive pulses with a cumulative unweighted SEL of 191–195 dB, and a weighted SEL of 167–171 dB (Sills et al. 2020). Kastelein et al. (2021b) found that susceptibility of TTS of California sea lions exposed to one-sixth-octave noise bands centered at 2, 4, and 8 kHz is similar to that of harbor seals, but at 16 kHz, California sea lion haring is less susceptible to TTS than harbor seals (Kastelein et al. 2022).

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

Previous information on TTS for odontocetes was primarily derived from studies on the bottlenose dolphin and beluga (see § 3.7.4.3 and Appendix E of the PEIS). Thus, it is inappropriate to assume that onset of TTS occurs at similar received levels in all cetaceans (*cf.* Southall et al. 2007; NMFS 2016, 2018). Some cetaceans could incur TTS at lower sound exposures than are necessary to elicit TTS in the beluga and bottlenose dolphin.

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 marine 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 noise exposure criteria for marine mammals that were released by NMFS (2016, 2018) account for the newly available scientific data on TTS, the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors. For impulsive sounds, such as airgun pulses, the thresholds use dual metrics of cumulative

SEL (SEL_{cum} over 24 hours) and peak SPL_{flat}. Onset of PTS is assumed to be 15 dB higher when considering SEL_{cum} and 6 dB higher when considering SPL_{flat}. Different thresholds are provided for the various hearing groups, including LF cetaceans (e.g., baleen whales), MF cetaceans (e.g., most delphinids), HF cetaceans (e.g., porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW).

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 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. Morell et al. (2020) describe new methodology that visualizes scars in the cochlea to detect hearing loss in stranded marine mammals.

Since 1991, there have been 71 marine mammal Unusual Mortality Events (UMEs) in the U.S. (NOAA 2022). 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 GoM, and the greater activity of oil and gas exploration in the GoM.

Non-auditory physical 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 and some odontocetes, 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 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 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 RVIB NBP. 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.

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

There is no available information on marine mammal behavioral response to MBES sounds (Southall et al. 2013). 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).

Frankel and Stein (2020) reported that gray whales responded to a 21–25 kHz active sonar by deflecting 1–2 km away from the sound. Sperm whales exposed to sounds from a low-frequency 1–2 kHz sonar transitioned to non-foraging and non-resting states, but did not respond to 4.7–5.1 kHz or 6–7 kHz sonar signals (Isojunno et al. 2016). Deng et al. (2014) measured the spectral properties of pulses transmitted by three 200-kHz echosounders and found that they generated weaker sounds at frequencies below the center frequency (90–130 kHz). These sounds are within the hearing range of some marine mammals, and the authors suggested that they could be strong enough to elicit behavioral responses within close proximity to the sources, although they would be well below potentially harmful levels. Hastie et al. (2014) reported behavioral responses by gray seals to echosounders with frequencies of 200 and 375 kHz. Short-finned pilot whales increased their heading variance in response to an EK60 echosounder with a resonant frequency of 38 kHz (Quick et al. 2017), and significantly fewer beaked whale vocalizations were detected while an EK60 echosounder was active vs. passive (Cholewiak et al. 2017).

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 ADCPs 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 RVIB NBP could affect marine animals in the proposed study 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. 1995a). However, some energy is also produced at higher frequencies (Hermannsen et al. 2014; Kyhn et al. 2019; Landrø and Langhammer 2020); low levels of high-frequency sound from vessels 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; Wisniewska et al. 2018), humpback whales (Blair et al. 2016), and killer whales (Williams et al. 2021).

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. 1995a; 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; Popov et al. 2020). In order to compensate for increased ambient noise, some cetaceans are known to increase the source levels of their calls in the presence of elevated noise levels from shipping, shift their peak frequencies, or otherwise change their vocal behavior (e.g., Parks et al. 2011, 2012, 2016a,b; Castellote et al. 2012; Melcón et al. 2012; Azzara et al. 2013; Tyack and Janik 2013; Luís et al. 2014; Sairanen 2014; Papale et al. 2015; Bittencourt et al. 2016; Dahlheim and Castellote 2016; Gospić and Picciulin 2016; Gridley et al. 2016; Heiler et al. 2016; Martins et al. 2016; O'Brien et al. 2016; Tenessen and Parks 2016).

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 during seismic surveys with RVIB NBP or other vessels of the 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. No injurious takes (Level A) would be expected. In the sections below, we describe methods to estimate the number of potential exposures to Level B 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 harassed or disturbed appreciably by Level B sound levels by the seismic surveys in the Ross Sea. The main sources of distributional and numerical data used in deriving the estimates are summarized below. The methods to estimate the number of potential exposures to Level B sound levels and estimates of the numbers of marine mammals that could be affected during icebreaking activities are presented in Appendix C.

It is assumed that, during simultaneous operations of the airgun array and the other sources, any marine mammals close enough to be affected by the MBES, SBP, and ADCP would already be affected by the airguns. However, whether or not the airguns are operating simultaneously with the other sources, marine mammals are expected to exhibit no more than short-term and inconsequential responses to the ADCP, SBP, and MBES, given their characteristics (e.g., narrow downward-directed beam of the MBES) 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 seismic surveys. To the extent that marine mammals tend to move away from seismic sources before the sound level reaches the criterion level and tend not to approach an operating airgun array, these estimates likely overestimate the numbers actually exposed to the specified level of sound.

We used the best available marine mammal density data for this region from NMFS (2015), which were also used for a previous seismic survey in the Ross Sea in 2015. For that survey, available sightings data from the 2002–2003 International Whaling Commission-Southern Ocean Whale and Ecosystem Research (IWC-SOWER) Circumpolar Cruise, Area V (Ensor et al. 2003) were used to estimate densities for four mysticete and six odontocete species; density data were obtained from surveys conducted from

December to March. Densities for sei and Arnoux's beaked whales were based on those reported in the Naval Marine Species Density Database (NMSDD) (Department of Navy 2012). Densities of pinnipeds were estimated using best available data (Waterhouse 2001; Pinkerton and Bradford-Grieve 2010) and dividing the estimated population of pinnipeds (number of animals) by the area of the Ross Sea (300,000 km^2). There is uncertainty about the representativeness of the data and the assumptions used to estimate exposures below. Thus, for some species, the densities may not precisely represent 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 activities.

Potential Number of Marine Mammals Exposed

The numbers of animals 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 were estimated by calculating the area that would be within the Level B threshold around the operating seismic source and the expected density of animals in the area. This involves determining the area potentially ensonified above threshold levels during the seismic surveys. The ensonified area is then multiplied by the densities to estimate the daily number of exposures. The area expected to be ensonified on a daily basis was determined by multiplying the number of line km to be acquired in one day (i.e., 200 km at 4.5 kt) and multiplying by the applicable 160-dB threshold buffer (radius) in intermediate water, on each side of the line (Appendix D). The ensonified area was then increased by 25% to allow for additional airgun operations such as testing of the source or re-surveying lines with poor data quality. This approach assumes that no animals would move away or toward the trackline in response to increasing sound levels before the levels reach the thresholds as RVIB NBP approaches.

Table 3 shows the densities and estimates of the number of marine mammals that potentially could be exposed to ≥160 dB re 1 μPa_{rms} during the planned seismic surveys. It should be noted that the estimates of exposures assume that the proposed surveys would be fully completed; in fact, the calculated takes have been increased by 25%. Thus, 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.

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 (e.g., Ellison et al. 2012; NMFS 2013; Hastie et al. 2021; Hückstädt et al. 2020; Southall et al. 2021; Miller et al. 2022). Southall et al. (2021) provide a detailed framework for assessing marine mammal behavioral responses to anthropogenic noise and note that use of a single threshold can lead to large errors in prediction impacts due to variability in responses between and within species.

TABLE 3. Marine mammal take estimates for the proposed seismic surveys in the Ross Sea. Species in italics are listed as endangered under the ESA.

Species	Estimated Density[1] (#/km²)	Level B Take: Seismic (≥160 dB)[2]	Level B Take: Icebreaking (≥120 dB)[3]	Total Requested Take Authorization	Population Size[4]	Percent of Population
LF Cetaceans						
Fin whale	*0.0306570*	*313*	*254*	*567*	*38,200*	*1.48*
Blue whale	*0.0065132*	*67*	*54*	*120*	*1,700*	*7.09*
Sei whale	*0.0046340*	*47*	*38*	*86*	*10,000*	*0.86*
Antarctic minke whale	0.0845595	864	700	1,564	515,000	0.30
Humpback whale	0.0321169	328	266	594	42,000	1.41
MF Cetaceans						
Sperm whale	*0.0098821*	*101*	*82*	*183*	*12,069*	*1.51*
Southern bottlenose whale	0.0117912	120	98	218	599,300	0.04
Arnoux's beaked whale	0.0134420	137	111	249	599,300	0.04
Strap-toothed beaked whale	0.0044919	46	37	83	599,300	0.01
Killer whale	0.0208872	213	173	386	25,000	1.55
Long-finned pilot whale	0.0399777	408	331	739	200,000	0.37
HF Cetaceans						
Hourglass dolphin	0.0189782	194	157	351	144,300	0.24
Pinnipeds						
Crabeater seal	0.6800000	6,946	5,629	12,575	1,700,000	0.74
Leopard seal	0.0266700	272	221	493	220,000	0.22
Ross seal	0.0166700	170	138	308	250,000	0.12
Weddell seal	0.1066700	1,090	883	1,973	1,000,000	0.20
Southern elephant seal	0.0001300	1	1	2	750,000	<0.01

[1] Densities from NMFS (2015).

[2] Based on a total ensonified area of 5272 km² for the Ross Bay survey and 4942 km² for the Drygalski Trough survey (see Appendix D).

[3] Based on a total ensonified area of 8278 km² (see Appendix C).

Conclusions

The proposed project would involve towing a small source, up to two 105-in³ GI airguns, that introduces pulsed sounds into the ocean. Routine vessel operations, other than the proposed seismic surveys and icebreaking activities, are conventionally assumed not to affect marine mammals sufficiently to constitute "taking". In § 3.6.7 and § 3.7.7, 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, that Level A effects were unlikely, and that operations were unlikely to adversely affect ESA-listed species. Estimates of the numbers of marine mammals that could be exposed to airgun sounds during the proposed program have been presented, together with the requested "take authorization".

The estimated numbers of animals potentially exposed to sound levels sufficient to cause Level B harassment are very low percentages of the regional population sizes (Table 3). 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.

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 R/V *Langseth* off the coast of North Carolina in September–October 2014, only 296 cetaceans were observed within the predicted 160-dB zone and potentially taken, representing <2% of the 15,498 takes authorized by NMFS (RPS 2015b). During an USGS-funded, ~2700 km, 2-D seismic survey conducted by R/V *Langseth* along the U.S. east coast in August–September 2014, only 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.

Numerous marine mammal species 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 subsurface horizons and unit thickness that would be mapped would be best imaged using a low-energy source consisting of up to two 105-in^3 GI guns (total volume of 210 in^3) at a tow depth of 1–4 m. The airgun array is one of the smaller sound sources used by the U.S. academic research community to conduct research during seismic survey activities. Based on experience, the PI has determined that this sound source, up to two GI airguns, would be the minimum source level necessary to reach the target depths for the largest offset ranges.

***Survey Timing*.—**The PI worked with NSF and its contractors to identify potential times to carry out the surveys, taking into consideration key factors such as environmental conditions (e.g., seasonal presence of marine mammals), weather conditions, equipment, and optimal timing for other proposed research cruises. The austral summer schedule (December–January) is proposed because sea ice cover is typically at a minimum during this time of year. Acquiring seismic and multibeam data in ice covered seas creates risk such as damage and/or loss to the seismic source and receivers that are deployed behind the vessel. However, a higher density of cetacean species, in particular baleen whales, are expected to occur in the area during the austral summer.

***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 the Level B (160 dB re 1µPa_{rms}) threshold. The background information and methodology for this are provided in Appendix A. The proposed surveys would acquire data with up to two GI airguns at a tow depth of 1–4 m. L-DEO model results are used to determine the 160-dB_{rms} radius for the largest airgun array configuration that could be used (two 105 in^3 GI airguns, with a total discharge volume of 210 in^3) in deep water (>1000 m) down to a maximum water depth of 2000 m, as animals are generally not anticipated to dive below 2000 m (Costa and Williams 1999). The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor of 1.5.

Table 1 shows the distances at which the 160-dB re 1µPa_{rms} sound level is expected to be received for the 2-GI airgun configuration (totaling 210 in^3) at a 4-m tow depth. Levels and distances for this configuration would be used in the ensuing analysis, as it has the greatest energy output of the proposed configurations; this is therefore the most conservative approach. The 160-dB level is the behavioral disturbance criterion that is used to estimate anticipated Level B takes for marine mammals.

The 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 GI airguns in all water depths. If marine mammals 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 PEIS.

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). Although Level A takes would not be anticipated, for other recent low-energy seismic surveys supported by NSF, NMFS required protected species observers (PSOs) to establish and monitor a 100-m exclusion zone (EZ) and a 200-m buffer zone beyond the EZ. In addition, a 500-m EZ was established for special circumstances, including observation of (1) beaked whales or southern right whales, (2) large whales with calf, and (3) aggregation of whales.

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 the EZ, 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 EZ—probably not enough to allow continued one-airgun operations if a marine mammal came within the safety radius for two airguns.

Speed or Course Alteration

If a marine mammal 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 (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 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 airgun(s) would be shut down before the animal is within the EZ. Likewise, if a marine mammal is already within the EZ when first detected, the GI airgun(s) would be shut down immediately. Following a shut down, seismic activity would not resume until the marine mammal 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, or
- it has not been seen within the zone for 30 min in the case of mysticetes and large odontocetes, including sperm and beaked whales.

Ramp up Procedures

A ramp up procedure would be followed when a 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 has not cleared the EZ as described earlier. Ramp up would begin with one GI airgun, and the second GI airgun would be added after 5 min. During ramp up, the PSOs would monitor the EZ, and if marine mammals are sighted, a shut down would be implemented as though the full array were operational.

If the EZ has not been monitored by PSOs for at least 30 min prior to the start of operations, ramp up would not commence. A ramp up from a shut down may occur in poor visibility/darkness as long as the EZ has been continually monitored by PSOs for 30 minutes prior to ramp up with no marine mammal detections. Ramp up of the GI airguns would not be initiated if a marine mammal is sighted within or near the EZ.

The number of individual marine mammals expected to be approached closely during the proposed activities would be relatively small in relation to regional population sizes. With the proposed monitoring and mitigation provisions, potential effects on most if not all individuals would be expected to be limited to minor behavioral disturbance. Those potential effects would be expected to have negligible impacts on both individual marine mammals and associated species and stocks. Survey operations would be conducted in accordance with all applicable U.S. federal regulations, including IHA and ITS requirements.

XII. Plan of Cooperation

> Where the proposed activity would take place in or near a traditional Arctic subsistence hunting area and/or may affect the availability of a species or stock of marine mammal for Arctic subsistence uses, the applicant must submit either a plan of cooperation or information that identifies what measures have been taken and/or will be taken to minimize any adverse effects on the availability of marine mammals for subsistence uses. A plan must include the following:
>
> (i) A statement that the applicant has notified and provided the affected subsistence community with a draft plan of cooperation;
>
> (ii) A schedule for meeting with the affected subsistence communities to discuss proposed activities and to resolve potential conflicts regarding any aspects of either the operation or the plan of cooperation;
>
> (iii) A description of what measures the applicant has taken and/or will take to ensure that proposed activities will not interfere with subsistence whaling or sealing; and
>
> (iv) What plans the applicant has to continue to meet with the affected communities, both prior to and while conducting activity, to resolve conflicts and to notify the communities of any changes in the operation.

Not applicable. The proposed activity would take place in the Ross Sea, Antarctica, 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...

NSF 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. NSF's proposed Monitoring Plan is described below. NSF 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. NSF 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 poor visibility/darkness/nighttime start ups of the airguns. GI airgun operations would be suspended when marine mammals are observed within, or about to enter, designated EZs [see § XI above] where there is concern about potential effects on hearing or other physical effects. PSOs would also watch for marine mammals near the seismic vessel for at least 30 min prior to the planned start of airgun operations. When feasible, PSOs would also make observations during daytime periods when the seismic system is not operating for comparison of animal abundance and behavior.

One dedicated PSO would monitor the EZ during all daytime seismic operations, and 2 PSOs when feasible. 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. PSOs would be approved by NMFS.

RVIB NBP is a suitable platform from which PSOs would watch for marine mammals. Standard equipment for marine mammal observers would be 7 x 50 reticle binoculars, optical range finders and night-vision equipment. 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 exposed to various received sound levels and to document apparent disturbance reactions or lack thereof. 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 shut down of the airguns when a marine mammal is within or near the EZ.

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

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

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

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

Results from the vessel-based observations would provide

1. The basis for real-time mitigation (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 in the area where the seismic study is conducted.
4. Information to compare the distance and distribution of marine mammals relative to the source vessel at times with and without seismic activity.
5. Data on the behavior and movement patterns of marine mammals seen at times with and without seismic activity.

A report would be submitted to NMFS and NSF within 90 days after the end of the cruise. The report would describe the operations that were conducted and sightings of marine mammals near the operations. The report would provide full documentation of methods, results, and interpretation pertaining to all monitoring. The 90-day report would summarize the dates and locations of seismic operations, all marine mammal sightings (dates, times, locations, activities, associated seismic survey activities) 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.

NSF would coordinate the planned marine mammal monitoring program associated with the seismic surveys with other parties that may have interest in this area. NMFS's interactive map (accessed during preparation of this IHA application) did not identify any other nearby planned or authorized activities in or near the proposed action area. NSF would coordinate with applicable U.S. agencies 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 the Level B (160 dB re 1µPa$_{rms}$) threshold. 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 105-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).

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 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 (Costa and Williams 1999). Figures 2 and 3 in Appendix H of the PEIS show how the values along the maximum SPL line that connects the points where the isopleths attain their maximum width (providing the maximum distance associated with each sound level) may differ from values obtained along a constant depth line. At short ranges, where the direct arrivals dominate and the effects of seafloor interactions are minimal, the data recorded at the deep 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.

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 105-in^3 GI guns (separated by up to 2.4 m) at a tow depth of 1–4 m. Table A-1 shows the distances at which the 160-dB re 1µPa$_{rms}$ sound level is expected to be received for the 2-GI airgun configuration (totaling 210 in^3) at a 4-m tow depth. 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 (Fig. A-1). The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor (multiplication) of 1.5, such that observed levels at very near offsets fall below the corrected mitigation curve (Fig. 16 in Appendix H of the PEIS).

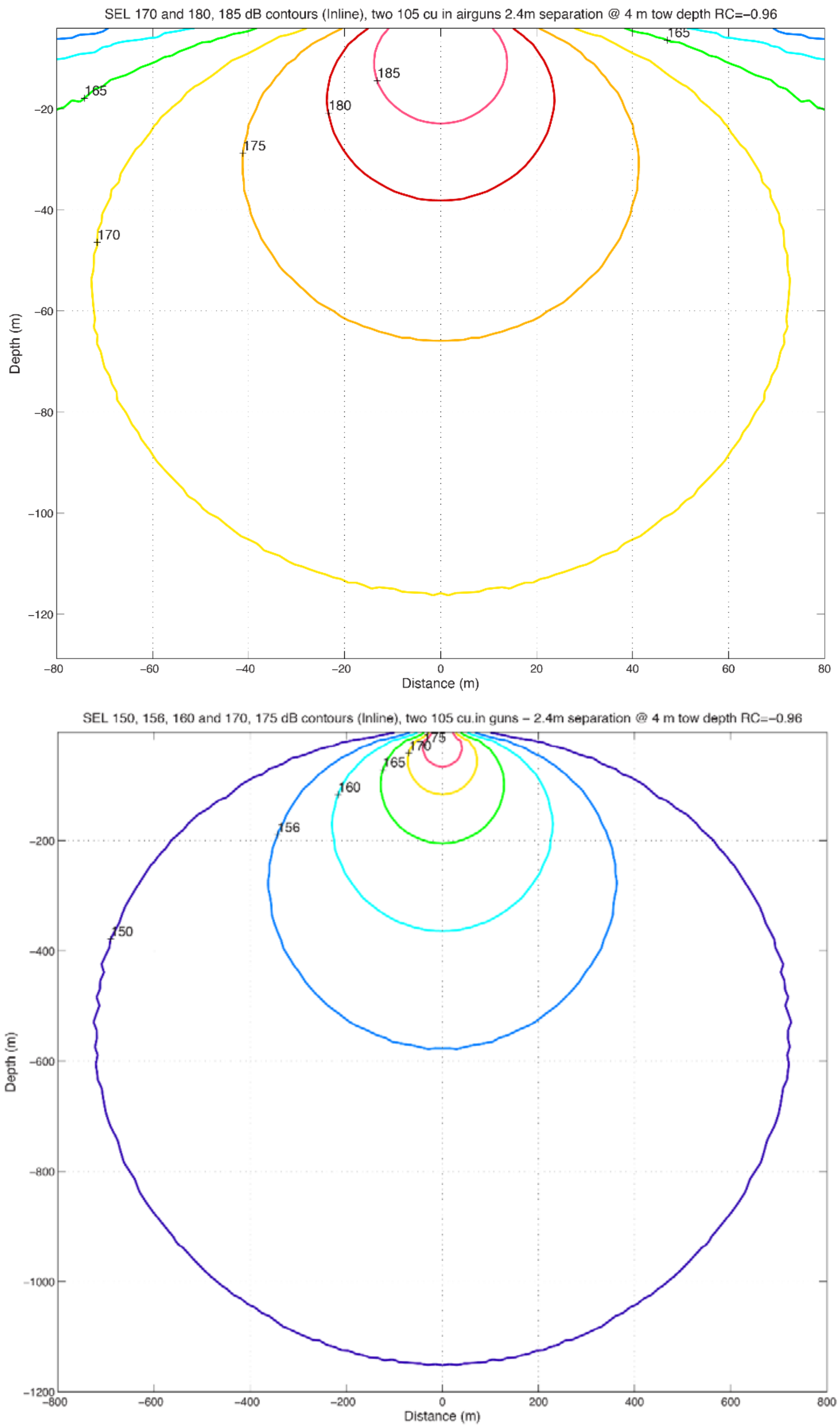

FIGURE A-1. Modeled deep-water received sound exposure levels (SELs) from the two 105-in^3 GI guns, with a 2.4-m gun separation, planned for use during the proposed surveys in the Ross Sea at a 4-m tow depth. Received rms levels (SPLs) are expected to be ~10 dB higher. The radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.

TABLE A-1. Level B. Predicted distances to the 160 dB re 1 μPa$_{rms}$ sound level that could be received from two 105-in^3 GI guns (separated by 2.4 m, at a tow depth of 4 m) that would be used during the seismic surveys in the Ross Sea during austral summer 2021 (model results provided by L-DEO).

Airgun Configuration	Water Depth (m)[1]	Predicted Distances (m)
Two 105-in^3 GI guns	>1000	726[2]
	100-1000	1089[3]

[1] No survey effort would likely occur in water >1000 m; the distance for this water depth is included for informational purposes only.
[2] Distance is based on L-DEO model results.
[3] Distance is based on L-DEO model results with a 1.5 × correction factor between deep and intermediate water depths.

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[2] have confirmed that the L-DEO model generated conservative mitigation zones, resulting in significantly larger zones than required by NMFS.

In July 2016, NMFS released technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (NMFS 2016, 2018). The guidance established new thresholds for permanent threshold shift (PTS) onset or Level A Harassment (injury), for marine mammal species, but did not establish new thresholds for Level B Harassment. 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). This document 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).

[2] 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).

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APPENDIX B: DETERMINATION OF LEVEL A ZONES FOR THE 2 X 105 IN^3 GI-AIRGUNS TOWED AT A 4-M DEPTH WITH A 2.4 M SEPARATION

SEL_{cum} methodology† (spreadsheet – Sivle et al. 2014)

Source Velocity (meters/second)	2.315 *
1/Repetition rate^ (seconds)	5

† Methodology assumes propagation of 20 log R; activity duration (time) independent.
^ Time between onset of successive pulses.
* 4.5 kts

TABLE B-1. One single SEL SL modeling without and with applying weighting function to the 5 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 log10 (Radial distance) is used to estimate the modified farfield SEL.

SEL_{cum} Threshold	**183**	**185**	**155**	**185**	**203**
Distance(m) (no weighting function)	20.87	16.83	537.08	16.83	2.40
Modified Farfield SEL*	209.39	209.52	209.60	209.52	210.60
Distance (m) (with weighting function)	9.68	N/A	N/A	N/A	N/A
Adjustment (dB)	-6.677	N/A	N/A	N/A	N/A

* Propagation of 20 log R

For the low-frequency cetaceans, 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 run the modeling for one single shot without applying any weighting function. The maximum 183 dB SEL_{cum} isopleth is located at 20.87 m from the source. We then run the modeling for one single shot with the low frequency Cetaceans weighting function applied to the full spectrum. The maximum 183 dB SEL_{cum} isopleth is located at 9.68 m from the source. Difference between 20.87 m and 9.68 m gives an adjustment factor of -6.67 dB assuming a propagation of 20log10(R).

TABLE B-2. Results for single shot SEL source level modeling for the two 105 in³ airguns with weighting function calculations for SEL_{cum} criteria.

F: MOBILE SOURCE: Impulsive, Intermittent (SAFE DISTANCE METHODOLOGY)

VERSION 1.1: Aug-16

KEY

(green)	Action Proponent Provided Information
(pink)	NMFS Provided Information (Acoustic Guidance)
(blue)	Resultant Isopleth

STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	
PROJECT/SOURCE INFORMATION	source : SIO portable system = 2 x 105 cu.in GI-gun at a 4m towed depth - (2.4 m separation in the fore-aft direction)
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)[¥]	User defined	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)	2.315
1/Repetition rate^ (seconds)	5

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

^Time between onset of successive pulses.

Modified farfield SEL	209.3917	209.5193	209.6007	209.5193	210.597
Source Factor	1.7386E+20	1.79044E+20	1.82432E+20	1.79044E+20	2.29472E+20

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)	25.4	0.0	0.0	0.3	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)†	-6.68	-54.82	-63.94	-24.73	-30.61	OVERIDE Using LDEO Modeling

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)	**25.4**	**0.0**	**0.0**	**0.3**	**0.0**

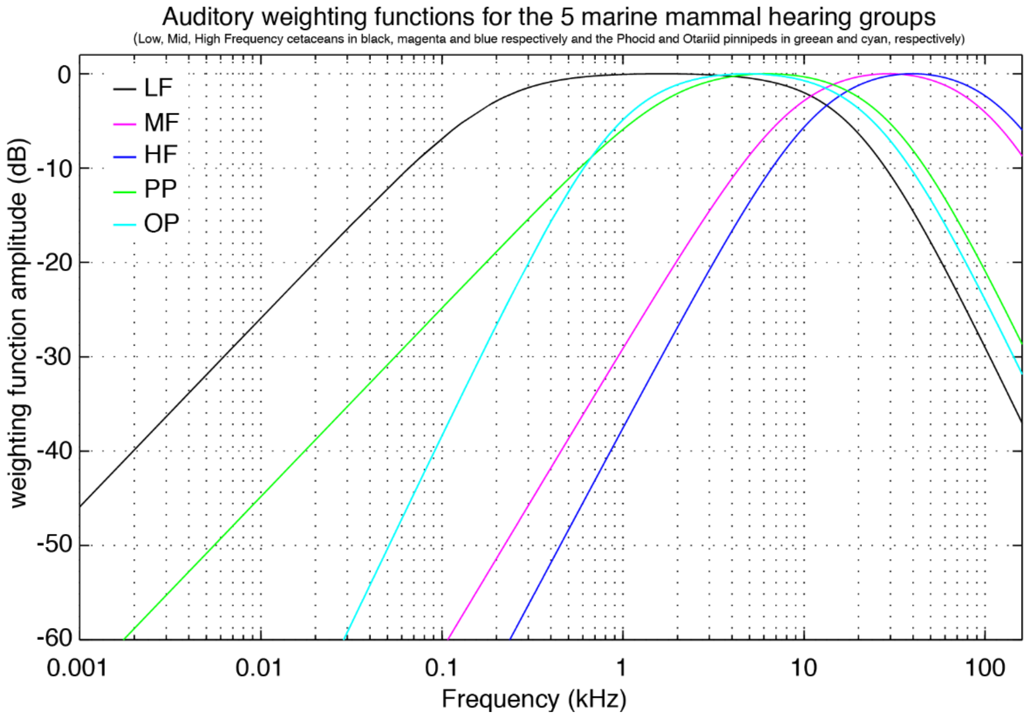

FIGURE B-1. Auditory weighting functions for five marine mammal hearing groups from the NMFS Technical Guidance Spreadsheet.

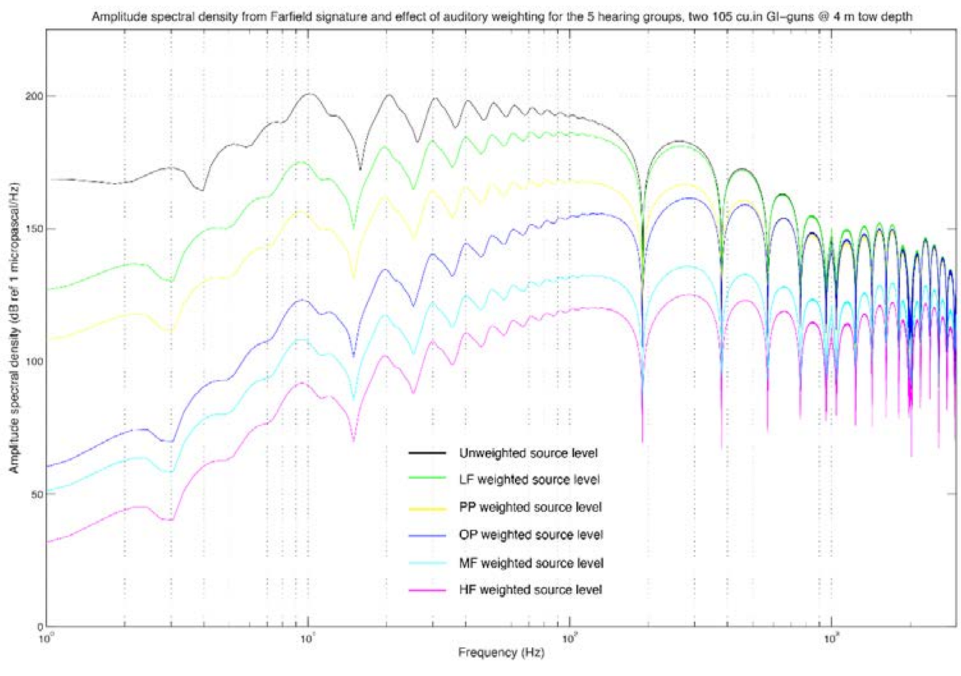

FIGURE B-2. Modeled amplitude spectral density of the two 105 in3 airgun farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting function for the low-frequency cetaceans, phocid pinnipeds, otariid pinnipeds, mid-frequency cetaceans, high-frequency cetaceans, respectively. Modeled spectral levels in micropascals are used to calculate the difference between the un-weighted and weighted source level at each frequency and to derive the adjustment factors for the phocid pinnipeds, otariid pinnipeds, mid-frequency cetaceans, and high-frequency cetaceans as inputs into the NMFS user spreadsheet.

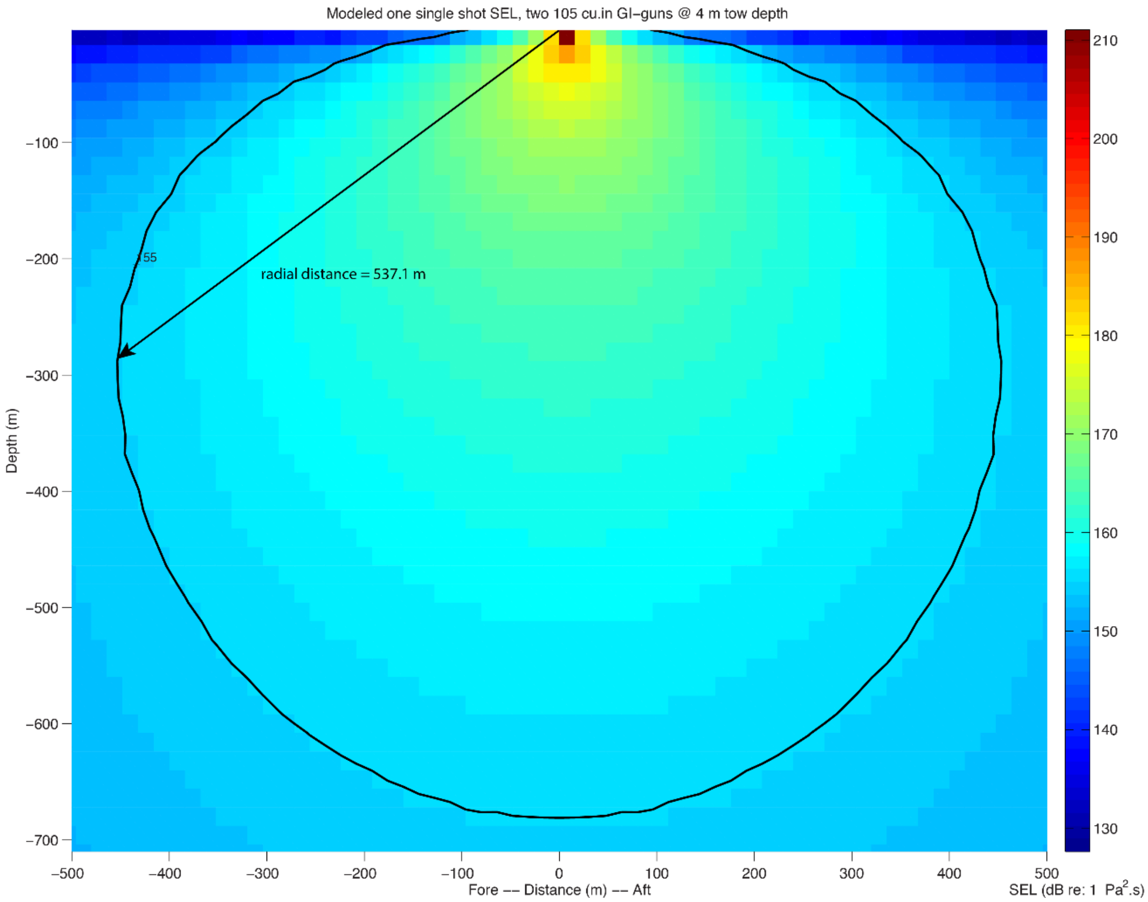

FIGURE B-3. Modeled received sound levels (SELs) in deep water from the two 105 in³ GI-guns at a 4-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (537.1 m).

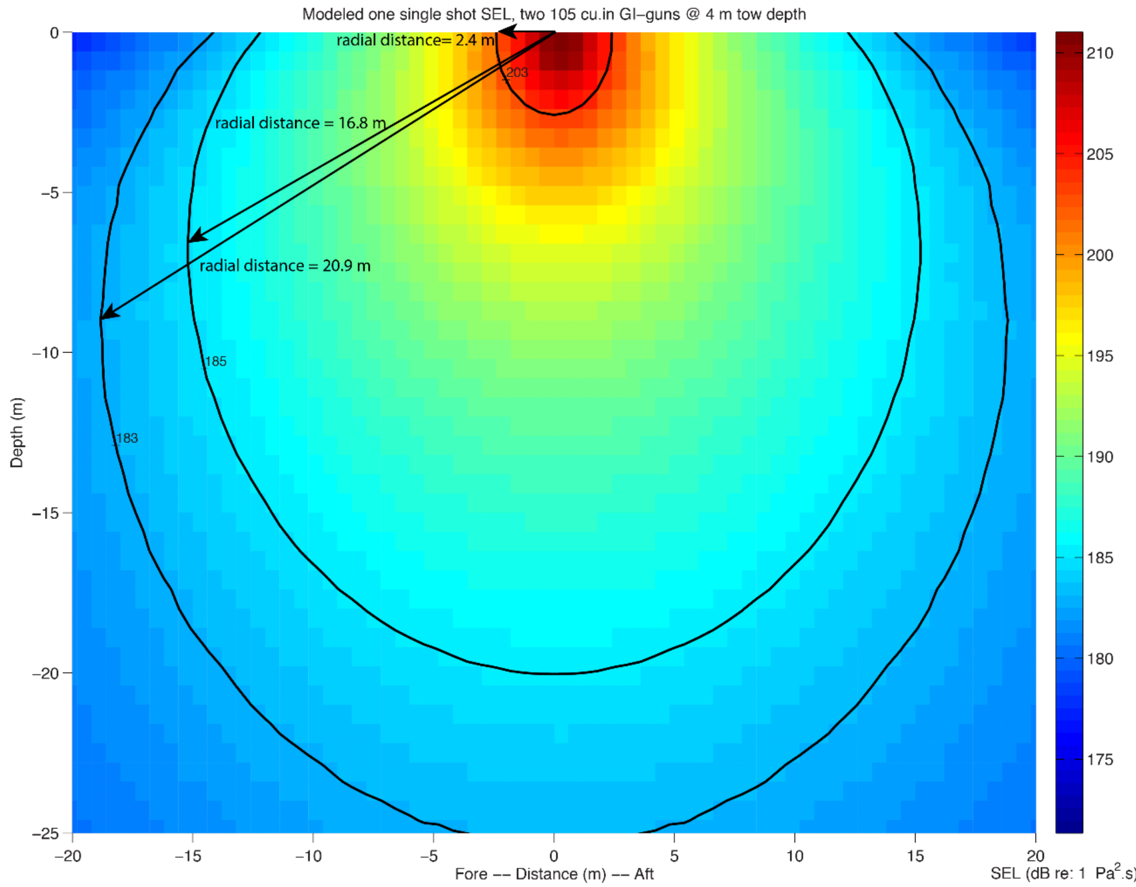

FIGURE B-4. Modeled received sound levels (SELs) in deep water from the two 105 in^3 GI-guns at a 4-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183, 185 and 203 dB SEL isopleths

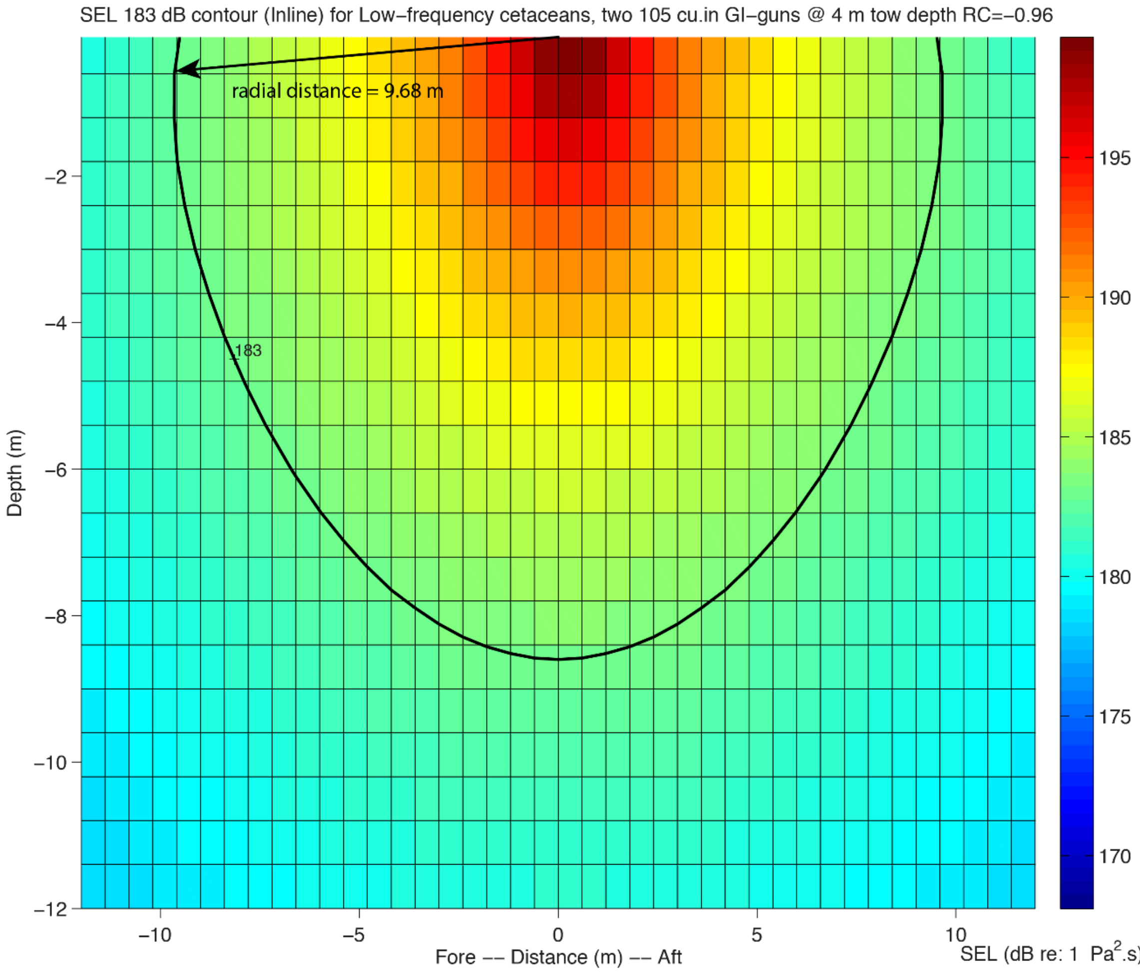

FIGURE B-5. Modeled received sound exposure levels (SELs) from the two 105 in³ GI-guns at a 4-m tow depth, after applying the auditory weighting function for the low-frequency cetaceans hearing group following to the new technical guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one shot. The difference in radial distances between Fig. B-4 (20.87 m) and this figure (9.68 m) allows us to estimate the adjustment in dB.

Peak Sound Pressure Level

TABLE B-3. Level A. NMFS Level A acoustic thresholds (Peak SPL_{flat}) for impulsive sources for marine mammals and predicted radial distances to Level A thresholds for various marine mammal hearing groups that could be received from the two 105 in³ airguns at a 4 m tow depth during the proposed seismic survey.

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
PK Threshold	219	230	202	218	232
Radius to threshold (meters)	**6.69**	**1.50**	**47.02**	**7.53**	**0.92**

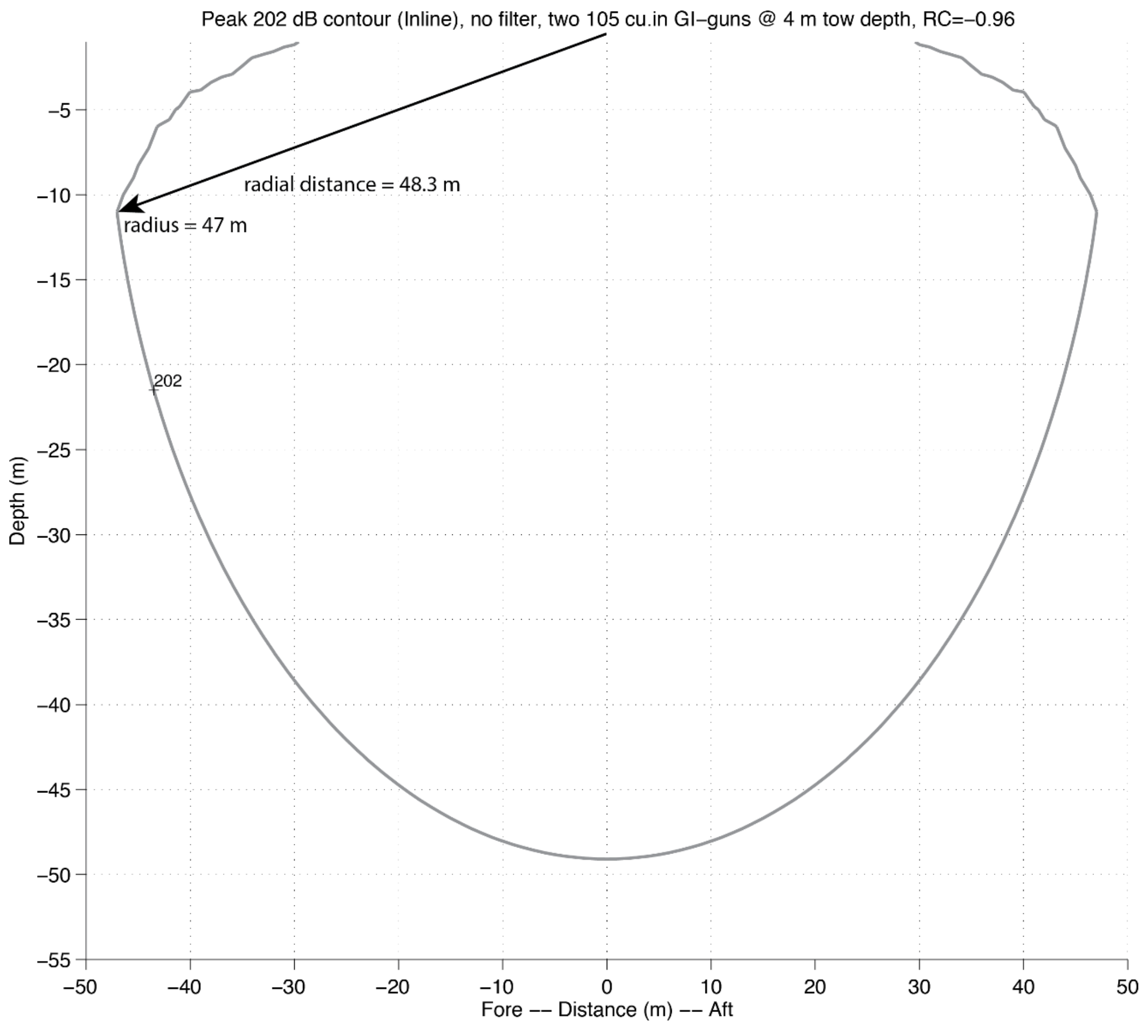

FIGURE B-6. Modeled deep-water received Peak SPL from two 105 in^3 airguns at a 4-m tow depth. The plot provides the radius of the 202-dB peak isopleth (47.02 m).

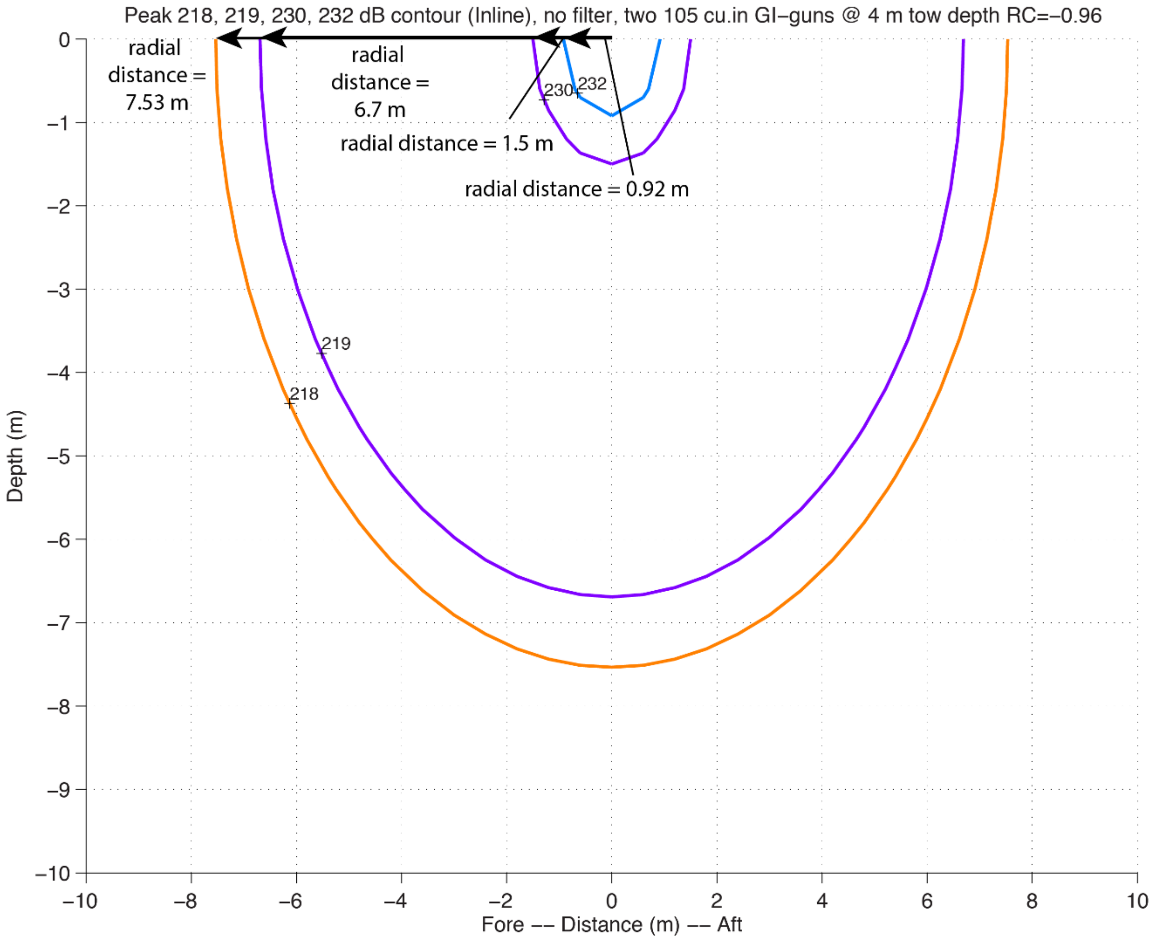

FIGURE B-7. Modeled deep-water received Peak SPL from two 105 in^3 airguns at a 3-m tow depth. The plot provides the radius of the 218-219-230 and 232 dB peak isopleths.

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APPENDIX C: ENSONIFIED AREA FROM ICEBREAKING ACTIVITIES AND POTENTIAL MARINE MAMMAL TAKE

For recent NSF seismic surveys conducted in the Antarctic for which an IHA was sought, NMFS required an assessment of and estimated takes for icebreaking activities; therefore, NSF includes here icebreaking information and analyses. Icebreaking activities are expected to be limited during the proposed surveys in the Ross Sea. The cruise dates were specifically chosen to avoid areas of heavy ice. The Ross Sea is generally clear of ice during December–January, because of the large Ross Sea Polynya that occurs in front of the RIS. In this application, takes have been presented for exposure to sound levels >160 dB from the proposed seismic surveys. Here we present takes for potential exposures to sound levels >120 dB from icebreaking activities. Based on the proposed transit to the survey areas, it is estimated that the RVIB NBP could break ice up to a distance of 500 km, that would alter local ice conditions in the immediate vicinity of the vessel, perhaps within ~10 m of either side of the vessel. Based on a ship speed of 5 kts under moderate ice conditions, this distance represents ~54 hrs of icebreaking (or 2.2 days). Transit through areas of primarily open water containing brash ice or pancake ice is not considered icebreaking for the purposes of this assessment.

Some marine mammal species (in particular seals) depend on sea ice for protection from predators; access to abundant food resources; and platforms for resting, mating, birthing, and raising young. Also, leads in sea ice provide critical migration corridors for some species as they move between wintering and summering areas. When marine mammals are engaged in the above activities, they may be vulnerable to ice-management activities and vessel transits through sea ice in those areas. Icebreaking activities introduce a substantial amount of underwater noise into the environment (Richardson et al. 1995). For example, Davis and Malme (1997) estimated that source levels of the ice-breaking cargo vessel M/V *Arctic* may be detectable by seals under fast ice at distances up to 20–35 km. The species of marine mammals that may be present and the nature of icebreaking activities are strongly influenced by ice type. Some species are more common in loose ice near the margins of heavy pack ice while others appear to prefer heavy pack ice. Propeller cavitation noise of icebreaking ships in loose ice is likely similar to that in open water while noise is expected to be much greater in areas of heavier pack ice or thick landfast ice where ship speed will be reduced, power levels will be higher, and there will be greater propeller cavitation (Richardson et al. 1995). Some whales are expected to avoid vessels that are underway, including icebreakers.

As RVIB NBP passes through sea ice, the ship would cause the ice to part and travel alongside the hull. This ice typically returns to fill the wake as the ship passes. In addition to avoidance reactions and potential masking, icebreaking may damage Weddell seal breathing holes and would reduce the haulout area for seals in the immediate vicinity of the ship's track, leading to a potential temporary reduction of habitat. However, the dynamic sea-ice environment requires that seals be able to adapt to changes in sea ice and snow conditions, and therefore, and they often use leads and cracks in the ice to surface and breathe. Disturbance to the ice would occur in a very small area relative to the Southern Ocean icepack.

The Level B harassment criterion for continuous sounds (such as icebreaking) is a received sound pressure level of 120 dB (NMFS 2015, 2020). Data characterizing the sound levels generated by icebreaking activities conducted by RVIB NBP are not available. Thus, NMFS (2020) used data for the U.S. Coast Guard Cutter (USCGC) *Healy* as a proxy for RVIB NBP for another recent survey in the Antarctic. NMFS (2020) used a 196.2 dB at 1 m source level, assumed a transmission loss of 20logR with spherical spreading, that resulted in a 6.456 km radius for the 120-dB harassment threshold. Here, the same threshold distance would be used for icebreaking activities. Therefore, as RVIB NBP travels through the ice, a ~13 km wide swath would be exposed to sound levels ≥120 dB. RVIB NBP is a smaller vessel and has less icebreaking capability than the USCG's polar icebreakers, being only capable of breaking ice up to 1 m thick at speeds of 3 kts. Therefore, the sound levels that could be generated during icebreaking by the NBP are expected to be lower than the levels estimated and measured for the USCGC *Healy*.

The estimated numbers of takes are based on the densities (numbers per unit area) of marine mammals expected to occur in the area in the absence of icebreaking. We used the best available marine mammal density data for this region from NMFS (2015), which were used for a previous seismic survey in the Ross Sea. The numbers of animals that could be exposed to icebreaking sounds with received levels ≥120 dB re 1 μPa_{rms} (Level B) for marine mammals were estimated by calculating the area that would be within this threshold around RVIB NBP during icebreaking and the expected density of animals in the area. This involves determining the area potentially ensonified above the threshold level during icebreaking activities. The ensonified area was then multiplied by the densities to estimate the daily number of exposures. The area expected to be ensonified was determined by assuming that icebreaking would occur for up to 500 km of transits in the Ross Sea and then multiplying this distance by the 120-dB buffer (6.456 km radius) on either side of the transect line, resulting in an area of 8278 km^2 (Table C-1). This approach assumes that no animals would move away or toward the trackline in response to increasing sound levels before the levels reach the specific thresholds as RVIB NBP approaches. The estimated number of takes for pinnipeds accounts for both seals that may be in the water and those hauled-out on ice. As the number of cetaceans that may be encountered within the ice margin habitat would be expected to be less than open water, the estimates are thought to be conservative, as the densities for open water were used.

TABLE C-1. Area ensonified above the 120 dB threshold level used to calculate potential takes for potential icebreaking activities in the Ross Sea

Criteria	Distance/Day (km)	Threshold Distance (km)	Daily Ensonified Area With Endcap (km^2)	Number of Survey Days	Plus 25% (Contingency)	Total Ensonified Area (km^2)
120 dB	223	6.456	3010	2.2	2.75	8278

Table C-2 shows the estimates of the number of marine mammals that potentially could be exposed to ≥120 dB re 1 μPa_{rms} during potential icebreaking activities during potential icebreaking activities. It should be noted that the estimates of exposures assume that there would be ~2 days of icebreaking activities; the calculated takes have been increased by 25%. As most cetaceans do not occur in pack ice, the estimates of the numbers of marine mammals potentially exposed to Level B sounds ≥120 dB re 1 μPa_{rms} are pre-cautionary and probably overestimate the actual numbers of marine mammals that could be involved. No Level A takes are expected, as these would be considered highly unlikely.

At least one PSO (and when feasible two) would monitor at all times while the NBP is conducting icebreaking activities. Cetaceans are expected to be seen during icebreaking activities, although some could occur along the ice margin. Monitoring would primarily involve searching for pinnipeds that may be hauled out on the sea ice and that could potentially dive into the water as the vessel approaches. Few cetaceans are expected to be seen during icebreaking activities, although some could occur along the ice margin.

TABLE C-2. Marine mammal take estimates for potential icebreaking activities in the Ross Sea. Species in italics are listed as endangered under the ESA.

Species	Estimated Density[1] (#/km²)	Level B Ensonified Area (km²)	Level B Take (exposures to levels ≥120 dB)	Total Requested Take Authorization	Population Size	Percent of Population
LF Cetaceans						
Fin whale	*0.0306570*	*8,278*	*254*	*254*	*38,200*	*0.66*
Blue whale	*0.0065132*	*8,278*	*54*	*54*	*1,700*	*3.17*
Sei whale	*0.0046340*	*8,278*	*38*	*38*	*10,000*	*0.38*
Antarctic minke whale	0.0845595	8,278	700	700	515,000	0.14
Humpback whale	0.0321169	8,278	266	266	42,000	0.63
MF Cetaceans						
Sperm whale	*0.0098821*	*8,278*	*82*	*82*	*12,069*	*0.68*
Southern bottlenose whale	0.0117912	8,278	98	98	599,300	0.02
Arnoux's beaked whale	0.0134420	8,278	111	111	599,300	0.02
Strap-toothed beaked whale	0.0044919	8,278	37	37	599,300	0.01
Killer whale	0.0208872	8,278	173	173	25,000	0.69
Long-finned pilot whale	0.0399777	8,278	331	331	200,000	0.17
HF Cetaceans						
Hourglass dolphin	0.0189782	8,278	157	157	144,300	0.11
Pinnipeds						
Crabeater seal	0.6800000	8,278	5,629	5,629	1,700,000	0.33
Leopard seal	0.0266700	8,278	221	221	220,000	0.10
Ross seal	0.0166700	8,278	138	138	250,000	0.06
Weddell seal	0.1066700	8,278	883	883	1,000,000	0.09
Southern elephant seal	0.0001300	8,278	1	1	750,000	<0.01

[1] Densities from NMFS (2015).

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APPENDIX D: ENSONIFIED AREA FROM SEISMIC SURVEYS AND POTENTIAL MARINE MAMMAL TAKE

The numbers of animals 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 were estimated by calculating the area that would be within the Level B threshold around the operating seismic source and the expected density of animals in the area. This involves determining the area potentially ensonified above threshold levels during the seismic surveys. The ensonified area is then multiplied by the densities to estimate the daily number of exposures. The area expected to be ensonified on a daily basis was determined by multiplying the number of line km to be acquired in one day (i.e., 200 km at 4.5 kt) and multiplying by the applicable 160-dB threshold buffer (radius) in intermediate water, on each side of the line (Table D-1). The daily ensonified area was then multiplied by the number of estimated seismic acquisition days –9.6 days for the Ross Bay survey and 9 days for the Drygalski Trough survey (Table D-1)). The ensonified areas were then increased by 25% to allow for additional airgun operations such as testing of the source or re-surveying lines with poor data quality. This approach assumes that no animals would move away or toward the trackline in response to increasing sound levels before the levels reach the thresholds as RVIB NBP approaches.

Table D-2 shows the densities and estimates of the number of marine mammals that potentially could be exposed to ≥160 dB re 1 μPa_{rms} during each of the two planned seismic surveys. It should be noted that the estimates of exposures assume that the proposed surveys would be fully completed; in fact, the calculated takes have been increased by 25%. Thus, 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 D-1. Areas ensonified above the 160 dB threshold level used to calculate potential takes for the proposed seismic surveys in the Ross Sea.

Survey Area	Distance/Day (km)	Threshold Distance (km)	Daily Ensonified Area With Endcap (km^2)	Number of Survey Days	Plus 25% (Contingency)	Total Ensonified Area (km^2)
Ross Bank	200	1.089	439	9.6	12	5272
Drygalski Trough	200	1.089	439	9	11.25	4942

Table D-2. Marine mammal take estimates for the proposed seismic surveys in the Ross Sea. Species in italics are listed as endangered under the ESA

			Ross Bank Survey				Drygalski Trough Survey			
Species	**Estimated Density[1] (#/km^2)**	**Population Size**	**Level B Ensonified Area (km^2)**	**Level B Take (exposures to levels ≥160 dB)**	**Total Requested Take Authorization**	**Percent of Population**	**Level B Ensonified Area (km^2)**	**Level B Take (exposures to levels ≥160 dB)**	**Total Requested Take Authorization**	**Percent of Population**
LF Cetaceans										
Fin whale	*0.0306570*	*38,200*	*5,272*	*162*	*162*	*0.42*	*4,942*	*152*	*152*	*0.40*
Blue whale	*0.0065132*	*1,700*	*5,272*	*34*	*34*	*2.02*	*4,942*	*32*	*32*	*1.89*
Sei whale	*0.0046340*	*10,000*	*5,272*	*24*	*24*	*0.24*	*4,942*	*23*	*23*	*0.23*
Antarctic minke whale	0.0845595	515,000	5,272	446	446	0.09	4,942	418	418	0.08
Humpback whale	0.0321169	42,000	5,272	169	169	0.40	4,942	159	159	0.38
MF Cetaceans										
Sperm whale	*0.0098821*	*12,069*	*5,272*	*52*	*52*	*0.43*	*4,942*	*49*	*49*	*0.40*
Southern bottlenose whale	0.0117912	599,300	5,272	62	62	0.01	4,942	58	58	0.01
Arnoux's beaked whale	0.0134420	599,300	5,272	71	71	0.01	4,942	66	66	0.01
Strap-toothed beaked whale	0.0044919	599,300	5,272	24	24	<0.01	4,942	22	22	<0.01
Killer whale	0.0208872	25,000	5,272	110	110	0.44	4,942	103	103	0.41
Long-finned pilot whale	0.0399777	200,000	5,272	211	211	0.11	4,942	198	198	0.10
HF Cetaceans										
Hourglass dolphin	0.0189782	144,300	5,272	100	100	0.07	4,942	94	94	0.07
Pinnipeds										
Crabeater seal	0.6800000	1,700,000	5,272	3,585	3,585	0.21	4,942	3,361	3361	0.20
Leopard seal	0.0266700	220,000	5,272	141	141	0.06	4,942	132	132	0.06
Ross seal	0.0166700	250,000	5,272	88	88	0.04	4,942	82	82	0.03
Weddell seal	0.1066700	1,000,000	5,272	562	562	0.06	4,942	527	527	0.05
Southern elephant seal	0.0001300	750,000	5,272	1	1	<0.01	4,942	1	1	<0.01

[1] Densities from NMFS (2015).