Request by the National Science Foundation for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during a Marine Geophysical Survey in the Amundsen Sea

NSF-Funded Research Project:
THwaites Offshore Research (THOR) Project

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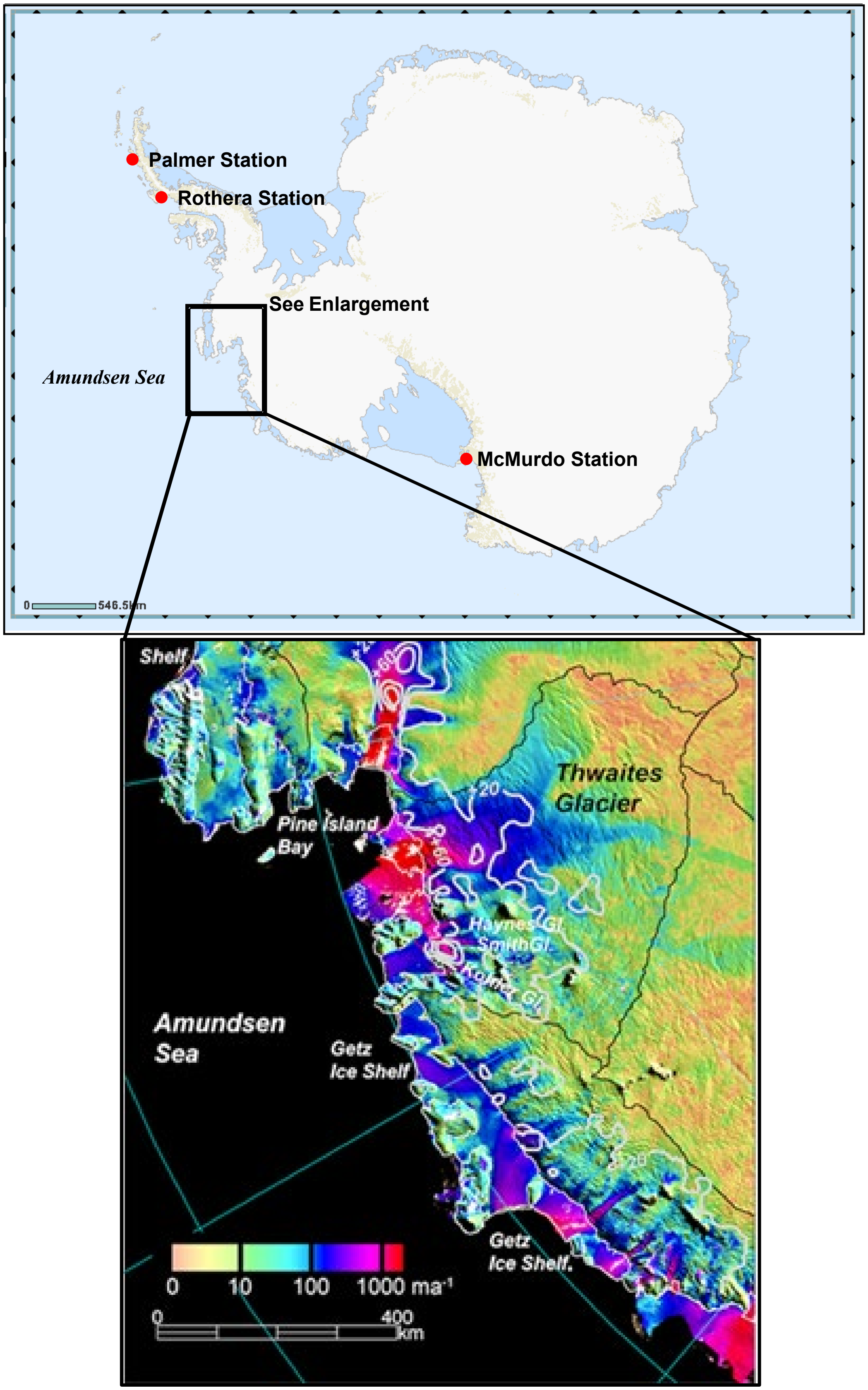
INTRODUCTION

In support of the United States Antarctic Program (USAP), National Science Foundation (NSF) proposes to conduct an integrated suite of marine and sub-ice shelf research activities designed to collect data that would facilitate more accurate projections of ice loss and sea-level rise originating from Thwaites Glacier in West Antarctica. The proposed research, known as the THwaites Offshore Research (THOR) project, is a collaborative, multidisciplinary component of the joint initiative by NSF and the U.K. Natural Environment Research Council (NERC). Figure 1 illustrates the location of the proposed study area.

Proposed research activities would include USAP vessel-based efforts in the Amundsen Sea, specifically a high-resolution geophysical (seismic) survey of the seafloor (Proposed Action). The USAP Research Vessel/Icebreaker (RVIB) *Nathaniel B. Palmer* (NBP) would support this research effort. The area proposed for the seismic survey is shown in Figure 2. Because of the extent of sea ice in the Amundsen Sea that typically occurs between January and February annually, icebreaking activities are expected to be required during the cruise. Pursuant to §101(a)(5)(D) of the Marine Mammal protection Act, 16 U.S.C. §137(a)(5) (MMPA), an Incidental Harassment Authorization is being sought for the activities associated with the Proposed Action that may have incidental impacts on marine mammals.

The items required to be addressed pursuant to 50 C.F.R. § 216.104, “Submission of Requests,” are set forth below. They include descriptions of the specific operations to be conducted, the marine mammals occurring in the survey areas, 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.

Descriptions of marine mammal species that may be found in the proposed study area are derived primarily from information contained in scientific research surveys and observations. Analysis of the effects on marine mammals was based on the final *Programmatic Environmental Impact Statement (EIS)/Overseas Environmental Impact Statement (OEIS) for Marine Seismic Research Funded by the National Science Foundation or Conducted by the U.S. Geological Survey* (NSF 2011) (hereafter called PEIS) and information contained in the *Draft Environmental Analysis of Low-Energy Marine Geophysical Surveys by R/V Thomas G. Thompson on the South Atlantic Ocean, November-December 2019*, prepared by LGL Ltd., environmental research associates on behalf of Lamont-Doherty Earth Observatory and NSF (June 2019). While the arrays described in the environmental analysis by LGL Ltd. (2019) could be slightly different than the proposed array, the described general effects are applicable.



Source: Scambos et al. 2017 in Global and Planetary Change

Figure 1. Amundsen Sea Study Area

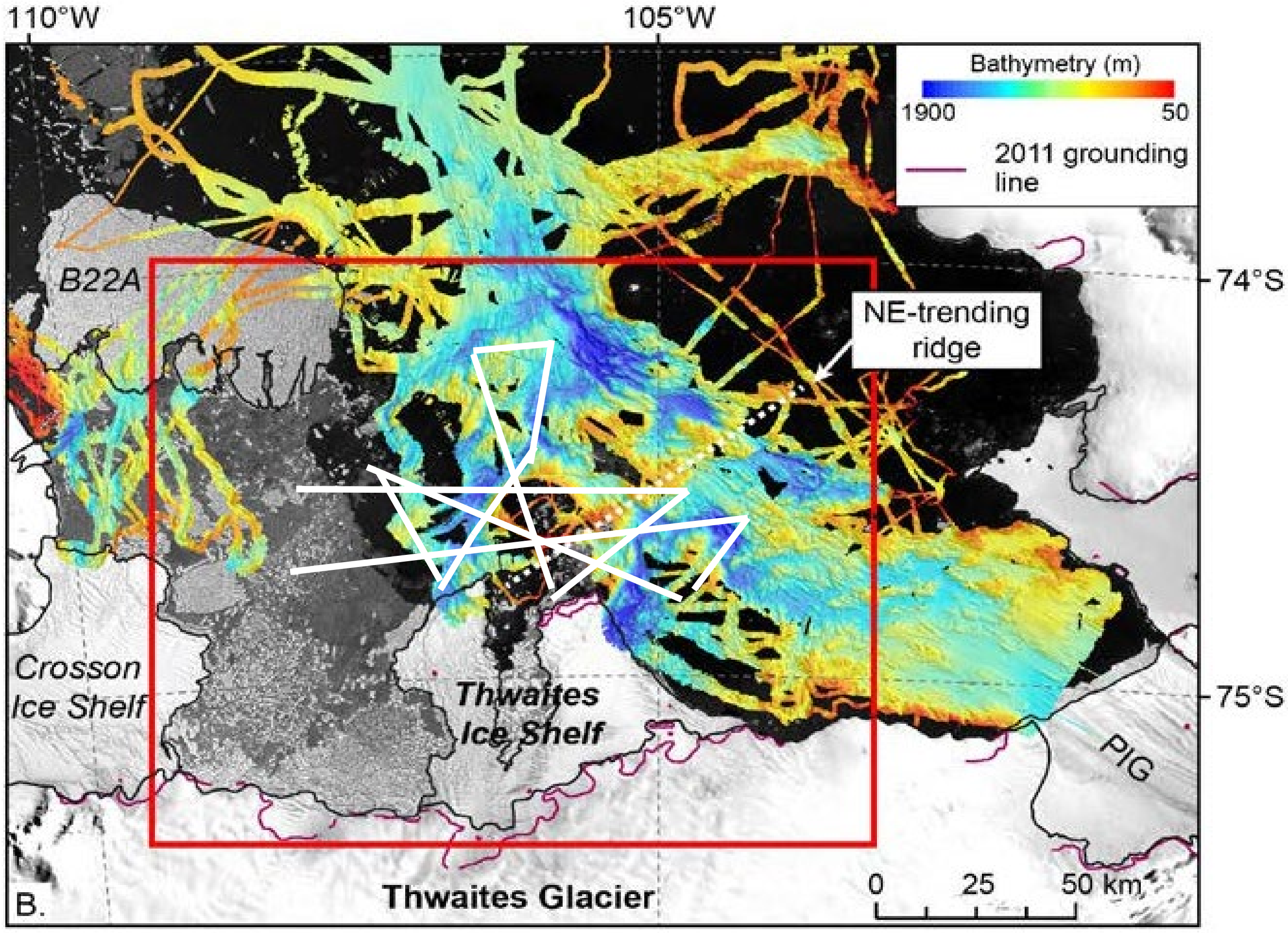


Figure 2. Thwaites Glacier study area (red box) and approximate seismic survey lines (white line within box). Black line is generalized coastline-grounding line (from http://www.add.scar.org/) and purple line is 2011 grounding line from Rignot et al., 2014. PIG = Pine Island Glacier.

1.0 DESCRIPTION OF SPECIFIED ACTIVITIES

National Oceanic and Atmospheric Administration (NOAA) Fisheries (also known as National Marine Fisheries Service [NMFS]) Requirement: A detailed description of the specific activity or class of activities that can be expected to result in incidental taking of marine mammals.

The proposed THOR project research would focus on the seafloor offshore from Thwaites Glacier and records of past glacial and ocean change contained in sediments deposited by the glacier and the surrounding ocean. Overall, data obtained by the project would assist in establishing boundary conditions seaward of the Thwaites Glacier grounding line, obtaining records of external drivers of change, improving knowledge of processes leading to the collapse of Thwaites Glacier, and determining the history of past change in grounding line migration and conditions at the glacier base. Sedimentary records and glacial landforms preserved on the seafloor would allow reconstruction of changes in drivers and glacial response to changes over a range of timescales, thus providing reference data that can be used to initiate and evaluate the model reliability. Further, such data would provide insights on poorly understood processes of marine ice sheet dynamics.

To support the research objectives, the Proposed Action would include a seismic survey that would be conducted along a 1600-km (994-mi) track (Figure 2) using a one- or two-generator injector (GI) airgun array (with a "hot spare") as a low-energy seismic source and returning acoustic signals would be collected via a hydrophone streamer (100-300 m in length). Other acoustic sources would be used during the Proposed Action, including acoustic doppler current profilers (ADCPs) and multi-, single, and split-beam echosounders.

Specific details of the proposed seismic survey are described below.

Seismic Survey

The proposed seismic survey would be contained in approximately 8400 km^2 (3205 mi^2) in the Amundsen Sea and performed along track lines totaling approximately 1600 km (994 mi). The ensonified area is estimated to be approximately 3341 km^2 (1290 mi^2), based on the maximum 1600 km (994 mi) length of the seismic survey multiplied by the maximum area anticipated to be ensonified to the predicted Level B threshold distance around planned seismic lines (1.044 km [3425 ft] x 2 in intermediate water and 696 km [2283 ft] x 2 in deep water). The Level B ensonified area is based on the maximum predicted range exhibiting a sound level of 160 dB re 1μPa (rms) or greater, based on modeling data (Attachment A). Water depths would range between 100-1000 m (328-3280 ft) in 65% of the survey area and depths greater than 1000 m (3280 ft) in 35% of the study area (Figure 2). Track line distance includes equipment testing, start-up, line changes, repeat coverage of areas as needed, and equipment recovery. Since the seismic survey would be conducted during the austral summer, operations would mainly occur in daylight conditions. Weather conditions permitting, it is anticipated that seismic surveying would not exceed 240 hours of operation.

Seismic surveys would involve using a low-energy acoustic source consisting of a either a single GI airgun or a two-GI airgun array in harmonic or true GI mode, with one 100-300 m (328-984 ft), solid-state, hydrophone streamer towed behind the vessel. An extra airgun would serve as a "hot spare" backup, to be used in the event that the primary airgun array malfunctions.

The airgun array would be deployed at a depth of approximately 2-4 m (6.6-13 ft) below the surface, spaced approximately 3 m (9.8 ft) apart (for the two-gun array), and between 15-40 m (49-131 ft) astern. Each airgun would be configured in the true GI or harmonic mode, with varying displacement volumes (Table 1). The total maximum discharge volume for the largest, two-airgun array would be 3441 cm^3 (210 in^3; Table 1).

The airguns would fire compressed air at an approximate firing pressure of 140 kg/cm^2 (2000 psi). In harmonic mode, the injector volume is designed to destructively interfere with the reverberations of the generator (the source component). Firing the airguns in harmonic mode maximizes resolution in the data and minimizes excess noise in the water column or in the data, caused by the reverberations (or bubble pulses).

If the preferred airgun configuration (two-gun array in true GI mode) does not provide data to meet scientific objectives, alternate configurations would be utilized (Table 1).

Table 1. Proposed Seismic Survey Activities in the Amundsen Sea[1]

Configuration	Airgun Array Total Volume (GI configuration)	Frequency Between Seismic Shots	Streamer Length
Preferred	2 x 45/105 in^3 (300 in^3 total) (true GI mode)	5 seconds	100-300 m (328-984 ft)
Alternate 1	1 x 45/105 in^3 (150 in^3 total) (true GI mode)	5 seconds	
Alternate 2 (used for take request)	2 x 105/105 in^3 (420 in^3 total) (harmonic mode)	5 seconds	
Alternate 3	1 x 105/105 in^3 (210 in^3 total) (harmonic mode)	5 seconds	

Note:
[1] Seismic surveying operations are planned for 1600 km (994 mi) in length

During the seismic survey, the vessel would attempt to maintain a constant cruise speed of approximately 8.3 km/hr (4.5 knots). There would be approximately 720 shots per hour, and the relative linear distance between shots would be 12.5 m (41 ft). The cumulative duration of airgun operation is anticipated to be no more than 240 hours, which includes equipment testing, ramp-up, line changes, and repeat coverage.

In addition to monitoring for the presence of marine mammals, weather and sea conditions, and visibility, the presence of pack ice that could hinder airgun array and streamer operations would be closely monitored. If researchers encounter situations that pose a risk to the equipment, impede data collection, or require the vessel to stop forward progress, seismic survey equipment would be shut down and retrieved until conditions improve. In general, the airguns and streamer can be retrieved in less than 30 minutes.

Proposed science operations are more difficult to conduct in icy conditions because ice noise degrades the quality of geophysical data. Additionally, time spent breaking ice takes away from available time to conduct the seismic survey. Logistically, if the vessel were in heavy ice, researchers would not tow the airgun and streamer, as this would likely damage equipment and generate noise interference. The exception to this is if an ice-free path opens up behind the vessel, which could be used to conduct research activities without causing issues.

While research activities would attempt to avoid areas of heavy sea ice, icebreaking is expected to be required during the cruise, based on the likely extent of sea ice in the Amundsen Sea region during the January to February period. The NBP may need to break ice along an estimated distance of up to 445 km (277 mi). In moderate ice conditions and based on a ship speed of 9.2 km/hr (5 knots), 445 km (277 mi) represents approximately 48 hours of icebreaking operations. However, because the NBP is not rated to routinely break multi-year ice, operations generally avoid transit through older ice (i.e., two years or older or thicker than 1 m [1.1 yd]). It is anticipated that the NBP would proceed primarily through one-year sea ice (including very thin, new ice) and would follow leads wherever possible. Note that typical transit through areas of primarily open water containing brash or pancake ice is not considered icebreaking.

<u>*Other Acoustic Sources*</u>

Other acoustic sources that could be used during the proposed survey include:

Single Beam Echo Sounder (Knudsen 3260) – The hull-mounted compressed high-intensity radiated pulse (CHIRP) sonar would be operated continuously during all phases of the cruise. This instrument is operated at 12 kilohertz (kHz) for bottom-tracking purposes or at 3.5 kHz in the sub-bottom profiling mode. The sonar emits energy in a 30° beam from the bottom of the ship and has a sound level of 224 dB re: 1 μPa m (rms).

Multibeam Sonar (Kongsberg EM122) – The hull-mounted, multibeam sonar would be operated continuously during the cruise. This instrument operates at a frequency of 12 kHz, has an estimated maximum source energy level of 242 dB re 1μPa (rms), 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 millisecond (ms) pulses.

Acoustic Doppler Current Profiler (ADCP) (Teledyne RDI VM-150) – The hull-mounted ADCP would be operated continuously throughout the cruise. The ADCP operates at a frequency of 150 kHz, with an estimated acoustic output level at the source of 223.6 dB re 1μPa (rms). 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 and it would be continuously operated. The ADCP operates at a frequency of 150 kHz with an estimated acoustic output level at the source of 223.6 dB re 1μPa (rms). Sound energy from the ADCP is emitted as a 30^0 conically-shaped beam.

EK biological echo sounder (Simrad ES200-7C, ES38B, ES-120-7C) – This echo sounder is a split-beam transducer with an estimated acoustic output level at the source of 183-185 dB re 1μPa and emits a 7^0 beam. It can operate at 38 kHz, 120 kHz and 200 kHz.) and would be continuously operated during the cruise.

Vessel Specifications

The USAP RVIB NBP would be used to conduct the proposed seismic survey. The NBP is 93.9 m (308 ft) in length and has a beam of 18.3 m (60 ft) and a design draft of 6.8 m (22.3 ft). It is equipped with four Caterpillar Model 3608 diesel engines (each rated at 3300 brake horsepower (BHP) at 900 revolutions per minute [rpm]) and a water jet azimuthing bow thruster. Electrical power is provided by four Caterpillar 3512, 1050-kW diesel generators. The maximum speed of the NBP is 26.8 km/hr (14.5 knots) and the average speed is 18.7 km/hr (10.1 knots). The cruising speed would be approximately 9.2 km/hr (5 knots), varying between 7.4-11.1 km/hr (4-6 knots) when GI airguns are operating. The NPB operating range is 27,780 km (17,262 mi), which translates to an operating period of approximately 70-75 days.

The NBP would also serve as the platform from which vessel-based protected species observers (PSOs) would watch for marine mammals before and during airgun operations. Characteristics of the vessel that make it suitable for visual monitoring are described in Section 11 and Section 13 of this document. Other details of the NBP include the following:

- Owner: Offshore Vessel Services LLC
- Operator: Galliano Marine Service LLC
- Chartered by: NSF
- Flag: United States of America
- Date Built: 1992
- Gross Tonnage: 5600 metric tons (6174 US tons)
- Accommodation Capacity: 22 crew and 39 scientists
- GI Airgun Compressor: Borsig-LMF Seismic Air Compressors at 34 m^3 min at 140 kg/cm^2 (1200 ft^3/min [cfm] at 2000 lb/in^2 [psi])

2.0 DATE, DURATION, AND SPECIFIED GEOGRAPHICAL REGION

NOAA Fisheries Requirement: The date(s) and duration of such activity and the specified geographical region where it will occur.

The seismic survey would take approximately eight days, beginning on or around 6 February 2020 and end on approximately14 February 2020. In addition to the eight days of seismic surveying, approximately two additional days are scheduled for contingency days, for such events as weather delays, mechanical issues, etc. The NBP would depart from (on/about 25 January) and return to Punta Arenas, Chile with the one-way transit covering approximately 3445 km (1860 nm).

The proposed research would occur in selected regions of the Amundsen Sea located just north (seaward) of the Thwaites Glacier (Figure 1) and focus on the region between 75.25°-73.5°S and 101.0°-108.5°W (as shown on Figure 2). Figure 2 also illustrates the general bathymetry of the study.

3.0 SPECIES AND NUMBERS OF MARINE MAMMALS IN PROJECT AREA

NOAA Fisheries Requirement: The species and numbers of marine mammals likely to be found within the activity area.

3.1 Number of Animals

The Amundsen Sea is biologically active and supports diverse biological resources, including marine mammals, penguins, fish, and macrobenthic communities. The Amundsen Sea and surrounding Southern Ocean is a feeding ground for a variety of marine mammals, including cetaceans (whales) — both baleen (mysticetes) and toothed (odontocetes) — and seals (pinnipeds). Attachment B provides a cross-reference of species names used in this document to their common names.

Population, marine mammal sightings, and density data specific to the Amundsen Sea and South Pacific region were reviewed and compiled to characterize the marine mammals expected to be present during proposed research activities. Attachment C summarizes data sources, observational characteristics associated with sightings, species observed within data sets, correction factors, and population density estimates by data source for cetacean and pinniped species that would be present in the proposed study area. Note that few studies provide comprehensive population data of marine mammal species in this region. Historical sightings data and estimated densities from previous cruises and other research specific to the Amundsen Sea were also reviewed and compiled to provide a more accurate representation of the species that may be encountered in the Amundsen Sea during the proposed activity and to provide quantitative estimates of species population density. Several of the species are considered endangered (Section 3.2).

Following the review of available data (provided in Attachment C), cetacean and pinniped population density estimates considered suitable for the proposed study area and time period (January-February) were selected (Table 2 and Table 3, respectively) for the purposes of estimating acoustic harassment takes. Population density estimates are based on sightings data, but also consider animals that may have been in the water but were not sighted and reported. Based on a previous NOAA-Fisheries authorization (NMFS 2014), a correction factor of five was used where applicable for cetaceans (i.e., assumes that only 20% of animals present were reported). For pinnipeds, sightings data was assumed to account for animals in the water, and a correction factor was not applied.

Table 2. Cetacean Densities in the Amundsen Sea

Common Name	Length Surveyed (km)[mi]	Animals (#)	Animals (# including unidentified)	Corrected Sightings (assume only 20% reported) Note 1	Estimated Linear Density (#/km)[mi]	Half Strip-Width (km)[mi]	Visual Transect Width (km)[mi] Note 2	Areal Density (#/ km²) [# mi²]	Data Source	Year/Season/Area
Low-frequency Cetaceans (baleen whales)										
Blue whale								0.0000510 [0.0000197]	Navy Marine Species Density Database (NMSDD) [3]	
Fin whale								0.0072200 [0.0027877]	NMSDD [3]	
Humpback whale								0.0001000 [0.0000386]	NMSDD [3]	
Minke whale	3494 [2171]	104	104	520	0.1488266 [0.09247656]	0.8 [0.06]	1.6 [0.99]	0.0930166 [0.0359139]	Ainley et al. 2007	Feb 15 to March 31 1994
Sei whale								0.0002550 [0.0000985]	NMSDD [3]	
Mid-frequency Cetaceans (dolphins, toothed whales, beaked whales, bottlenose whales)										
Arnoux's beaked whale								0.0062410 [0.0024097]	NMSDD [3]	
Killer whale								0.0014110 [0.0005448]	NMSDD [3]	
Layard's beaked whale								0.000638 [0.000186]	NMSDD [3]	
Long-finned pilot whale								0.007859 [0.002291]	NMSDD [3]	
Southern bottlenose whale								0.0067570 [0.0026089]	NMSDD [3]	
Sperm whale	Note 4	2	2	Note 5				0.0169934 [0.0065612]	Ainley et al. 2007	Feb 15 to March 31 1994
Gray's beaked whale								0.000281 [0.000082]	NMSDD [3]	
High-frequency Cetaceans (true porpoises, Kogia, river dolphins, cephalorhynchid, Lagenorhynchus cruciger & L. australis)										
(all)								0.000000		

Notes:

[1] Sightings data accounts for all individuals observed in groups; corrected sightings assumes only 20% of animals present were observed and reported.
[2] Visual transect width = half strip-width x 2, representing the total width of observations.
[3] Density values (#/km² [#mi²]) directly from NMSDD; maximum density values during the austral summer for the Amundsen Sea (between 75.25°-73.5°S and 101.0°-108.5°W).
[4] Sightings within the Amundsen Sea region; assumed to represent an area of 315,000 km² (121,622 mi²).
[5] Assume reported number of animals has been corrected in the reference.

Table 3. Pinniped (Phocid) Densities in the Amundsen Sea

Common Name	Area Surveyed (km^2)	Animals (#)[1]	Animals (# including unidentified)	Correction Factor [2]	Estimated # in the Water	Estimated Linear Density (#/km)	Half Strip-Width (km)	Visual Transect Width (km)	Areal Density (#/ km^2)[#/mi^2] [3]	Data Source	Year/Season/Area
Crabeater		2400	2400	1	NA	NA	NA	NA	0.0076190 [0.0029417]	Gohl 2010	January 29-April 5, 2010
Leopard		15	15	1	NA	NA	NA	NA	0.0000476 [0.0000184]	Gohl 2010	January 29-April 5, 2010
Ross		4	4	1	NA	NA	NA	NA	0.0000127 [0.0000049]	Gohl 2010	January 29-April 5, 2010
Weddell		40	40	1	NA	NA	NA	NA	0.0001270 [0.0000490]	Gohl 2010	January 29-April 5, 2010

Notes:

NA = Not Applicable

[1] Assumes reported number of animals accounts for animals in the water, and a correction factor was not applied.

[2] Not applicable for Amundsen Sea pinniped data. Reported numbers provided in the reference include animals swimming near the vessel.

[3] Density values (#/km^2 [#mi^2]) based on sightings within the Amundsen Sea region; assumed to represent an area of 315,000 km^2 (121,622 mi^2).

3.2 Endangered Species

NOAA Fisheries is responsible for listing marine species under the Endangered Species Act (ESA) and implementing conservation and recovery efforts under its Protected Resource Program. ESA listings include species inhabiting the Southern Ocean around Antarctica. The proposed activity has the potential to affect these species. Table 4 presents ESA-listed species occurring in the Southern Ocean and their potential to be present in the Amundsen Sea during implementation of the proposed activity.

Table 4. Status of ESA-Listed Species Occurring in the Southern Ocean

ESA-listed Species	Year Listed	Status [1]	Critical Habitat	Recovery Plan	Potentially Present in the Amundsen Sea
Cetaceans					
Blue whale	1970	E	N/A	Final	✓
Fin whale	1970	E	N/A	Final	✓
Humpback whale	1970	E	N/A	Final	✓
Sei whale	1970	E	N/A	Final	✓
Sperm whale	1970	E	N/A	Final	✓
Pinnipeds					
None identified in the study area.					
Sea Turtles					
None identified in the study area.					

Notes:
[1] **E** = endangered; **F**= foreign species that occur entirely outside of U.S. territory; critical habitat and recovery plans are not required for foreign species; critical habitat is also not required for species listed prior to the 1978 ESA amendments that added critical habitat provisions.
Source: NOAA September 2018. NSF noted that no listed species occur on or near Antarctica or the Southern Ocean according to the published United States Fish and Wildlife (USFWS) listing of foreign species.

A number of marine organisms inhabiting the South Pacific Ocean and adjacent Southern Ocean are included in the International Union for Conservation of Nature (IUCN) "Red List," a comprehensive inventory of the global extinction risk to plant and animal species. The Red List also established criteria to evaluate the extinction risk of thousands of species and subspecies. Table 5 identifies the status of penguin and marine mammal species in the Southern Ocean. No fish or benthic invertebrates in the Southern Ocean are considered endangered in the IUCN Red List.

Additionally, the Convention on International Trade in Endangered Species (CITES) of Wild Fauna and Flora is an international agreement between governments to ensure that international trade in specimens of wild animals and plants does not threaten their survival. CITES protects roughly 5000 species of animals and 29,000 species of plants against over-exploitation through international trade. CITES categorizes these species in three appendices based on the severity and types of threats.

Table 5 lists the IUCN Red List and CITES appendix categorizations for species occurring in the Southern Ocean, as well as the potential for those species to be present in the Amundsen Sea.

Table 5. IUCN Red List and CITES Categorization of Southern Ocean Species

Common Name(s)	Red List Category [1, 2]	CITES [3]	Potentially Present in the Amundsen Sea
Adelie penguin	LC (2018)	--	✓
Chinstrap penguin	LC (2018)	--	
Emperor penguin	NT (2018)	--	✓
Gentoo penguin	LC (2018)	--	
King penguin	LC (2018)	--	
Macaroni penguin	VU (2018)	--	
Northern rockhopper penguin	EN (2018)	--	
Southern rockhopper penguin	VU (2018)	--	
Antarctic minke whale	NT (2018)	App I	✓
Arnoux's beaked whale	DD (2008)	App I	✓
Blue whale, sibbald's rorqual, sulphur-bottom whale	EN (A1abd;2018)	App I	✓
Common dolphin	LC (2008)	App II	
Common rorqual, fin whale, fin-backed whale, finback, finner, herring whale, razorback	VU (A1d) (2018)	App I	✓
Flatheaded bottlenose whale, southern bottlenose whale	LC (2008)	--	✓
Gray's beaked whale, southern beaked whale	DD (2008)	App II	✓
Hector's dolphin	EN (A4d; 2008)	App II	
Hourglass dolphin	LC (2018)	App II	✓
Humpback whale	EN (2008)	App I	✓
Killer whale, orca	DD (2017)	App II	✓
Layard's beaked whale, strap-toothed whale	DD (2008)	App II	✓
Long-finned pilot whale	LC (2018)	App II	✓
Pygmy right whale	LC (2018)	App I	
Sei whale	EN (A1abd; 2018)	App I	✓
Southern right whale	LC (2017)	App I	
Southern right whale dolphin	LC (2018)	App II	
Spectacled porpoise	LC (2018)	App II	
Sperm whale	VU (A1d; 2008)	App I	✓
Antarctic fur seal, Subantarctic fur seal	LC (2014)	App II	
Crabeater seal	LC (2014)	--	✓
Leopard seal	LC (2015)	--	✓
Ross seal	LC (2014)	--	✓
Southern elephant seal	LC (2014)	App II	
Weddell seal	LC (2014)	--	✓

Notes:

[1] All categories listed in this column are from Version 3.1 of the revised IUCN system for classifying species at high risk of global extinction. Version 3.1 was developed in 2001 and is the most recent revision of IUCN classification system.

[2] IUCN Red List Categories: **EX** – Extinct; **EW** - Extinct in the Wild; **CR** - Critically Endangered; **EN** – Endangered; **VU** – Vulnerable; **LR/cd** - Lower Risk/conservation dependent; **NT** - Near Threatened (includes **LR/nt** - Lower Risk/near threatened); **DD** - Data Deficient; **LC** - Least Concern (includes **LR/lc** - Lower Risk, least concern).

"A1d" and "A1abd" represent the following components of the IUCN hierarchy of criteria, which categorizes a species as EN: A. Reduction in population size based on any of the following: 1. An observed, estimated, inferred, or suspected population size reduction of ≥ 70% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are clearly reversible AND understood AND ceased, based on (and specifying) any of the following: (a) direct observation, (b) an index of abundance appropriate to the taxon, (c) a decline in area of occupancy, extent of occurrence, and/or quality of habitat, (d) actual or potential levels of exploitation, and (e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

"A4d" represent the following components of the IUCN hierarchy of criteria used to categorize a species as EN: A. Reduction in population size based on any of the following: An observed, estimated, inferred, projected or suspected population size reduction of ≥ 80% over any 10 year or three generation period, whichever is longer (up to a maximum of 100 years in the future), where the time period must include both the past and the future and where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1. (http://www.iucnredlist.org/static/categories_criteria_3_1)

[3] CITES = Convention on International Trade in Endangered Species of Wild Fauna and Flora (www.cites.org). APP = Appendix. Appendix I includes species threatened with extinction. Appendix II includes species not necessarily threatened with extinction but in which trade must be controlled to avoid utilization incompatible with their survival.

3.3 Protected Area Status

The Amundsen Sea region is not currently designated a marine protected area. The proposed project area is within the region administered by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), on the boundary of subarea 88.2 and 88.3. The Commission's decisions establish the regulatory framework applied to managing each fishery in the Convention Area.

4.0 AFFECTED SPECIES STATUS AND DISTRIBUTION

NOAA Fisheries Requirement: A description of the status, distribution, and seasonal distribution of the affected species or stocks of marine mammals likely to be affected by such activities.

4.1 Cetaceans

Low-frequency Cetaceans (Mysticetes)

The following provides general information on mysticetes that may feed or migrate in the study area and may be present during the proposed activity (Table 2 and Table 3). Generally, the functional hearing for low-frequency cetaceans (mysticetes) is estimated to occur between approximately 7 Hz and 35 kHz (NMFS 2018).

Blue Whale/Pygmy Blue Whale

The Antarctic blue whale (*Balaenoptera musculus intermedia*) occurs as a subspecies in the Antarctic, mainly in relatively high latitudes south of the "Antarctic Convergence" and close to the ice edge. It is relatively rare in the Southern Ocean, with abundance estimates of 1700 animals (Perrin et al. 2009) and 1150 to 4500 animals (International Whaling Commission [IWC] 2019). The population structure of the Antarctic blue whale in the Southern Ocean is not well understood. Blue whales arrive in Antarctic feeding grounds each austral summer, and some may migrate past 60°S early in the austral summer (October-November). Visual and acoustic surveys in Antarctic waters conducted in 2002 by the IWC recorded 710 blue whale calls in January and 2559 calls in February. More recently, several individuals were observed in the Amundsen Sea during transects conducted by the *Polarstern* (Gohl 2010). Blue whales begin migrating north out of the Antarctic to winter breeding grounds earlier than fin and sei whales.

The pygmy blue whale (*Balaenoptera musculus brevicauda*) is also found in the Southern Hemisphere, typically north of the Antarctic Convergence, at approximately 55°S.

Fin Whale

Fin whales (*Balaenoptera physalus*) are found throughout the world's oceans, with a world-wide population ranging between 85,200 and 119,000 animals (Boyd 2002). They likely migrate beyond 60°S during the early to mid-austral summer, arriving at southern feeding grounds after blue whales. During the austral summer, the distribution of fin whales ranges from 40°S-60°S in the southern Indian and South Atlantic oceans and 50°S-65°S in the South Pacific. The *Polarstern* observed 33 fin whales in the Amundsen Sea during transects (Gohl 2010). The New Zealand stock of fin whales spends summers from 170°E-145°W. Fin whales migrate north before the end of the austral summer toward breeding grounds in and around the Fiji Sea. NOAA-Fisheries used an estimated population of 1735 animals south of 60°S (NOAA 2015).

Humpback Whale

The humpback whale (*Megaptera novaeangliae*) is found in all ocean basins and 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 (LGL 2019). Although considered to be mainly a coastal species, it often traverses deep pelagic areas while migrating.

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All Southern Hemisphere humpback whales share feeding grounds in the Antarctic, near 60°S and between 120°E and 110°W during the austral summer (December-March). The *Polarstern* observed 44 humpback whales in the Amundsen Sea during transects (Gohl 2010). The population in the southern hemisphere is estimated to range between 34,000 and 52,000 animals (IWC 2019). NOAA-Fisheries used an estimated population of 42,000 animals south of 60°S (NOAA 2015).

Minke Whales (Antarctic Minke, Dwarf Minke)

Two species of minke whales are found in the Southern Hemisphere: the Antarctic minke (*Balaenoptera bonaerensis*) and the dwarf minke (*Balaenoptera acutorostrata*). In the southern Atlantic Ocean, the Antarctic minke whale is usually found between 20°S-65°S and has been reported as far south as 78°S in the Ross Sea during the austral summer.

Antarctic minke whales begin their southern migration from northern breeding grounds in November (austral spring) and arrive in Antarctic feeding grounds by January (early summer), where they are abundant from 60°S to the edge of the pack ice. During a research cruise, the *Polarstern* observed 135 individuals in the Amundsen Sea (Gohl 2010). The southern hemisphere population estimate ranges from 360,000 to 730,000 animals (IWC 2019).

Dwarf minke whales have a circumpolar distribution in the Southern Hemisphere (reported as far south as 60°S-65°S), especially during the summer months, overlapping that of the Antarctic minke, but are more common in temperate and warmer waters of middle and lower latitudes.

Sei Whale

The sei whale (*Balaenoptera borealis*) occurs in all ocean basins, predominantly inhabiting deep water throughout its range (LGL 2019). It undertakes seasonal migrations to feed in sub-polar latitudes during the summer, returning to lower latitudes during winter to calve. In the Southern Hemisphere, sei whales typically concentrate between the Subtropical and Antarctic convergences during the summer between 40ºS and 50ºS; larger, older whales typically travel into the northern Antarctic zone while smaller, younger individuals remain in the lower latitudes (Acevedo et al. 2017). Boyd (2002) estimated the world-wide population to be approximately 10,000 animals. NOAA-Fisheries used an estimated population of 626 animals south of 60°S (NOAA 2015).

Populations of sei whales may migrate seasonally — toward lower latitudes in the winter and higher latitudes in the summer. No population estimates are available for the Amundsen Sea region.

Mid-frequency cetaceans (Odontocetes)

The following provides general information on odontocetes that may feed or migrate in the study area and may be present during the proposed activity. Certain species of odontocetes have a stratified distribution within the Southern Ocean relative to the polar front and edge of the pack ice. In generally, the functional hearing for mid-frequency cetaceans (odontocetes) is estimated to occur between approximately 150 Hz and 160 kHz (NMFS 2018).

Arnoux's Beaked Whale

Arnoux's beaked whales (*Berardius arnuxii*) inhabit vast areas of the Southern Hemisphere outside the tropics, as far south as the Ross Sea at approximately 78°S (Perrin et al. 2009). The world-wide population of all beaked whales south of the Antarctic Convergence is estimated at approximately 599,300 animals (Kasamatsu and Joyce 1995). Habitat preferences are not well known but are likely similar to those of Baird's beaked whales, which prefer deep waters over the continental slopes. Arnoux's beaked whales feed primarily on deep-water bottom fish. This species has been sighted in waters near New Zealand and Antarctica during January-March. Twelve individuals were observed during a research cruise conducted by the *Polarstern* (Gohl 2010).

Killer Whales

Orca or killer whales (*Orcinus orca*) are present in all oceans and are commonly found in coastal and temperate waters of high productivity. It is estimated that 25,000 killer whales are found in the Southern Ocean (Perrin et al. 2009), although other estimates indicate a total of 80,000 animals south of the Antarctic Convergence (Perrin et al. 2009; Jefferson et al. 2008).

Layard's Beaked Whale (Strap-toothed Whale)

Layard's beaked whale (*Mesoplodon layardii*), also known as the strap-toothed whale due to its unusual tooth configuration, is distributed in cool temperate waters of the Southern Hemisphere between 30°S and the Antarctic Convergence. There have been reports of strandings of this species from New Zealand, Australia, southern Argentina, Tierra del Fuego, southern Chile, and the Falkland Islands. The world-wide population of all beaked whales south of the Antarctic Convergence is estimated at approximately 599,300 animals (Kasamatsu and Joyce 1995).

Long-finned Pilot Whales

Millions of long-finned pilot whales (*Globicephala melas*) are found throughout the mid-latitude waters of the North Atlantic and Southern Hemisphere. They are pelagic, feeding on squid and some fish.

In the Southern Hemisphere, the range of long-finned pilot whales extends from 19°S-60°S, but they are sighted regularly in the Antarctic Convergence zone (47°S-62°S) and in the Central and South Pacific, as far south as 68°S. Their distribution is considered circumpolar, and they have been documented near the Antarctic sea ice. In the Southern Hemisphere, there are an estimated 200,000 long-finned pilot whales in Antarctic waters (NOAA 2018).

Southern Bottlenose Whale

The southern bottlenose whale (*Hyperoodon planifrons*) is a large, robust, beaked whale distinguished by its large, bulbous forehead and short, dolphin-like beak (Perrin et al. 2009). It can be 6-9 m (20-29 ft) long. The southern bottlenose whale has a circumpolar distribution in the Southern Ocean, from ice edges to 30°S. There is no information on population status, trends, or known areas of concentration in the

Southern Hemisphere, but it is estimated that 500,000 animals are found south of the Antarctic Convergence (Jefferson et al. 2008).

Sperm Whales

The sperm whale (*Physeter macrocephalus*) is widely distributed, occurring from the edge of the polar pack ice to the Equator in both hemispheres, with the sexes occupying different distributions (LGL 2019). Sperm whales, consisting of solitary males and mixed sex/age classes, are likely to occur in the Southern Ocean during the austral summer. Young calves could also be present at this time. The world-wide population is estimated at 300,000 to 450,000 animals, with approximately 12,000 estimated south of 60°S (Whitehead 2002). Female and immature sperm whales generally occur at tropical and temperate latitudes of 50°N to 50°S, while solitary adult males are found from 75°N to 75°S. Home ranges of individual females span distances of up to 1000 km (621 mi). However, some females travel several thousand miles across large parts of an ocean basin. Sperm whales generally occur in waters more than 180 m (590 ft) deep; waters in the sub-Antarctic to the Antarctic coastal shelf are more than 1000 m (3281) deep. During a 1994 survey covering 3500 km (2175 mi), a total of 19 individuals were observed (Ainley et al. 2007). NOAA-Fisheries used an estimated population of 12,069 animals south of 60°S (NOAA 2015).

Gray's Beaked Whale

Gray's beaked whale (*Mesoplodon grayi*), also known as Haast's beaked whale, the scamperdown whale, or the southern beaked whale, typically lives in the Southern Hemisphere, between 30°S-45°S. Numerous strandings have occurred off New Zealand; others have occurred off South America and the Falkland Islands. This species has been sighted in groups in the Antarctic area. However, they would likely not be present as far south as the Amundsen Sea. No abundance estimates are available.

High-frequency cetaceans (Odontocetes)

No high-frequency cetacean sightings have been documented south of 60°S, near the study area. Therefore, no high-frequency species are expected to be present in the Amundsen Sea during the proposed activity.

4.2 Pinnipeds

Six species of seals live in the Southern Ocean, and five of these species are expected to be present in the Amundsen Sea study area. These six species belong to two families. The first is the Phocidae family, or true seals, of which there are five Antarctic species expected in the Amundsen Sea: the crabeater, leopard, Weddell, elephant, and Ross seals. The second is the Otariidae family, or eared seals, which includes the Antarctic fur seal. For the phocids, functional hearing in water is estimated to occur between approximately 50 Hz and 86 kHz (NMFS 2018).

Crabeater Seals

Crabeater seals (*Lobodon carcinophaga*) are found throughout Antarctica but are almost never spotted on land because they breed and rest on pack ice. Crabeaters account for over half of the world's seal population. Worldwide population estimates have ranged widely, but a reasonable range is 5-15 million (Perrin et al. 2009). Crabeater seals have a circumpolar Antarctic distribution, spending the entire year in the pack ice zone. They can occasionally be found along the southern fringes of South America (Perrin et al. 2009). Crabeaters migrate over large distances in association with the annual advance and retreat of pack ice, and it is typical to find higher densities of crabeater seals over and at the edge of the continental shelf as well as in the marginal ice zone. During a research cruise conducted by the *Polarstern*, 2400 individuals were observed in the Amundsen Sea (Gohl 2010).

“Crabeater” is actually a misnomer, as 90% of this seal's diet is krill. Female crabeaters can reach 2.5 m (8.2 ft) and weigh 225 kg (4905 lb), while males are smaller. Crabeater seals sometimes congregate in large groups.

Leopard Seals

The leopard seal’s (*Hydrurga leptonyx*) name comes from its spotted coat. Leopard seals hunt and travel alone on the northern edge of the pack ice and move north to the Sub-Antarctic islands in the austral winter. The strong jaws and highly developed teeth of leopard seals allow them to consume a variety of prey, including krill, fish, cephalopods, penguins, seabirds, and seals (Kooyman 1981a). Female leopard seals measure about 3 m (11.5 ft) in length and weigh, on average, 540 kg (1190 lb). Males are smaller.

Leopard seals breed on the outer fringes of pack ice, and acoustics play an important role; they become highly vocal before and during breeding. Mating occurs in December and early January (Perrin et al. 2009) and females give birth during the following October to mid-November. Lactation lasts about four weeks.

There are no systematic, large-scale population census studies for this species, but population estimates range between 220,000 and 440,000 animals (Jefferson et al. 2008; Perrin et al. 2009). Population densities are greatest in areas of abundant cake ice and lowest in areas with larger floes; densities range from 0.003-0.051 seals/km^2 (0.001-0.019 mi^2) (Perrin et al. 2009). Fifteen leopard seals were observed in the Amundsen Sea during transects conducted by the *Polarstern* (Gohl 2010).

Ross Seals

Ross seals (*Ommatophoca rossii*) are considered the rarest of all Antarctic seals. They are the least documented because they are infrequently observed. Ross seals have a short snout, big eyes, long flippers, and hooked teeth. While widely distributed, they are generally solitary (Costas and Crocker 1996). Ross seals breed on pack ice in the austral spring and early austral summer and feed on squid, fish, and krill. They are in open water from late summer through the austral winter. Single seals are observed on occasion in the South Sandwich and South Orkney Islands (Perrin et al. 2009). Their population is estimated from 20,000-50,000 up to 220,000 individuals (Scheffer 1958; Erikson et al. 1971). Ross seals are the smallest of the five species of true seals in the Antarctic. The females grow to approximately 2 m (7 ft) and weigh 185 kg (408 lb). Males are slightly smaller. There are no estimates available for Ross seal populations in the Amundsen Sea, but four individuals were observed during transects conducted by the *Polarstern* (Gohl 2010).

Weddell Seals

The Weddell seal (*Leptonychotes weddellii*) has a circumpolar distribution around Antarctica, preferring land-fast ice habitats that have access to open water. These seals haul-out through cracks in the ice. Their range is farther south than that of all other Antarctic seals. Occasionally, Weddell seals are seen at sub-Antarctic islands (Perrin et al. 2009).

There have been no systematic, large-scale population census studies, but it is known that the Weddell seal is abundant, with the estimated number of seals ranging from 500,000 to one million (Perrin et al. 2009). Forty Weddell seals were observed in the Amundsen Sea during transects conducted by the *Polarstern* (Gohl 2010).

Since they do not migrate north, adult Weddell seals live under the vast coating of sea ice during the coldest months and maintain breathing holes open by reaming them with their canine and incisor teeth, which are robust and project forward (Kooyman 1981b). They may suffer shortened lives due to damage sustained by their teeth and gums. The females can grow longer than three meters and weigh nearly 450 kg (992 lb). The seal's black fur with grayish-silver streaks covers its entire body, except for a small portion of the underside of the fore and hind flippers; they do not have an under-fur.

Weddell seals breed and pup on fast ice, while mating takes place in the water. Males establish underwater territories and exhibit a variation of harem defense polygamy (Kooyman 1981b; Perrin et al. 2009). While patrolling, males use loud trills (up to 193 dB re 1 μPa) to advertise and defend their underwater territories (Perrin et al. 2009). Females give birth on fast ice in late September to early November.

The diet of Weddell seals includes Antarctic toothfish (*Dissostichus mawsoni*) and smaller fish, mainly Antarctic silverfish (*Pleuragramma antarctica*), as well as squid and krill. They forage in the upper water column, but may dive to 600 m (1968 ft) for up to 82 minutes, although shallow dives are more typical (Kooyman 1981b; Perrin et al. 2009). Weddell seals may range out to five km (3.1 mi) from a breathing hole and return on a single dive. Type B or "pack ice" ecotype killer whales are known to consume Weddell seals off the western Antarctic Peninsula (Pitman and Durban 2012).

5.0 REQUESTED TYPE OF INCIDENTAL TAKE AUTHORIZATION

NOAA Fisheries Requirement: 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 Office of Polar Programs (OPP) requests an incidental harassment authorization (IHA) pursuant to Section 101(a)(5)(D) of the Marine Mammal Protection Act (MMPA) for incidental take by harassment for its planned 8-day seismic survey in the Amundsen Sea in 2020.

As described in Section 2, some of the activities associated with the Proposed Action may have the potential to "take" marine mammals by harassment. Takes by harassment may result when marine mammals near the activities are exposed to, and behaviorally disturbed by, pulsed sounds generated from the airguns during seismic surveying. Potential impacts may depend on the species of marine mammal, the behavior of the animal at the time of exposure to the acoustic source, the received sound level (Section 7), and environmental conditions in the proposed study areas. Marine mammals in the general vicinity of seismic surveying track lines may display disturbance reactions to the airguns (Level B Harassment). Although only Level B harassment would be anticipated given the proposed activities, NMFS requires that Level A takes also be estimated and requested. In addition, "take authorization" is being requested for icebreaking operations, as provided in Attachment D.

No takes or injury by physical strike or entanglement are anticipated, given the proposed activities (e.g., slow moving vessel and use of PSOs) and implementation of mitigating measures that would occur during the seismic survey.

6.0 TAKE ESTIMATES FOR MARINE MAMMALS

NOAA Fisheries Requirement: **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 paragraph (a)(5) of this section and the number of times such takings by each type of taking are likely to occur.**

Detailed data characterizing the age, sex, and reproductive condition for marine mammals in the Amundsen Sea is extremely limited. Available information for marine mammal species potentially present in the study area is presented in Section 4.0. Due to the use of low-energy acoustic sources, all potential takes due to the proposed activity would be anticipated as "takes by harassment" that involve temporary changes in behavior (Level B). The mitigation measures to be applied (Section 11) would further minimize the possibility of injurious takes (Level A). Although only Level B harassment would be anticipated given the proposed activities, NMFS requires that Level A takes also be estimated and requested. The following paragraphs describe methods to estimate the number of potential exposures to various received sound levels. The density of marine mammals expected to be present in the Amundsen Sea region are based on data from visual surveys conducted in the region.

Potential Number of Marine Mammals Exposed

Level A and B takes were estimated for the proposed survey. The methodology followed to calculate the Level B takes was the daily ensonified methodology required by NMFS for previous similar seismic surveys (LGL 2019). The thresholds and dual criteria established in the NMFS 2018 revision to *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* (Version 2.0) was followed to calculate Level A takes. Per the 2018 guidance, Level A calculations took into consideration the various marine mammal functional hearing groups (e.g., low-, mid- and high-frequency). Calculation results for Level A and B takes conservatively assume that all animals sighted within these zones would be exposed to sound levels larger than or equal to the respective Level A and B thresholds, resulting in takes. Because of the uncertainty of the source level needed to be used during operations due to potentially poor environmental conditions, predicted distances determined for the largest airgun array (2 x 105/105 in^3) (Attachment A) were used to calculate takes for the Proposed Action. Although this is a conservative approach, the differences among the predicted distances of the other proposed source levels are nominal.

Table 6 presents the predicted distances to the 160 re $1\mu Pa_{rms}$ isopleth (Level B threshold), by water depth, based on modeling conducted by Lamont-Doherty Earth Observatory for this application (Attachment A). The majority of the proposed seismic survey (65%) would be conducted in waters between 100-1000 m (328-3280 ft) deep. As noted previously, the daily ensonified methodology was used to calculate Level B takes. This methodology involved picking a survey trackline that would be conducted on a typical operational day, with proportions occurring in intermediate and deep water (approximately 160 km or 99.4 nm per day) representative of the full survey. The area of ensonification for one day of survey effort was determined by using the predicted radii for the largest airgun array (2 x 105/105 in^3) multiplied by 2 (for the diameter around the survey trackline) multiplied by the survey tracklength estimated for one day of 160 km (99.4 mi). The ensonified area was then multiplied by the number of proposed survey days (eight days). To account for survey contingency (e.g., poor weather, mechanical issues, etc.), an additional 25% was included in the take estimate calculation through an increase in the number of survey days (8 days x 1.25 days = 10 days).

Per the 2018 NMFS Technical Guidance (NMFS 2018), determining the exclusion zone (EZ) is based on the dual criteria of either cumulative sound exposure level for permanent hearing impairment (PTS; SELcumPTS) or Peak (SPLflat) that would result in injury (Level A take). Table 7 presents the proposed EZs for each marine mammal hearing group, which are based on LDEO modeling incorporated into the companion user spreadsheet (NMFS 2018). Table 6 also presents the mitigation zone (MZ), which is based on modeling conducted by Lamont-Doherty Earth Observatory for this application (Attachment A). The Level A and Level B take estimates for the proposed survey are shown in Table 8.

Table 6. Level B - Predicted Distances to the Level B Threshold (160 re 1µPa$_{rms}$ isopleths)

Source and volume (cm[3])[in[3]]	Tow depth (m)[ft]	Water depth (m)[ft] [1]	Predicted 160 re 1µPa$_{rms}$ (m)[ft] isopleth[2]
2 x 45/105 in^3 (300 in^3) GI guns	3 [9.8]	100-1000 [328-3280]	979 [3211]
		>1000 [>3280]	653 [2142]
1 x 45/105 in^3 (150 in^3) GI guns	3 [9.8]	100-1000 [328-3280]	503 [1650]
		>1000 [>3280]	335 [1099]
2 x 105/105 in^3 (420 in^3) GI guns	3 [9.8]	100-1000 [328-3280]	1044 [3425]
		>1000 [>3280]	696 [2283]
1 x 105/105 in^3 (210 in^3) GI guns	3 [9.8]	100-1000 [328-3280]	531 [1742]
		>1000 [>3280]	354 [1161]

Notes:

[1] No seismic operations would be conducted in shallow depths (0-100 m [0-328 ft]).

[2] RMS radii is based on LDEO modeling and empirical measurements. Radii for 100-1000 m (328-3280 ft) depth values = deep water values * 1.5 correction factor.

Table 7. Predicted distances to the Level A threshold for Marine Mammals

Hearing Group	SEL Cumulative PTS Threshold (dB) [1]	SEL Cumulative PTS Distance (m)[ft] [1]	Peak PTS Threshold (dB) [1]	Peak PTS Distance (m)[ft] [1]	Proposed EZ[2] for all depths (m)[ft]
Low-frequency cetaceans	183	31.1 [102]	219	7.55 [24.8]	31.1 [102]
Mid-frequency cetaceans	185	0.0	230	1.58 [5.2]	1.58 [5.2]
Phocid pinnipeds	185	0.3 [0.98]	218	8.47 [27.8]	8.47 [27.8]

Notes:

[1] Cumulative sound exposure level for PTS (SEL$_{cum}$PTS) or Peak (SPLflat) resulting in Level A harassment (i.e., injury). Based on 2018 NMFS Acoustic Technical Guidance (NMFS 2018).

[2] Per NMFS Acoustic Technical Guidance (NMFS 2018), the larger of the dual criteria results are used for the EZ

Table 8 summarizes the estimated density of cetaceans and pinnipeds that would be exposed to underwater sounds during the seismic survey. Information in Table 8 is based on the daily ensonified methodology required by NMFS.

Table 8. Densities and Estimates of the Possible Numbers of Individuals that could be Exposed to Level A and Level B Thresholds for Species

Common Name	Areal Density (No. /km^2 [No. / mi^2]	Estimated Level A Harassment/Take (No. of animals) [1]	Estimated Level B Harassment/Take (No. of animals) [2]	Requested Take Authorization (=Level A + Level B takes being requested)[3]	Species Population Estimate[4]	Level A + Level B as % of Population
Low-frequency Cetaceans (baleen whales)						
Blue whale	0.0000510 [0.0000197]	1	1	2	1700	0.118
Fin whale	0.0072200 [0.0027877]	1	21	22	1735	1.268
Humpback whale	0.0001000 [0.0000386]	1	1	2	42,000	0.005
Minke whale	0.0930166 [0.0359139]	10	266	276	360,000	0.077
Sei whale	0.0002550 [0.0000985]	1	1	2	626	0.319
Mid-frequency Cetaceans (dolphins, toothed whales, beaked whales, bottlenose whales)						
Arnoux's beaked whale	0.0062410 [0.0024097]	1	19	20	599,300	0.003
Killer whale	0.0014110 [0.0005448]	1	5	6	80,000	0.008
Layard's beaked whale	0.000638 [0.000186]	1	2	3	599,300	0.001
Long-finned pilot whale	0.007859 [0.002291]	1	24	25	200,000	0.013
Southern bottlenose whale	0.0067570 [0.0026089]	1	20	21	500,000	0.004
Sperm whale	0.0169934 [0.0065612]	1	51	52	12,069	0.431
Gray’s beaked whale	0.000281 [0.000082]	1	1	2	599,300	0.0003
Pinnipeds (Phocids)						
Crabeater seal	0.0076190 [0.0029417]	1	23	24	5,000,000	0.0005
Leopard seal	0.0000476 [0.0000184]	1	1	2	220,000	0.001
Ross seal	0.0000127 [0.0000049]	1	1	2	20.000	0.010
Weddell seal	0.0001270 [0.0000490]	1	1	2	500,000	0.0004

Note:
[1] Daily ensonified methodology = estimated species density multiplied by the one day survey effort of 160 km (99.4 mi) x the larger value of SEL Cumulative or Peak thresholds from Table 7
[2] Daily ensonified methodology = estimated species density multiplied by the one day survey effort of 160 km (99.4 mi)) x area ensonified to 160 dB (rms) x number of survey days increased by 25% [10 days]).
[3] Requested Level A and Level B takes (used by NMFS as proxy for number of individuals exposed) expressed as % of population (see Section 4 text).
[4] Population estimates are provided in Section 4

Densities used to estimate acoustic harassment takes do not account for patchy distributions of marine mammals in an ecosystem, at least on the moderate to fine scales over which they are known to occur. Instead, animals are considered evenly distributed throughout the assessed area, and seasonal movement patterns and sea ice extent are not taken into account.

Estimated takes represent less than one percent of the populations (Table 8 and Section 4.1) for each species with the exception of fin whales (1.3% of the population) and are within the small number of takes defined by the MMPA. For mysticetes, auditory impairment or other non-auditory physical effects (Level A exposures) would be unlikely and limited to exposures within short distances from the acoustic sources, since this group of whales typically avoids seismic vessels (Richardson et al. 1995). Level B disturbances may occur, but are not expected to result in long-term or significant consequences to disturbed individuals or their populations. No exposures resulting in injury or mortality are expected. As noted previously, however, NMFS requires Level A take to be estimated and requested.

Odontocetes display variable reactions to seismic surveys, such as disruption of foraging, but can be generally tolerant; therefore, short-term, Level B exposures may occur. Injuries may occur at a received level from a single seismic pulse. However, similar to mysticetes, potential injuries (Level A exposures) are not likely due to behavioral avoidance.

Several cetacean species that may be taken during the proposed activity (including sei, fin, blue, humpback, and sperm whales) are listed as endangered under the ESA. The number of possible exposures may include repeated exposures of the same individuals; however, these would be minimal over the short duration of the survey (approximately 240 hours). It is also unlikely that a particular animal would remain in the vicinity of the ship for the entire cruise. In addition, monitoring and mitigating measures that would be used to protect marine mammals during the seismic survey include immediately shutting down the airguns if an animal (including species protected under the ESA and MMPA) is observed in or entering the EZ (and would result in a Level A exposure).

Based on the wide distribution of pinnipeds in the Southern Ocean (with over one million crabeater seals alone), the estimated number of takes would affect less than one percent of the Southern Ocean populations (see Section 4.2) for each pinniped species and would be within the small number of takes defined by the MMPA. The effects of exposure are expected to be limited to behavioral disturbance, including localized avoidance of the area near active airguns.

Possible Effects of Multibeam Echo Sounder (MBES) and Single Beam Echo Sounder (Sub-bottom Profiler [SBP]) Signals

During simultaneous operation of the airgun array and other acoustic sources, it is assumed that any marine mammals close enough to be affected by the MBES and SBP would have already sensed the acoustic releases from airguns and responded accordingly. However, whether or not airguns are operating simultaneously with other acoustic sources, marine mammals are expected to exhibit no more than short-term and inconsequential responses to MBES and SBP, given the characteristics of such devices (*e.g.*, narrow, downward-directed beam) and other considerations described in Sections 3.6.4.3, 3.7.4.3, 3.8.4.3, and Appendix E of the PEIS. Such reactions are not considered "taking" (NMFS 2001).

Conclusions

The proposed seismic survey would involve towing an airgun array that introduces pulsed sounds into the marine environment. The survey would employ a one or two airgun array, with the total airgun discharge volume no more than 3441 cm^3 (210 in^3). Routine vessel operations, other than the proposed airgun operations, are conventionally assumed to not affect marine mammals sufficiently to constitute "taking."

In this IHA application, estimates of the numbers of marine mammals that could be exposed to low-energy airgun sounds during the proposed research activities have been presented, together with the requested "take authorization." In addition, "take authorization" is requested for icebreaking operations in Attachment D. Note that the proposed seismic survey activities and icebreaking operations would not occur simultaneously. Because of limited, site-specific, quantitative population density data, sightings reported during previous research cruises and conservative correction factors were used to estimate the number of takes. It is likely the estimated number of cetacean and pinniped takes overestimate the actual number of animals that would be exposed and react to seismic sounds, as many pinnipeds may not be in the water and marine mammals likely would leave the affected area when a disturbance is first recognized. The relatively short-term exposures that may occur would be unlikely to result in any long-term, negative consequences for the individuals or their populations.

No "taking" of marine mammals is expected in association with the other acoustic sources proposed during operations, given the considerations discussed in Section 3.6.4.3, 3.7.4.3, 3.8.4.3 and Appendix E of the PEIS.

7.0 ANTICIPATED IMPACT OF THE ACTIVITY

NOAA Fisheries Requirement: The anticipated impact of the activity upon the species or stock of marine mammal.

Summary of Potential Effects of Airgun Sounds

The effects of sounds from airguns could include one or more of the following:

- tolerance,
- masking of natural sounds,
- behavioral disturbance, and
- temporary or permanent hearing impairment or non-auditory physical or physiological effects (Richardson et al. 1995; Erbe 2012; Peng et al. 2015; Erbe et al. 2016; Kunc et al. 2016; National Academies of Sciences, Engineering, and Medicine 2017; NMFS 2018).

In the unlikely event that it occurs, PTS would constitute injury, but temporary threshold shift (TTS) is not an injury (Le Prell 2012; NMFS 2018). Rather, the onset of TTS has been considered an indicator that, if the animal is exposed to higher levels of that sound, physical damage is ultimately a possibility. However, research has shown that sound exposure can cause cochlear neural degeneration, even when threshold shifts and hair cell damage are reversible (Kujawa and Liberman 2009; Liberman 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.

A portion of the following description of potential effects from airgun acoustic releases is derived from information contained in the *Draft Environmental Analysis of Low-Energy Marine Geophysical Surveys by R/V Thomas G. Thompson in the South Atlantic Ocean, November–December 2019*, prepared by LGL Ltd., (LGL 2019), which references marine mammals in other areas of the world's oceans.

Tolerance

Numerous studies show that pulsed sounds from airguns are readily detectable in the water at distances of many kilometers (e.g., Nieukirk et al. 2012). Several studies indicate that marine mammals at distances more than a few kilometers from operating seismic vessels often show no apparent response. That is 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 mysticetes, odontocetes, and (less frequently) pinnipeds have been shown to react behaviorally to airgun pulses under some conditions, at other times mammals of all three types have shown no overt reactions. The relative responsiveness of whales is quite variable.

Masking

The 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 is very little, specific data on masking. The proposed airguns for the seismic survey have dominant frequency components of 2-188 Hz. This frequency range fully overlaps the lower part of the frequency range of odontocete calls and/or functional hearing (a full range of about 150 Hz-180 kHz). Airguns also produce a small proportion of their sound at mid- and high frequencies, which overlap most (if not all) frequencies produced by odontocetes. While it is assumed that all mysticetes can detect acoustic impulses from airguns and vessel sounds, such impulses would likely be detectable only by some mysticetes, based on presumed mysticete hearing sensitivity (Richardson et al. 1995). A more comprehensive review of relevant background information for odontocetes appears in Section 3.6.4.3, Section 3.7.4.3, and Appendix E of the PEIS.

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 for the entire interval between pulses, which could mask calls (Simard et al. 2005; Clark and Gagnon 2006). 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 the 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 the dominant components of airgun sounds, thus limiting the potential for masking. In general, the masking effects of seismic pulses on cetaceans are expected to be minor, given the normally intermittent nature of the pulses.

Sills et al. (2017) reported that recorded airgun sounds masked the detection of low-frequency sounds by ringed and spotted seals, especially at the onset of the airgun pulse when signal amplitude was variable. We are not aware of any information concerning masking of hearing in sea turtles.

Disturbance Reactions

Disturbance includes a variety of effects, including displacement and subtle to conspicuous changes in behavior and movement. Exposure to sound, or brief reactions that do not disrupt behavioral patterns in a potentially significant manner, do not constitute harassment or "taking" and would not have deleterious effects on the well-being of individual marine mammals or their populations (NMFS 2001; NRC 2005; Southall et al. 2007).

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) depends 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, impacts of the change are unlikely to be significant to the individual, let alone the stock or population. 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. 2013; Nowacek et al. 2015; Forney et al. 2017).

Given the many uncertainties in predicting the quantity and types of impacts of sound on marine mammals, and the lack of abundance estimates and population trend data for marine mammals in the Southern Hemisphere, the conservative approach used in this application is to estimate how many marine mammals would be encountered and/or exposed to the acoustic outputs generated by the seismic source during the 240-hour survey period. This approach likely overestimates the numbers of marine mammals that would be affected in a biologically important manner.

The criteria used to estimate how many marine mammals might be disturbed to some biologically important degree by a seismic program is based primarily on behavioral observations of a few species. Detailed studies have been completed on humpback, gray, bowhead, and sperm whales, and less detailed data are available for other whale species, but for many species there are no data on responses to marine seismic surveys.

A description of observed reactions to disturbances for different types of marine mammals is presented below.

Mysticetes - These whales tend to avoid operating airguns, but avoidance radii are quite variable. Whales are reported to show no overt reactions to pulses from large arrays of airguns at distances beyond a few kilometers, even though airgun pulses remain well above ambient noise levels out to much greater distances. However, mysticetes exposed to strong noise pulses from airguns often react by deviating from their normal migration route and/or interrupting feeding and moving away. In the cases of migrating gray and bowhead whales, 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 stayed within the natural boundaries of migration corridors.

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 in Brazilian wintering grounds. Off the coast of western Australia, avoidance reactions began at 5-8 km (3.1-

4.9 mi) from the array. Those reactions kept most pods at about 3-4 km (1.9-2.5 mi) from the seismic vessel. There was localized displacement during migration of 4-5 km (2.5-3.1 mi) by traveling pods and 7-12 km (4.3-7.5 mi) by more sensitive, resting pods of cow-calf pairs. However, some individual humpback whales, especially males, approached to within of 100-400 m (328-1312 ft) of the array.

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 did not cause humpbacks to move away from the vessel more than 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; 2016b). 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 to 170 dB re 1 $\mu Pa^2 \cdot s$ (Dunlop et al. 2018).

In the Northwest Atlantic, sighting rates were significantly greater during non-seismic periods compared with periods when a full array was operating. Humpback whales were observed to be more likely to swim away and less likely to swim towards a vessel during seismic operations, as opposed to non-seismic periods. On their summer feeding grounds in southeast Alaska, there was no clear evidence of avoidance, despite the possibility of subtle effects, at received levels up to 172 re 1 µPa on an approximate rms basis. Research suggests that South Atlantic humpback whales wintering off Brazil may be displaced or even stranded upon exposure to seismic surveys (Engel et al. 2004), but data from subsequent years indicated that there was no direct, observable correlation between stranding and seismic surveys (IWC 2007).

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 (12.4-18.6 mi) from a medium-sized airgun source. However, recent research on bowhead whales corroborates earlier evidence that, during the summer feeding season, bowheads are not as sensitive to seismic sources. The reactions of migrating and feeding (but not wintering) gray whales to seismic surveys have been studied off St. Lawrence Island in the northern Bering Sea. Based on small sample sizes, it was estimated that 50% of feeding gray whales stopped feeding at an average received pressure level of 173 dB re 1 µPa on an (approximate) rms basis, and that 10% of feeding whales interrupted feeding at received levels of 163 dB re 1 µPa (rms). Such findings are generally consistent with results of experiments conducted on larger numbers of gray whales migrating along the California coast, as well as western Pacific gray whales feeding off Sakhalin Island, Russia.

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 off the United Kingdom from 1997 to 2000 suggest that sighting rates for mysticetes (mainly fin and sei whales) were similar when large arrays of airguns were either shooting or silent (there was localized avoidance), while singing fin whales in the Mediterranean moved away from an operating airgun array.

Data on short-term reactions by cetaceans to impulsive noises are not necessarily indicative of long-term or biologically significant effects. It is unknown whether impulsive sounds affect reproductive rates or distribution and habitat use in subsequent days or years. However, gray whales continue to migrate annually along the west coast of North America, with substantial increases in population over recent years, despite intermittent seismic exploration and heavy ship traffic continuing in the area for decades. The western Pacific gray whale population did not seem affected by a seismic survey in its feeding ground during a previous year, and bowhead whales continue travel to the eastern Beaufort Sea each summer. Bowhead whale 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 of an effect on reproductive success.

Odontocetes - Little systematic information is available about reactions of toothed whales to sound pulses. However, there are recent systematic studies on sperm whales and there is an increasing amount of information concerning the responses of various odontocetes to seismic surveys, based on monitoring studies. Seismic operators and marine mammal observers on seismic vessels regularly see dolphins and other small-toothed whales near operating airgun arrays, but in general there is a tendency for most delphinids to show some avoidance of operating seismic vessels (e.g., Stone and Tasker 2006; Moulton and Holst 2010; Barry et al. 2012; Wole and Myade 2014; Stone 2015; Monaco et al. 2016). In most cases, the avoidance radii for delphinids appear to be small — on the order of one km (0.6 mi) or less — and some individuals show no apparent avoidance.

Most studies of sperm whales exposed to airgun sounds indicate that they show considerable tolerance of airgun pulses. In most cases, the whales do not show strong avoidance and continue to call, but foraging behavior can be altered when exposed to an airgun sound (Stone and Tasker 2006; Moulton and Holst 2010). 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 and periods with airgun operations (Sidorovskaia et al. 2014).

There are almost no specific data on the behavioral reactions of beaked whales to seismic surveys. However, 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. Most beaked whales tend to avoid approaching vessels of other types and may also dive for an extended period when approached by a vessel. It is likely that most beaked whales would show strong avoidance of an approaching seismic vessel, although this has not been documented explicitly. Odontocete reactions to large arrays of airguns are variable and, at least for delphinids, seems confined to a smaller radius than has been observed for more responsive mysticetes and some other odontocetes. An equal to or greater than 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 other cetaceans. As behavioral responses are not consistently associated with received levels, some authors have made recommendations on different approaches to assess behavioral reactions (e.g., Gomez et al. 2016; Harris et al. 2017).

Pinnipeds – Pinnipeds are not likely to show a strong avoidance reaction to an airgun array. Visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds and only slight (if any) changes in behavior. However, telemetry work has suggested that avoidance and other behavioral reactions may be stronger than evidenced 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 also no significant differences in CPA distances of gray or harbor seals during seismic vs. non-seismic periods (Stone 2015). Lalas and McConnell (2015) made observations of New Zealand fur seals from a seismic vessel operating a 3090-in^3 airgun array in New Zealand during 2009. However, the results from the study were inconclusive in showing whether New Zealand fur seals respond to seismic sounds. Reichmuth et al. (2016) exposed captive spotted and ringed seals to single airgun pulses; only mild behavioral responses were observed.

Hearing Impairment and Other Physical Effects

TTS or PTS hearing impairment is a possibility when marine mammals are exposed to very strong sounds. TTS has been studied and demonstrated in certain captive odontocetes and pinnipeds exposed to strong sounds. However, there is no specific documentation of TTS, let alone permanent hearing damage (PTS) in free-ranging marine mammals exposed to sequences of airgun pulses during realistic field conditions. Current NOAA Fisheries policy regarding exposure of marine mammals to high-level sounds is based on guidance documents that identify the received levels (thresholds) at which individual marine mammals are predicted to experience changes in hearing sensitivity for acute, incidental exposure to all underwater anthropogenic sound sources (NMFS 2018). These science-based noise exposure criteria incorporate hearing frequency and weighting procedures and were used to estimate take for the proposed seismic survey.

NMFS guidance documentation includes protocols for the following:

- estimating PTS onset thresholds for impulsive (e.g., airguns) and non-impulsive (e.g., vibratory pile drivers) sound sources,
- forming marine mammal hearing groups (low-, mid-, and high- frequency cetaceans, and pinnipeds), and
- incorporating marine mammal auditory weighting functions into the derivation of PTS onset thresholds.

These thresholds are presented using dual metrics of weighted cumulative sound exposure level (SEL_{cum}) and peak sound level (PK) for impulsive sounds and are weighted SEL_{cum} for non-impulsive sounds.

NMFS guidance reflects the current state of scientific knowledge regarding the characteristics of sound that could potentially impact marine mammal hearing sensitivity. NMFS has also developed tools, including a spreadsheet and accompanying user guidance (NMFS 2018).

Several aspects of 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 (in theory) cause hearing impairment. Additionally, many marine mammals show some avoidance of the area where received levels of airgun sounds are high enough such that hearing impairment could potentially occur. In those cases, avoidance responses of the animals themselves would reduce or (most likely) prevent hearing impairment.

Non-auditory physical effects may also occur in marine mammals exposed to strong, pulsed underwater sound. Possible types of non-auditory physiological effects or injuries that, in theory, could occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, and other types of organ or tissue damage. It is possible that some marine mammal species (e.g., beaked whales) are especially susceptible to injury and/or stranding when exposed to strong transient sounds. However, there is no definitive evidence that any of these effects occur, even for marine mammals in close proximity to large airgun arrays. Such effects, if any, would presumably be limited to short distances and prolonged activities. Marine mammals that show behavioral avoidance of seismic vessels — including most mysticetes, some odontocetes, and some pinnipeds — are especially unlikely to incur non-auditory, physical effects. The brief duration of exposure of any given mammal, the deep water in the study area, 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

Sections 3.6.4.3, 3.7.4.3, 3.8.4.3, and Appendix E of the PEIS state MBES and SBP operations are not likely to impact mysticetes or odontocetes because the intermittent and narrow, downward-directed nature of these acoustic sources would result in no more than one or two brief ping exposures of any individual animal, given the movement and speed of the vessel. Similarly, the intermittent nature of ADCPs and other pingers would, at most, result in short-term, localized behavioral changes.

8.0 ANTICIPATED IMPACTS ON SUBSISTENCE USES

NOAA Fisheries Requirement: 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 activity would not occur near the Alaska region. Furthermore, there are no indigenous or native people in the Antarctic. Subsequently, there is no subsistence hunting of marine mammals near the survey areas. Therefore, the proposed activity would not have an adverse impact on the availability of the species or stocks used as a food source, including on the ability of Alaska Natives to conduct subsistence hunts.

9.0 ANTICIPATED IMPACTS ON HABITAT

NOAA Fisheries Requirement: 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 survey would not result in any permanent impact on habitats used by marine mammals or the food sources they use, such as fish and invertebrates. 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 Section 7.0 of this document. Effects of airguns on fish and invertebrates are reviewed in Section 3.2.4.3, Section 3.3.4.3, and Appendix D of the PEIS.

10.0 ANTICIPATED EFFECTS OF HABITAT IMPACTS ON MARINE MAMMALS

NOAA Fisheries Requirement: The anticipated impact of the loss or modification of the habitat on the marine mammal populations involved.

Effects of the planned activity on marine mammal habitats and food resources are expected to be negligible, as described above. Some marine mammals present near the proposed activity may be temporarily displaced up to a few kilometers by planned research activities, but there would be no permanent loss or modification to their habitat.

During the proposed survey, marine mammals would be distributed according to their habitat preferences in pelagic waters, in depths of 100-1000 m (328-3280 ft) and depths greater than 1000 m (3280 ft) (for cetaceans), and or on or near sea ice (for pinnipeds). While some marine mammals may be feeding when encountered in the proposed survey areas, the proposed activity would not be expected to have any habitat-related effects that could cause significant or long-term consequences for individual marine mammals or their populations, as operations would be limited in duration.

11.0 MITIGATION MEASURES TO PROTECT MARINE MAMMALS AND THEIR HABITAT

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

Marine mammals are known to be present in the proposed study area. To minimize the likelihood that impacts occur to species and stocks, airgun operations would be conducted in accordance with the MMPA and the ESA, including obtaining permission for incidental harassment or incidental “take” of marine mammals and other endangered species. The following provides more detailed information about mitigation measures integral to the planned activities, including the use of an operational EZ of 100 m (per the PEIS) and procedures for ramp-up, power-down, and shutdown.

Mitigation measures for the low-energy seismic survey would consist of:

- identifying the smallest airgun array that could be used and still meet geophysical science objectives;
- employing PSOs consistent with NOAA Fisheries requirements, including a marine mammal expert familiar with species in the Southern Ocean to serve as the lead PSO;
- establishing the operational EZ (100 m) and MZ (depending on the array deployed; see Table 6);
- assigning one PSO (at a minimum) to maintain visual watch for marine mammals during all daylight airgun operations;
- assigning two PSOs to maintain visual watch for marine mammals from 30 minutes before ramp-up and during ramp-up (and at other times, when possible); and
- implementing shutdowns when marine mammals are detected in or are about to enter the operational EZ.

Based on NOAA Fisheries guidance documentation (NMFS 2018), data were used to calculate the SELcum and SPLflat (Attachment A) to identify the area where an exposed animal may be injured for each respective marine mammal hearing group (i.e., Level A take). The larger calculated area between SELcum and SPLflat was used to estimate Level A takes for the Proposed Action (Table 7). Per the PEIS, and recently issued IHAs for NSF-funded low energy seismic surveys, a standard “operational EZ” of 100 m would be implemented for the Proposed Action. This operational EZ is conservative, as the predicted EZs noted in Table 7 are significantly smaller.

Modeling results (as provided in Attachment A) were used to define the MZ ($\geq$160 dB re 1 μPa [rms]) where behavioral disturbance might occur (Level B take). The MZ depends on the array used and the water depth (Table 7). As previously noted, the MZ for the largest airgun array was used to determine Level B takes. However, the applicable MZ for the deployed array (see Table 6) would be used for operational monitoring and mitigation.

To implement these measures, PSOs would visually monitor for the presence of cetaceans and pinnipeds before and during seismic survey operations. Monitoring procedures and resources are described in detail in Section 13.

During January and February in the proposed study area, darkness or low-light hours are not expected to be encountered, therefore, seismic operations likely would be conducted continuously during daylight hours. Visual PSOs may be on watch for a maximum of four consecutive hours, followed by a break of at least one hour between watches. They may conduct a maximum of 12 hours of observation per 24-hour period. Combined observational duties may not exceed 12 hours per 24-hour period for any individual PSO. However, during off-hours the resting PSO may be called for consultation should a second opinion be needed. Other crew would also be instructed to assist in detecting marine mammals and implementing mitigation requirements, if practical. Before the start of the seismic survey, the crew would be given additional instruction. PSOs will have direct radio contact with the bridge and chief scientist during seismic surveys. The vessel operator, science support personnel, and science party would comply immediately with the observer's call to shutdown the airguns.

For at least 30 minutes before the seismic survey, two PSOs would scan the surface, looking for animals within the operational EZ from the ship. If no animals are in or approaching the respective operational EZ, airguns would be ramped up (i.e., gradually increasing the output sound level by first using one GI gun and then adding the second) to provide time for undetected animals to vacate the area. The time between airgun shots would be five minutes during ramp-up. Observations would continue during the seismic survey, and if a marine mammal is sighted within the MZ, the crew would be notified of a possible shutdown if the animal approaches the operational EZ. Observations within the MZ would also include searching for pinnipeds that may be present on the surface of the sea ice (i.e., hauled-out) and that could potentially dive into the water as the vessel approaches. The ship may use evasive maneuvers, such as altering vessel course and speed, to avoid intercepting the path of an approaching marine mammal, if the maneuver can be implemented safely and without damaging deployed equipment.

12.0 MITIGATION MEASURES TO PROTECT SUBSISTENCE USES

NOAA Fisheries Requirement: 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.

The proposed activities would not occur in or near the Arctic but rather in the Antarctic. Unlike the Arctic, the proposed activities would not occur in an area accessed by subsistence users and would not have an impact on the availability of the species or stocks for subsistence users.

13.0 MONITORING AND REPORTING

NOAA Fisheries Requirement: 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 perform marine mammal monitoring during the proposed activity in order to implement mitigation measures that require real-time monitoring and satisfy the monitoring requirements of the IHA.

NSF's proposed monitoring plan is described below. NSF understands that this monitoring plan is subject to review by NOAA Fisheries and that refinements may be required. The monitoring work described here was planned as a self-contained project independent of any other related monitoring projects that may be occurring simultaneously in the same region. 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. Given the remote location of the Proposed Action, there are likely few, if any, other activities in the region.

Vessel-based Visual Monitoring

PSO observations (described in Section 11) would take place during airgun operations, as described in detail below.

The NBP is a suitable platform for marine mammal observations. When stationed on the bridge, eye level would be about 16.5 m (54 ft) above sea level, and the position affords an approximate 270° view around the vessel. In addition, there is an aloft observation tower at approximately 24.4 m (80 ft) above sea level that is protected from the weather and affords observers a 360° view around the vessel. PSOs would systematically scan the area around the vessel with reticle binoculars and with the naked eye. Reticle binoculars are equipped with a built-in daylight compass, and the range reticle and would be used to measure distances to animals.

Protected Species Observers

NSF would utilize NOAA Fisheries-approved, vessel-based PSOs to visually watch for and monitor marine mammals near the vessel during daytime airgun operations (from nautical twilight-dawn to nautical twilight-dusk) and before and during airgun ramp-ups, day or night. The NBP vessel crew would also assist in detecting marine mammals, when practicable.

PSOs would have access to reticle binoculars (7 x 50 Fujinon or equivalent) that are equipped with a built-in daylight compass and range reticle.

PSO shifts would last no longer than four hours at a time. When feasible, PSOs would observe during the daytime, when seismic airguns are not operating, for comparisons of animal abundance and behavior. PSOs would also conduct monitoring while the airgun array and streamer are being deployed or recovered from the water.

Visual Monitoring at the Start of the Airgun Operations

PSOs would visually observe the entire extent of the EZ (defined in Table 6) for at least 30 minutes before the airgun array is started (day or night).

If a PSO sees a marine mammal within the operational EZ (100 m), the seismic survey would be delayed until the marine mammal has left the area. If a PSO sees a marine mammal that surfaces, then dives below the surface, the PSO would wait 15 minutes for species with shorter dive durations (small odontocetes) or 30 minutes for species with longer dive durations (mysticetes and large odontocetes). If the PSO sees no marine mammals during that time, it should be assumed that the animal has moved beyond the operational EZ (100 m).

Ramp-up at night and at times of poor visibility would occur where operational planning could not reasonably avoid such circumstances. Ramp-up would occur at night and during poor visibility if the 100 m EZ had been continually monitored by visual PSOs for 30 minutes prior to ramp-up with no marine mammal detections.

Ramp-up Procedures

The proposed activities would implement a "ramp-up" procedure when starting up at the beginning of seismic operations or any time after the entire array has been shut down for more than 15 minutes. This means starting with a single GI airgun and adding a second GI airgun after five minutes. During ramp-up, two PSOs would monitor the operational EZ (100 m). If any marine mammals are sighted, a shutdown would be implemented as though the full array (both GI airguns) were operational. Therefore, initiating ramp-up procedures from shutdown requires that two PSOs be able to view the full operational EZ (100 m), as described above.

Following a shutdown, airgun activity would not resume until the PSO has either visually observed the marine mammal (or mammals) exiting the operational EZ and concluded that the mammal is unlikely to return, or has not seen the mammal(s) within the operational EZ for 15 minutes for species with shorter dive durations (e.g., small odontocetes) or 30 minutes for species with longer dive durations (e.g., mysticetes and large odontocetes). Although power-down procedures are often a standard operating practice for seismic surveys, they are not proposed during this planned seismic survey because powering down from two airguns to one would make only a small difference in the EZ, not enough to allow continued, single-airgun operations if a marine mammal comes within the two-airgun EZ.

Shutdown Procedures

1. Shut down the airgun (or airguns) if a marine mammal is detected within, approaching, or entering the operational EZ (100 m). A shutdown means that all operating airguns are shut down (i.e., turned off).

2. Following a shutdown, airgun activity shall not resume until a PSO has visually observed the marine mammal(s) exiting the operational EZ and determined it is unlikely to return or has not been seen within the operational EZ for 15 minutes (for species with shorter dive durations; e.g., small odontocetes) or 30 minutes (for species with longer dive durations; e.g., mysticetes and large odontocetes, including sperm, killer, and beaked whales).

3. Following a shutdown and subsequent animal departure, airgun operations may resume following the ramp-up procedures described above.

Speed or Course Alteration

The proposed activities would alter the vessel's speed or course during seismic operations if a marine mammal, based on its position and relative motion, appears likely to enter the operational EZ (100 m). If speed or course alteration is not safe or practicable or, if after alteration, the marine mammal still appears likely to enter the operational EZ (100 m), further mitigation measures (such as a shutdown) would be taken.

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 the lack thereof. These data would be used to estimate the numbers of animals potentially taken by harassment (as defined in the MMPA). As noted previously, PSOs would also provide the information needed to order a power-down or shutdown of airguns when a marine mammal is within or near the operational 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 airguns or vessel (e.g., none, avoidance, approach, paralleling, etc.); and behavioral pace.
2. Time; location, heading, speed, and activity of the vessel (including number of airguns operating and whether in a state of ramp-up or shutdown); sea state and wind force; visibility; and sun glare.

This data 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 variable.

All observations and shutdowns would be recorded in a standardized format. Data would be entered into an electronic database and 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 preparation of initial data summaries during and shortly after the field program and would facilitate data transfer to statistical, graphical, and other programs for further processing and archiving.

Results from vessel-based observations would provide:

1. The basis for real-time mitigation (e.g., airgun shutdown).
2. The information needed to estimate the number of marine mammals potentially taken by harassment, which must be reported to NOAA Fisheries. During proposed activities, the number of takes would be monitored and used to stop seismic operations, should the requested number of takes be reached.
3. Data on the occurrence, distribution, and activities of marine mammals in the area where the seismic study would be 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 NOAA Fisheries within 90 days of the end of the cruise. The report would describe the operations conducted and sightings of marine mammals near such operations. The report would provide full documentation of methods, results, and an interpretation of all monitoring. The report would summarize the dates and locations of seismic operations and all marine mammal sightings (including dates, times, locations, activities, and associated seismic survey activities). The report would also include estimates of the number and nature of exposures that may be considered “takes” of marine mammals by harassment or in other ways.

14.0 SUGGESTED MEANS OF COORDINATION

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

ASC and NSF would coordinate the planned marine mammal monitoring program associated with the seismic survey with other parties that may have interest in this area. ASC and NSF would coordinate with applicable U.S. agencies (e.g., NOAA Fisheries) and will comply with their requirements.

This project involves a joint initiative launched by NSF and NERC and would improve decadal and longer-term projections of ice loss and sea-level rise originating from Thwaites Glacier in West Antarctica. The proposed activity will complement Thwaites Glacier and other Amundsen Sea oceanographic and geological/geophysical studies and provide reference data that can be used to initiate and evaluate the reliability of ocean models. Data obtained by the project would assist in establishing boundary conditions seaward of the Thwaites Glacier grounding line, obtaining records of external drivers of change, and improving knowledge of processes leading to the collapse of Thwaites Glacier.

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Attachments

Attachment A – Model Report Estimating the Mitigation Zones for Airgun Arrays that could be used in the Amundsen Sea

Attachment B – Species Cross-reference

Attachment C – Marine Mammal Sightings Data

Attachment D – Estimated Ensonified Area from Icebreaking Activities and Potential Marine Mammal Take

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Attachment A – Model Report Estimating the Mitigation Zones for Airgun Arrays that could be used in the Amundsen Sea

Background

Current NMFS policy regarding exposure of marine mammals to high-level sounds is based on guidance documents that identify the received levels, or thresholds, at which individual marine mammals are predicted to experience changes in their hearing sensitivity for acute, incidental exposure to all underwater anthropogenic sound sources (NMFS 2018). The NMFS guidance document reflects the current state of scientific knowledge regarding the characteristics of sound that have the potential to impact marine mammal hearing sensitivity. NMFS has also developed tools, including a spreadsheet and accompanying user guidance (NMFS 2018).

These science-based noise exposure criteria incorporate hearing frequency and weighting procedures and were used in establishing the mitigation (i.e., shutdown) zones planned for the proposed seismic survey.

The NMFS guidance document includes a protocol for estimating PTS onset thresholds for impulsive (e.g., airguns) and non-impulsive (e.g., vibratory pile drivers) sound sources, the formation of marine mammal hearing groups (low-[LF], mid-[MF], and high-[HF] frequency cetaceans, and otariid [OW] and phocid [PW] pinnipeds), and the incorporation of marine mammal auditory weighting functions into the derivation of PTS onset thresholds. These thresholds are presented using dual metrics of weighted cumulative sound exposure level (SEL_{cum}) and peak sound level (PK) for impulsive sounds and weighted SEL_{cum} for non-impulsive sounds.

Determination of Mitigation Zones for a Two Airgun Array with a Configuration of 737/1720 cm^3 (2 x 45/105 in^3) (True GI Mode)

(2 x 150 cu.in (3 m separation) @ a 3m tow depth [total volume 300])

Mitigation Zones.—During the planning phase, mitigation zones for the proposed marine seismic surveys were calculated based on modeling by L-DEO for both the exclusion and safety zones. 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 150-in^3 GI-guns. This modeling approach uses ray tracing for the direct wave traveling from the array to the receiver and its associated source ghost (reflection at the air-water interface in the vicinity of the array), in a constant-velocity half-space (infinite homogeneous ocean layer, unbounded by a seafloor). In addition, propagation measurements of pulses from the 36-airgun array at a tow depth of 6 m have been reported in deep water (~1600 m), intermediate water depth on the slope (~600–1100 m), and shallow water (~50 m) in the Gulf of Mexico (GoM) in 2007–2008 (Tolstoy et al. 2009; Diebold et al. 2010).

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

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

The proposed surveys would acquire data with two 150 in^3 GI-guns (separated by 3 m) at a tow depth of 3 m. For deep water (>1000 m), we use the deep-water radii obtained from L-DEO model results down to a maximum water depth of 2000 m (Fig. 1 and 2). 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).

The shallow-water radii are obtained by scaling the empirically derived measurements from the GoM calibration survey to account for the differences in volume and tow depth between the calibration survey (6600 cu.in at 6 m tow depth) and the proposed survey (300 cu.in at 3 m tow depth); whereas the shallow water GOM may not exactly replicate the shallow water environment at the proposed survey sites, it has been shown to serve as a good and very conservative proxy (Crone et al. 2014). A simple scaling factor is calculated from the ratios of the isopleths calculated by the deep-water L-DEO model, which are essentially a measure of the energy radiated by the source array:

- The 150-decibel (dB) Sound Exposure Level (SEL)[1] corresponds to deep-water maximum radii of 653 m for the two 150 in^3 GI-guns at 3 m tow depth (Fig. 1), and 7,244 m for the 6600 in^3 at 6-m tow depth (Fig. 2), yielding scaling factors of 0.090 to be applied to the shallow-water 6-m tow depth results.
- The 165-decibel (dB) Sound Exposure Level (SEL) corresponds to deep-water maximum radii of 115.65 m for the two 150 in^3 GI-guns at 3 m tow depth, and 1284 m for a 6-m tow depth, yielding a scaling factor of 0.090 to be applied to the shallow-water 6-m tow depth results.
- Similarly, the 170 dB SEL corresponds to deep-water maximum radii of 65.742 for the two 150 in^3 GI-guns at 3 m tow depth (Fig. 1) and 719 m for the 6600 in^3 at 6-m tow depth (Fig. 2), yielding a scaling factor of 0.091.
- the 185-decibel (dB) Sound Exposure Level (SEL) corresponds to deep-water maximum rad of 12.605 m for the two 150 in^3 at 3-m tow depth, and 126.3 m for a 6-m tow depth, yielding a scaling factor of 0.099 to be applied to the shallow-water 6-m tow depth results.

Measured 160-, 175-, 180-, 190- and 195-dB re 1µPa_{rms} distances in shallow water for the 36-airgun array towed at 6 m depth were 17.5 km, 2.84 km, 1.6 km, 458 m and 240 m, respectively, based on a 95th percentile fit (Tolstoy et al. 2009). Multiplying by the scaling factor to account for the tow depth and discharge volume differences between the 6600 cu.in airgun array at 6 m tow depth and the 420 cu.in GI-gun array at 3 m tow depth yields distances of 1.575 km, 256 m, 144 m, 42 m and 23.76 m, respectively.

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

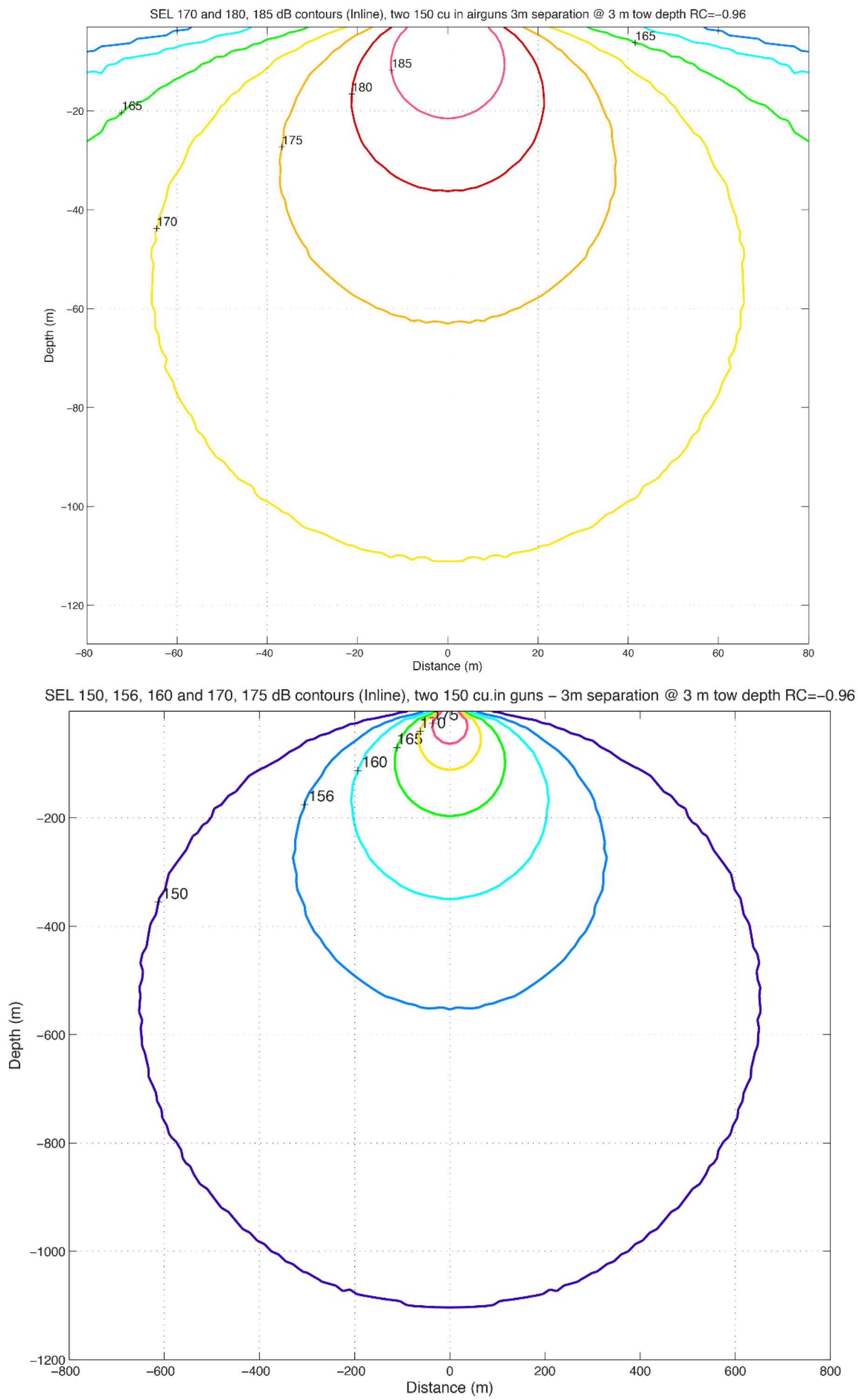
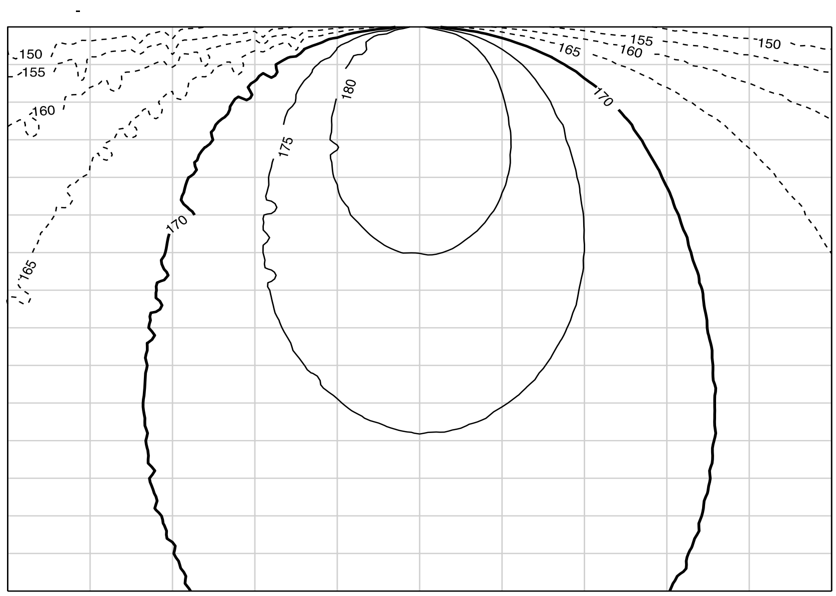


FIGURE 1. Modeled deep-water received sound exposure levels (SELs) from the two 150 in^3 GI-guns planned for use during the proposed surveys in the Antarctic at a 3-m tow depth. Received rms levels (SPLs) are expected to be ~10 dB higher. The plot at the top provides the radius to the 170-dB SEL isopleth as a proxy for the 180-dB rms isopleth, and the plot at the bottom provides the radius to the 150 and 165-dB SEL isopleths as a proxy for the 160 and 175-dB rms isopleths.



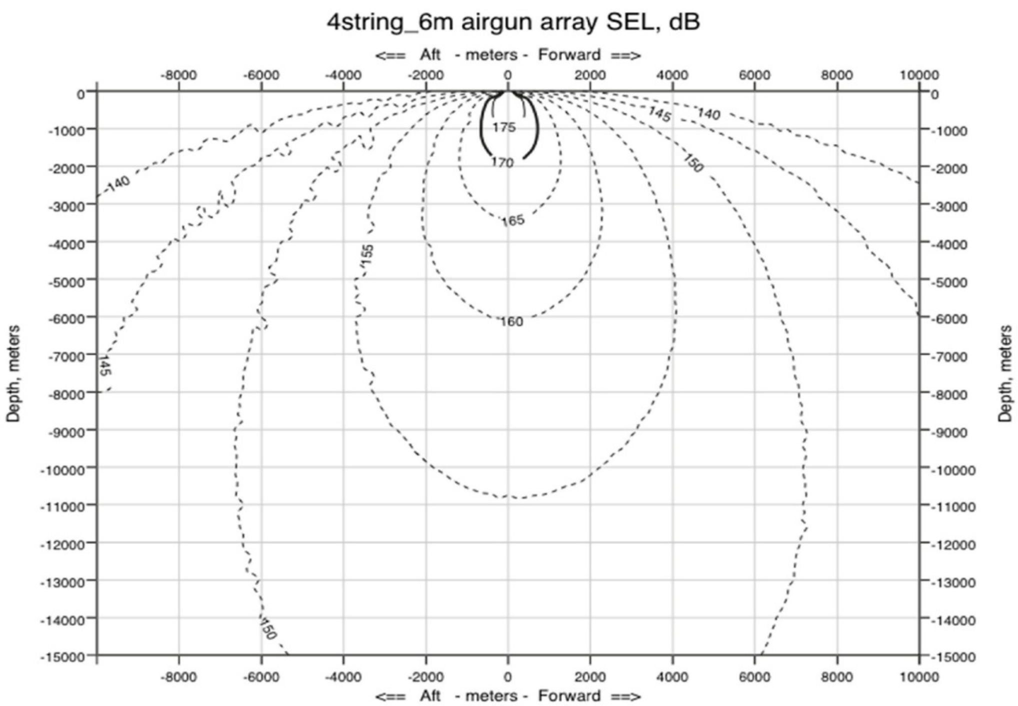


FIGURE 2. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array at a 6-m tow depth used during the GoM calibration survey. Received rms levels (SPLs) are expected to be ~10 dB higher. The plot at the top provides the radius to the 170 dB SEL isopleth as a proxy for the 180-dB rms isopleth, and the plot at the bottom provides the radius to the 150-dB SEL isopleth as a proxy for the 160-dB rms isopleth.

Table 1 shows the distances at which the 160-, 175-, 180-, 190 and 195-dB re 1μPa_{rms} sound levels are expected to be received for the two 150 in^3 GI-guns at 3 m tow depth. . The 160-dB level is the behavioral disturbance criterion (Level B) that is used by NMFS to estimate anticipated takes for marine mammals; a 175-dB level is used by the National Marine Fisheries Service (NMFS) to determine behavioral disturbance for sea turtles.

A recent retrospective analysis of acoustic propagation of *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 *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, preliminary analysis by Crone (2015, L-DEO, pers. comm., Crone et al., 2017) of data collected 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 the *Langseth* hydrophone streamer were similarly 2–3 times smaller than the predicted operational mitigation radii. In fact, five separate comparisons conducted of the L-DEO model with *in situ* received levels[2] have confirmed that the L-DEO model generated conservative exclusion zones, resulting in significantly larger EZs than necessary.

Southall et al. (2007) made detailed recommendations for new science-based noise exposure criteria. In 2018, NOAA published a revised version of its 2016 guidance for assessing the effects of anthropogenic sound on marine mammals (NOAA 2018). This assessment has been prepared in accordance with the current NOAA acoustic practices, and *also take into consideration* best practices noted by Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013), Wright (2014), and Wright and Cosentino (2015).

Enforcement of mitigation zones via power and shut downs would be implemented in the Operational Phase.

TABLE 1. Predicted distances to which sound levels ≥ 195, 190-, 180-, 175-, and 160-dB re 1 μPa_{rms} are expected to be received during the proposed surveys in the Antarctica. For the single mitigation airgun, the 100 m EZ is the conservative EZ for all low-energy acoustic sources defined in the PEIS for water depths >100 m that would be used during airgun operations and the EZ in parentheses is the modeled level for water depths <100 m[5].

Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted rms Radii (m)				
			195 dB	190dB	180 dB	175 dB	160 dB
Two 150-in^3 G-guns, 3 m separation	3	>1000 m	100[4] (13)	100[4](21)	100[4] (66)	115[1]	653[1]
		100–1000 m	100[4](19)	100[4](32)	100 (98)	173[2]	979[2]
		<100 m	24[3]	42[3]	144[3]	256[3]	1,575[3]

[1] Distance is based on L-DEO model results.
[2] Distance is based on L-DEO model results with a 1.5 x correction factor between deep and intermediate water depths.
[3] Distance is based on empirically derived measurements in the GoM with scaling applied to account for differences in tow depth.
[4] Modeled distances based on empirically derived measurements in the GoM are smaller.

[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 2015, L-DEO, pers. comm.)

Peak and cumulative sound exposure levels (SEL) were estimated and reported in Tables 2, 3, and 4. Graphic depiction of modeled SEL are provided in Figures 3-8.

SELcum 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
** shot interval will be assume to be 5 seconds

Table 2: Table showing the results for 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 SELcum threshold is the largest. A propagation of 20 $\log_{10}$ (Radial distance) is used to estimate the modified farfield SEL.

SEL_{cum} Threshold	**183**	**185**	**155**	**185**	**203**
Distance(m) (no weighting function)	19.8808	16.2732	532.5124	16.2732	2.2804
Modified Farfield SEL*	208.9687	209.2295	209.5266	209.2295	210.1602
Distance (m) (with weighting function)	10.1720	**N/A**	**N/A**	**N/A**	**N/A**
Adjustment (dB)	-5.82	**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 183dB SEL cum isopleth is the largest. We first run the modeling for one single shot without applying any weighting function. The maximum 183dB SEL cum isopleth is located at 19.88 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 10.17 m from the source. Difference between 19.88 m and 10.17 m gives an adjustment factor of -5.82 dB assuming a propagation of 20log10(R).

TABLE 3. Results for single shot SEL source level modeling for the two 150 in^3 airguns with weighting function calculations for SEL_{cum} criteria.

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	208.9687	209.2295	209.5266	209.2295	210.1602
Source Factor	1.57725E+20	1.67487E+20	1.79345E+20	1.67487E+20	2.07515E+20

RESULTANT ISOPLETHS*

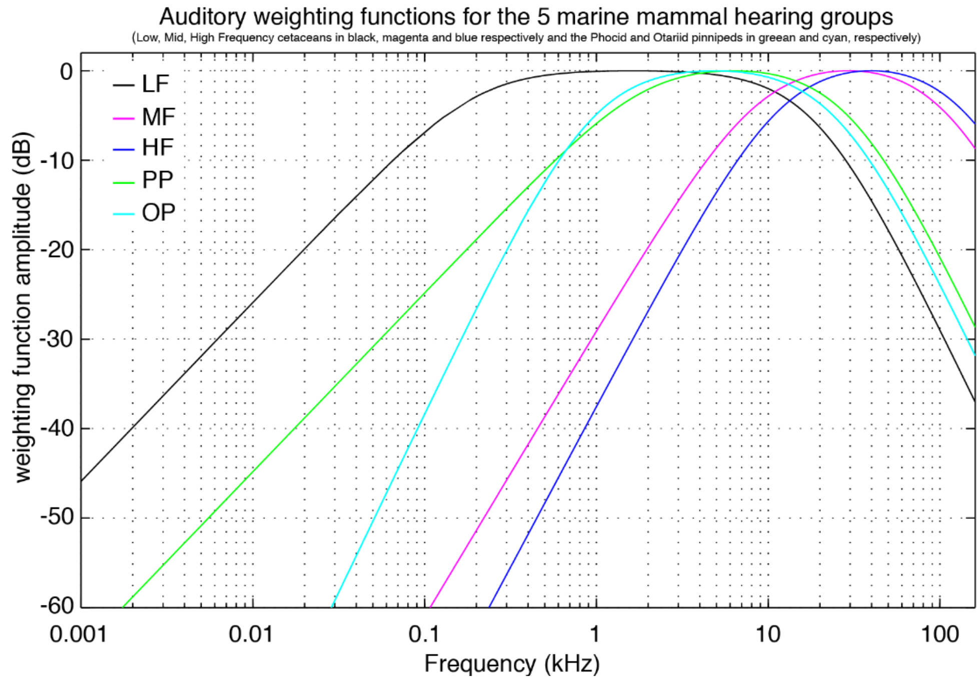
*Impulsive sounds have dual metric thresholds (SELcum & PK). Metric producing largest isopleth should be used.

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)	28.1	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)†	-5.82	-54.73	-63.98	-24.00	-30.65	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)	**28.1**	**0.0**	**0.0**	**0.3**	**0.0**



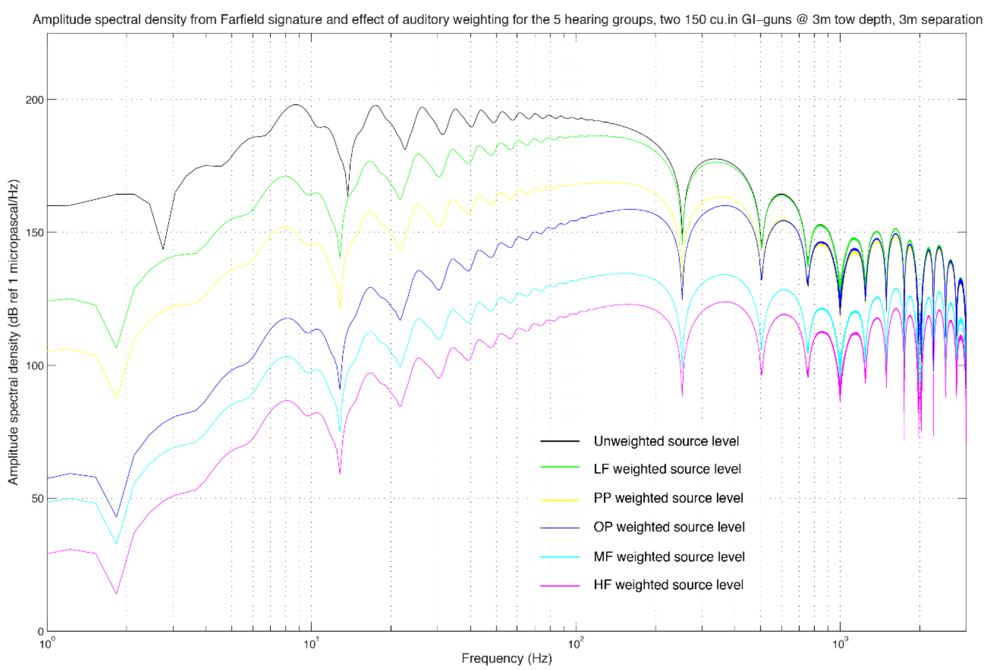


FIGURE 3: Modeled amplitude spectral density of the two 150 cu.in airgun farfield signature. Amplitude spectral density before (black) and after (green, yellow, blue, cyan, magenta) applying the auditory weighting function for the low frequency cetaceans, phocid pinnipeds, otariid Pinnipeds, mid frequency 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.

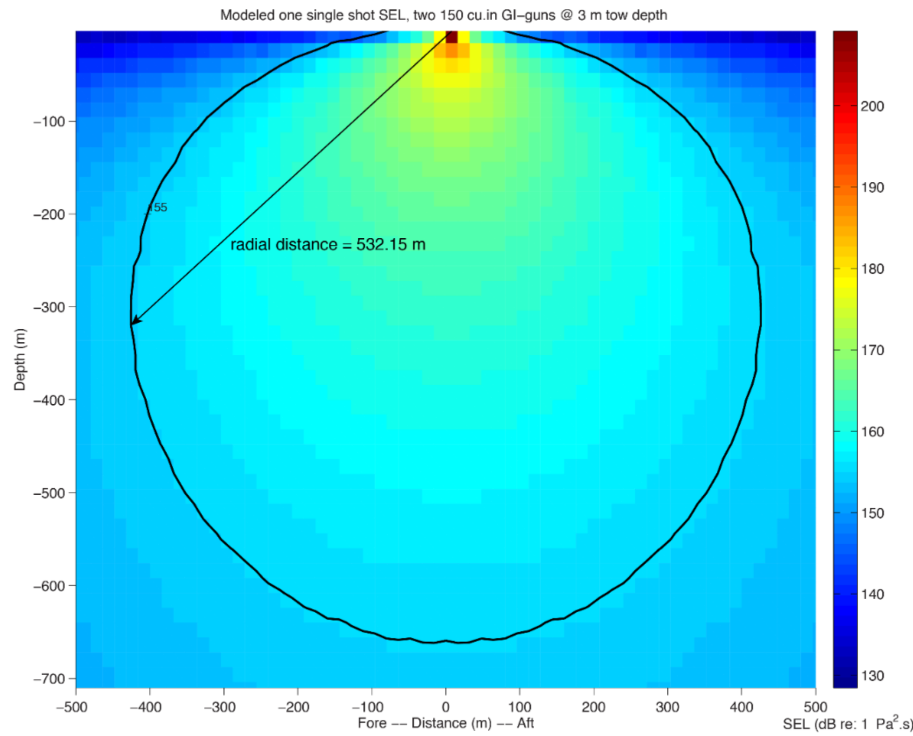


FIGURE 4: Modeled received sound levels (SELs) in deep water from the two 150 cu.in GI-guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (532.15 m).

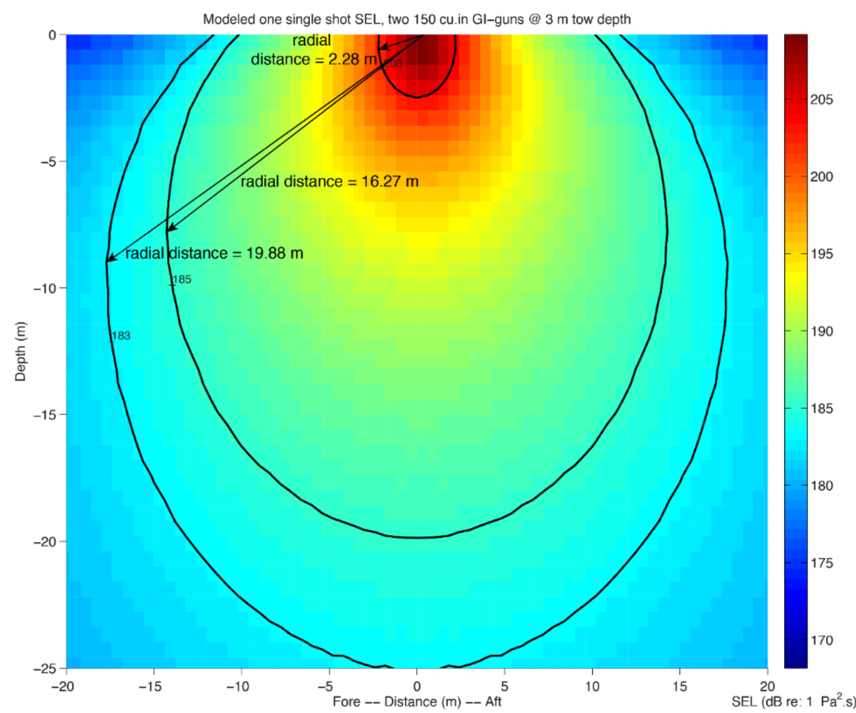


FIGURE 5 : Modeled received sound levels (SELs) in deep water from the two 150 cu.in GI-guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183, 185 and 203 dB SEL isopleths.

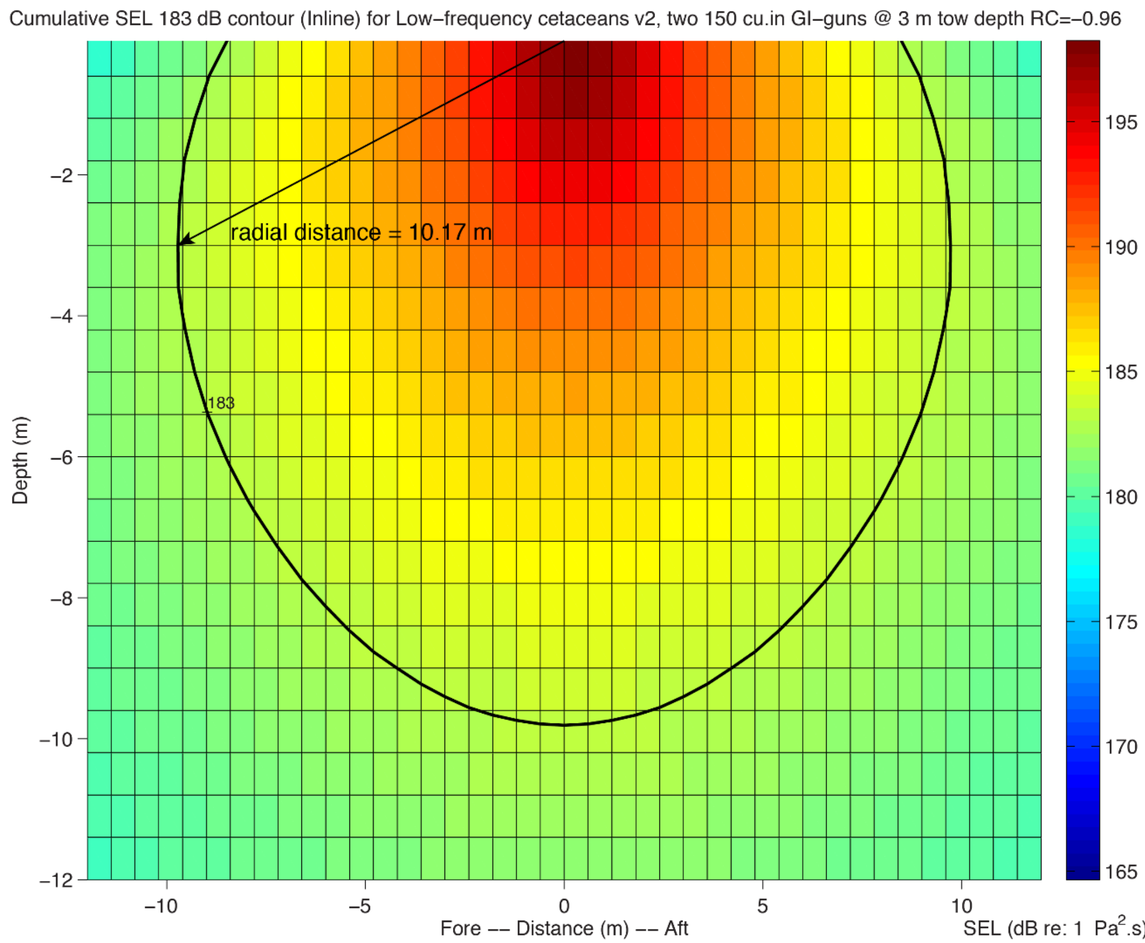


FIGURE 6: Modeled received sound exposure levels (SELs) from the two 150 cu.in GI-guns at a 3-m tow depth, after applying the auditory weighting function for the Low Frequency Cetaceans hearing group following to the new technical guidance. The plot provides the radial distance to the 183-dB SELcum isopleth for one shot. The difference in radial distances between Fig. 4 (19.88 m) and this figure (10.17 m) allows us to estimate the adjustment in dB.

Peak Sound Pressure Level

TABLE 4. 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 150 cu.in airguns at a 3 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)	**7.15**	**1.42**	**49.00**	**8.07**	**0.65**

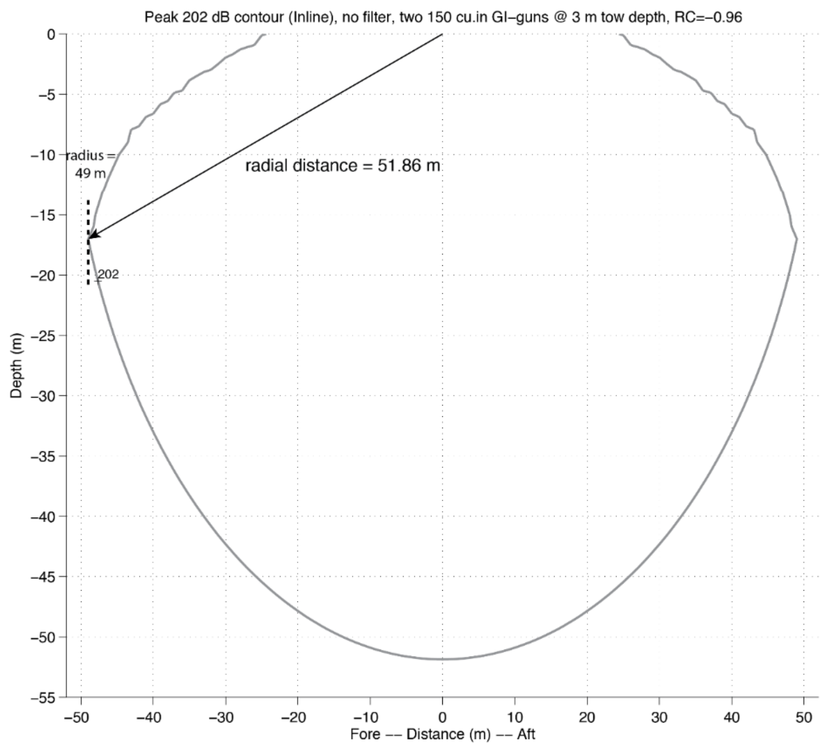


FIGURE 7: Modeled deep-water received Peak SPL from two 150 cu.in airguns at a 3-m tow depth. The plot provides the radius of the 202-dB peak isopleth (51.86 m).

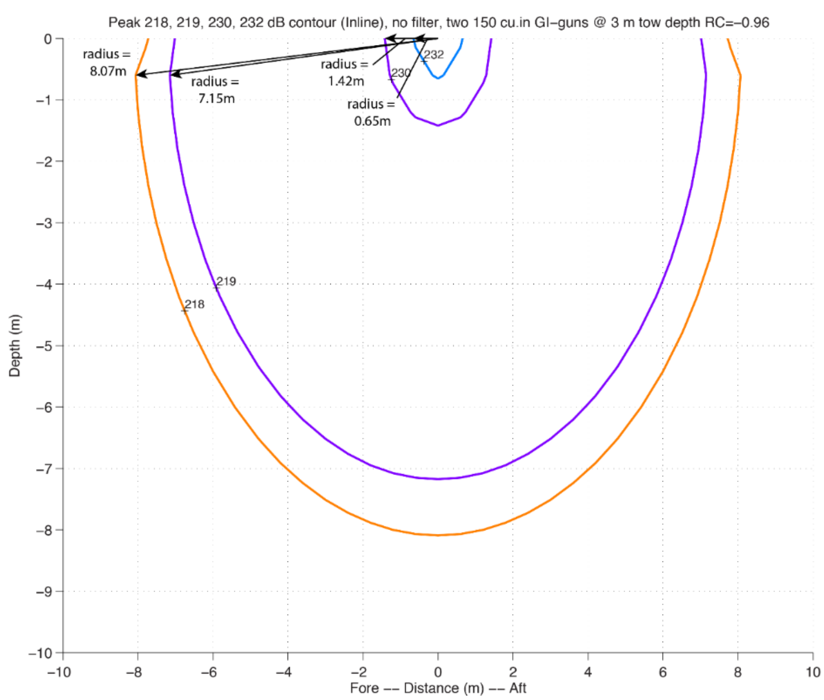


FIGURE 8: Modeled deep-water received Peak SPL from two 150 cu.in airguns at a 3-m tow depth. The plot provides the radius of the 218-219-230 and 232 dB peak isopleths.

Determination of Mitigation Zones for a One Airgun Array with a Configuration of 737/1720 cm^3 (1 x 45/105 in^3) (True GI Mode)

(1 x 150 cu.in (3 m separation) @ a 3m tow depth [total volume150])

***Mitigation Zones.*—**During the planning phase, mitigation zones for the proposed marine seismic surveys were calculated based on modeling by L-DEO for both the exclusion and safety zones. 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 one 150-in^3 GI-gun. This modeling approach uses ray tracing for the direct wave traveling from the array to the receiver and its associated source ghost (reflection at the air-water interface in the vicinity of the array), in a constant-velocity half-space (infinite homogeneous ocean layer, unbounded by a seafloor). In addition, propagation measurements of pulses from the 36-airgun array at a tow depth of 6 m have been reported in deep water (~1600 m), intermediate water depth on the slope (~600–1100 m), and shallow water (~50 m) in the Gulf of Mexico (GoM) in 2007–2008 (Tolstoy et al. 2009; Diebold et al. 2010).

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

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

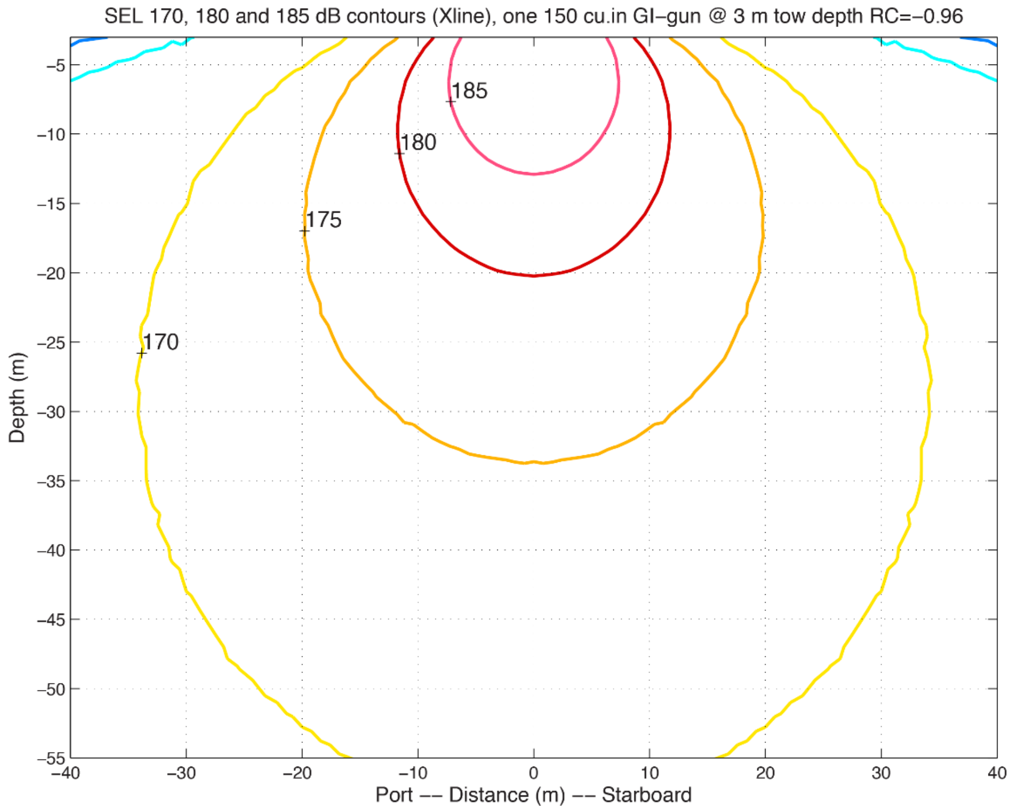
The proposed surveys would acquire data with one 150 in^3 GI-gun (separated by 3 m) at a tow depth of 3 m. For deep water (>1000 m), we use the deep-water radii obtained from L-DEO model results down to a maximum water depth of 2000 m (Figures 9 and 10). The radii for intermediate water depths (100–1000 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).

The shallow-water radii are obtained by scaling the empirically derived measurements from the GoM calibration survey to account for the differences in volume and tow depth between the calibration survey (6600 cu.in at 6 m tow depth) and the proposed survey (150 cu.in at 3 m tow depth); whereas the shallow water GOM may not exactly replicate the shallow water environment at the proposed survey sites, it has been shown to serve as a good and very conservative proxy (Crone et al. 2014). A simple scaling factor is calculated from the ratios of the isopleths calculated by the deep-water L-DEO model, which are essentially a measure of the energy radiated by the source array:

- The 150-decibel (dB) Sound Exposure Level (SEL)[3] corresponds to deep-water maximum radii of 335.4 m for the one 150 in^3 GI-gun at 3 m tow depth (Fig. 9), and 7,244 m for the 6600 in^3 at 6-m tow depth (Fig. 10), yielding scaling factors of 0.0463 to be applied to the shallow-water 6-m tow depth results.
- The 165-decibel (dB) Sound Exposure Level (SEL) corresponds to deep-water maximum radii of 60.26 m for the one 150 in^3 GI-gun at 3 m tow depth, and 1,284 m for a 6-m tow depth, yielding a scaling factor of 0.0469 to be applied to the shallow-water 6-m tow depth results.
- Similarly, the 170 dB SEL corresponds to deep-water maximum radii of 34.32 for the one 150 in^3 GI-gun at 3 m tow depth (Fig. 9) and 719 m for the 6600 in^3 at 6-m tow depth (Fig. 10), yielding a scaling factor of 0.0477.
- The 185-decibel (dB) Sound Exposure Level (SEL) corresponds to deep-water maximum radii of 7.339 m for the one 150 in^3 at 3-m tow depth, and 126.3 m for a 6-m tow depth, yielding a scaling factor of 0.058 to be applied to the shallow-water 6-m tow depth results.

Measured 160-, 175-, 180-, 190- and 195-dB re $1\mu Pa_{rms}$ distances in shallow water for the 36-airgun array towed at 6 m depth were 17.5 km, 2.84 km, 1.6 km, 458 m and 240 m, respectively, based on a 95th percentile fit (Tolstoy et al. 2009). Multiplying by the scaling factor to account for the tow depth and discharge volume differences between the 6600 cu.in airgun array at 6 m tow depth and the 150 cu.in GI-gun at 3 m tow depth yields distances of 810 m, 133 m, 76 m, 26 m and 13.9 m, respectively.

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



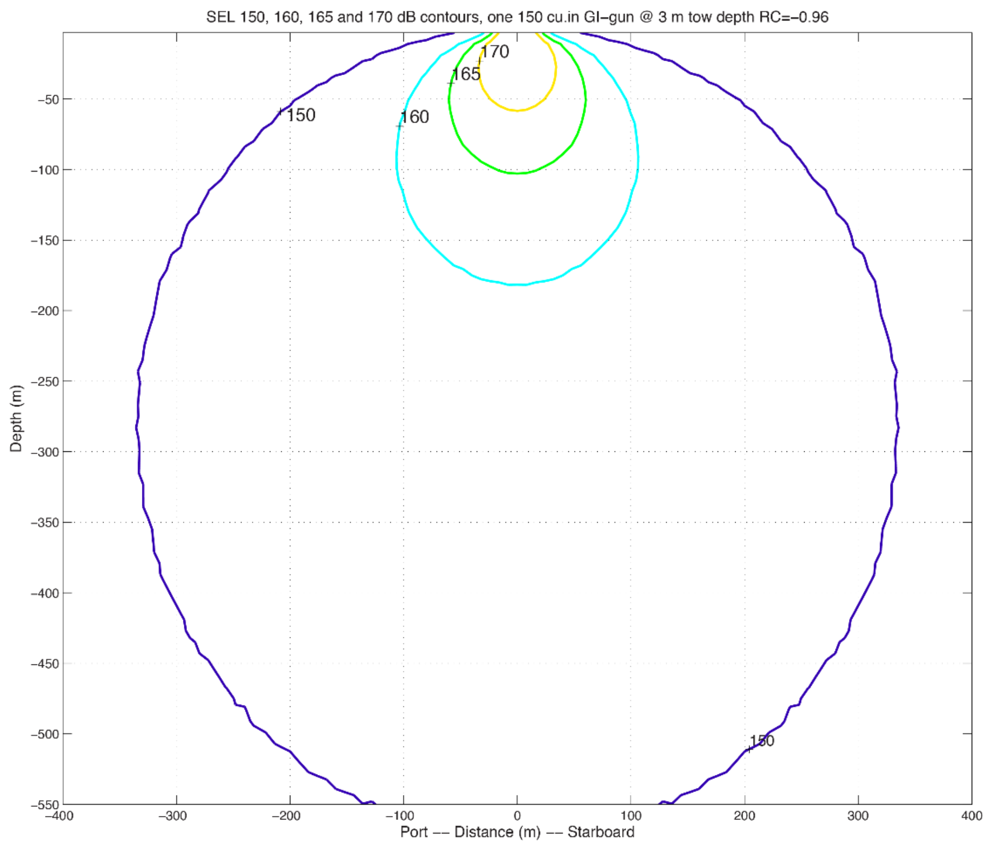


FIGURE 9. Modeled deep-water received sound exposure levels (SELs) from the one 150 in^3 GI-gun planned for use during the proposed surveys in the Antarctic at a 3-m tow depth. Received rms levels (SPLs) are expected to be ~10 dB higher. The plot at the top provides the radius to the 170-dB SEL isopleth as a proxy for the 180-dB rms isopleth, and the plot at the bottom provides the radius to the 150 and 165-dB SEL isopleths as a proxy for the 160 and 175-dB rms isopleths.

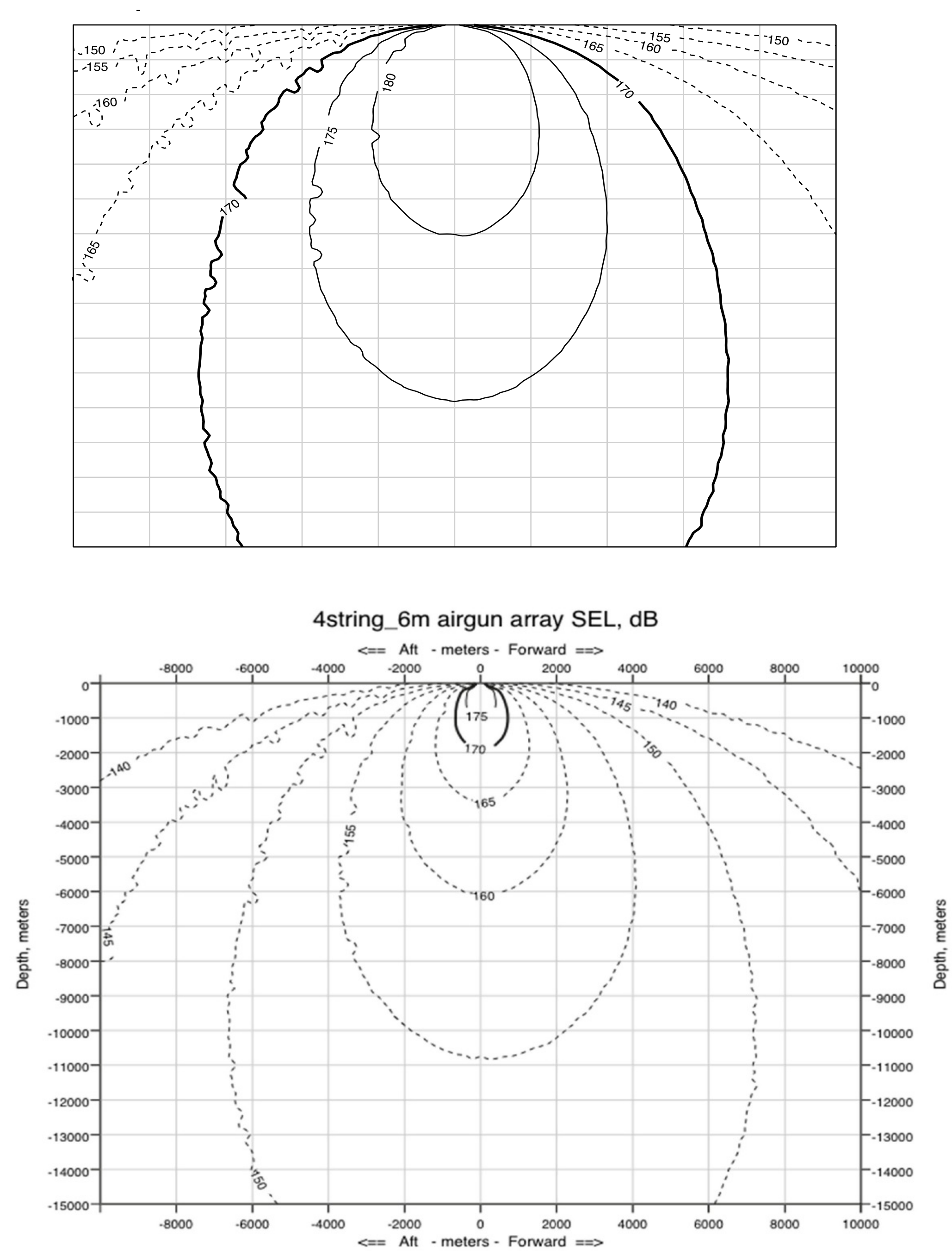


FIGURE 10. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array at a 6-m tow depth used during the GoM calibration survey. Received rms levels (SPLs) are expected to be ~10 dB higher. The plot at the top provides the radius to the 170 dB SEL isopleth as a proxy for the 180-dB rms isopleth, and the plot at the bottom provides the radius to the 150-dB SEL isopleth as a proxy for the 160-dB rms isopleth.

Table 5 shows the distances at which the 160-, 175-, 180-, 190 and 195-dB re 1µPa_{rms} sound levels are expected to be received for the one 150 in^3 GI-gun at 3 m tow depth. . The 160-dB level is the behavioral disturbance criterion (Level B) that is used by NMFS to estimate anticipated takes for marine mammals; a 175-dB level is used by the National Marine Fisheries Service (NMFS) to determine behavioral disturbance for sea turtles.

A recent retrospective analysis of acoustic propagation of *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 *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, preliminary analysis by Crone (2015, L-DEO, pers. comm., Crone et al., 2017) of data collected 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 the *Langseth* hydrophone streamer were similarly 2–3 times smaller than the predicted operational mitigation radii. In fact, five separate comparisons conducted of the L-DEO model with *in situ* received levels[4] have confirmed that the L-DEO model generated conservative exclusion zones, resulting in significantly larger EZs than necessary.

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Enforcement of mitigation zones via power and shut downs would be implemented in the Operational Phase.

TABLE 5. Predicted distances to which sound levels ≥ 195, 190-, 180-, 175-, and 160-dB re 1 µPa_{rms} are expected to be received during the proposed surveys in the Antarctica. For the single mitigation airgun, the 100 m EZ is the conservative EZ for all low-energy acoustic sources defined in the PEIS for water depths >100 m that would be used during airgun operations and EZ in parentheses is the modeled level for water depths <100 m[5].

Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted rms Radii (m)				
			195 dB	190dB	180 dB	175 dB	160 dB
One 150 in^3 G-guns	3	>1000 m	100[4] (7.33)	100[4](12)	100[4] (34)	60[1]	335[1]
		100–1000 m	100[4](11)	100[4](18)	100 (51)	90[2]	503[2]
		<100 m	14[3]	26[3]	76[3]	133[3]	810[3]

[1] Distance is based on L-DEO model results.
[2] Distance is based on L-DEO model results with a 1.5 x correction factor between deep and intermediate water depths.
[3] Distance is based on empirically derived measurements in the GoM with scaling applied to account for differences in tow depth.
[4] Modeled distances based on empirically derived measurements in the GoM are smaller.

[4] 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 2015, L-DEO, pers. comm.)

Peak and cumulative sound exposure levels (SEL) were estimated and reported in Tables 6, 7, and 8. Graphic depiction of modeled SEL are provided in Figures 9-14.

SELcum 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
** shot interval will be assume to be 5 seconds

Table 6: Table showing the results for 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 SELcum threshold is the largest. A propagation of 20 $\log_{10}$ (Radial distance) is used to estimate the modified farfield SEL.

SEL_{cum} Threshold	**183**	**185**	**155**	**185**	**203**
Distance(m) (no weighting function)	10.8261	8.8001	268.6873	8.8001	1.6357
Modified Farfield SEL*	203.6894	203.8898	203.5849	203.8898	207.2741
Distance (m) (with weighting function)	4.7381	**N/A**	**N/A**	**N/A**	**N/A**
Adjustment (dB)	-7.1773	**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 183dB SEL cum isopleth is the largest. We first run the modeling for one single shot without applying any weighting function. The maximum 183dB SEL cum isopleth is located at 10.83 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 4.74 m from the source. Difference between 10.83 m and 4.74 m gives an adjustment factor of -7.1773 dB assuming a propagation of 20log10(R).

TABLE 7. Results for single shot SEL source level modeling for the one 150 in^3 airgun with weighting function calculations for SEL_{cum} criteria.

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	203.6894	203.8898	203.5849	203.8898	207.2741
Source Factor	4.67703E+19	4.8979E+19	4.56583E+19	4.8979E+19	1.06768E+20

RESULTANT ISOPLETHS*

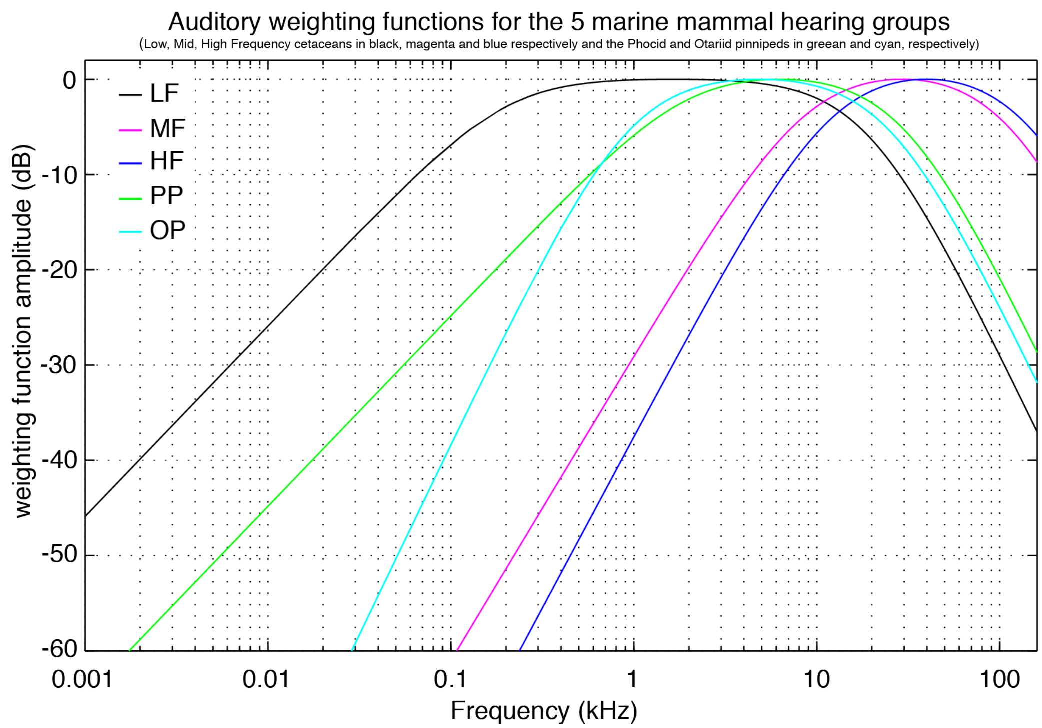
*Impulsive sounds have dual metric thresholds (SELcum & PK). Metric producing largest isopleth should be used.

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)	6.1	0.0	0.0	0.1	0.0

WEIGHTING FUNCTION CALCULATIONS

Weighting Function Parameters	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	
a	1	1.6	1.8	1	2	
b	2	2	2	2	2	
f_1	0.2	8.8	12	1.9	0.94	
f_2	19	110	140	30	25	
C	0.13	1.2	1.36	0.75	0.64	
Adjustment (dB)†	-7.18	-55.04	-64.30	-24.25	-30.97	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)	**6.1**	**0.0**	**0.0**	**0.1**	**0.0**



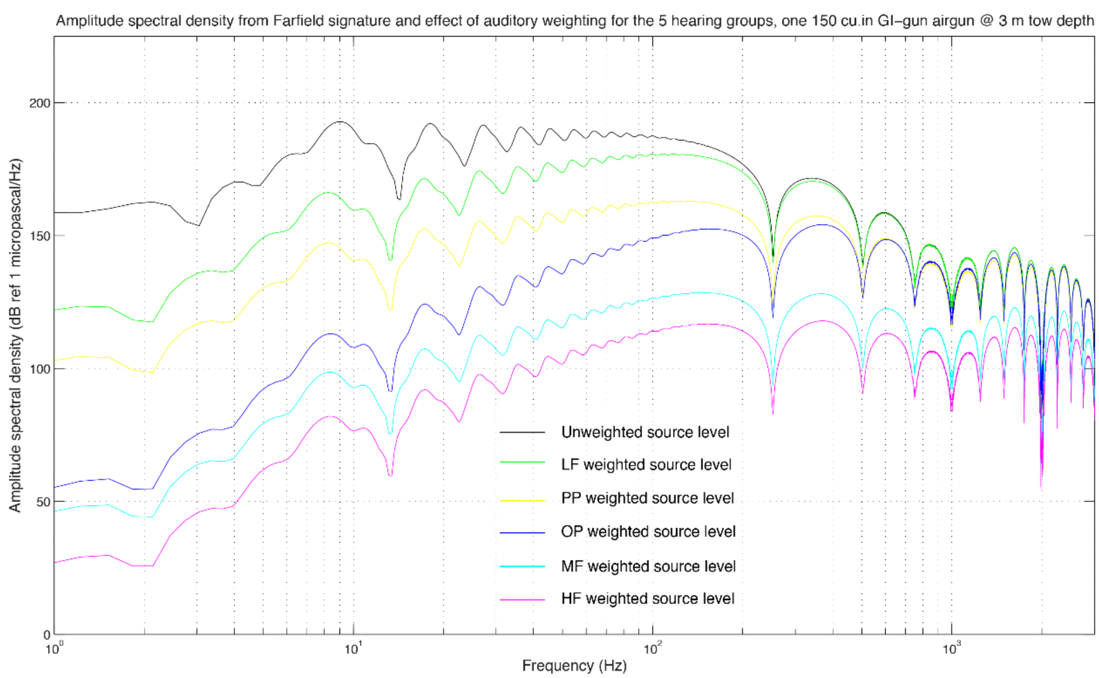


FIGURE 9: Modeled amplitude spectral density of the one 150 cu.in airgun farfield signature. Amplitude spectral density before (black) and after (green, yellow, blue, cyan, magenta) applying the auditory weighting function for the low frequency cetaceans, phocid pinnipeds, otariid pinnipeds, mid frequency 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.

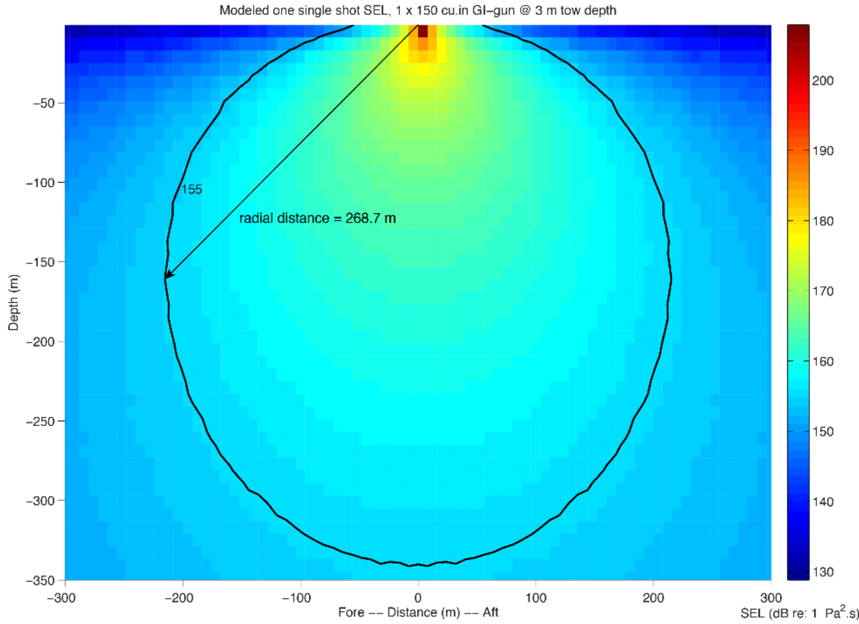


FIGURE 10: Modeled received sound levels (SELs) in deep water from the two 150 cu.in GI-guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (268.687 m).

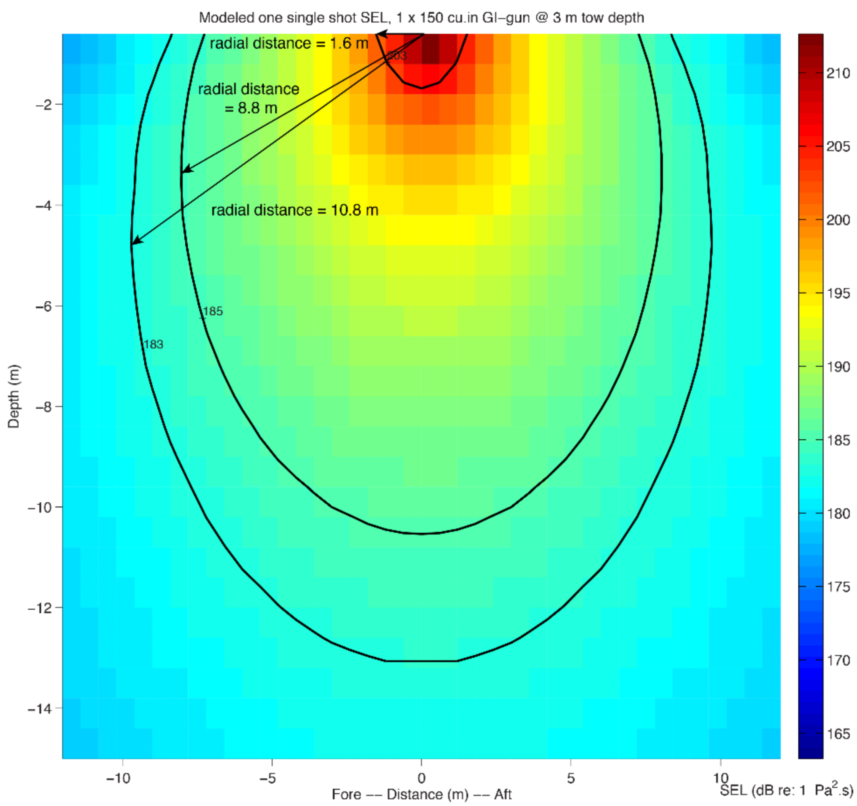


FIGURE 11 : Modeled received sound levels (SELs) in deep water from the one 150 cu.in GI-guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183, 185 and 203 dB SEL isopleths.

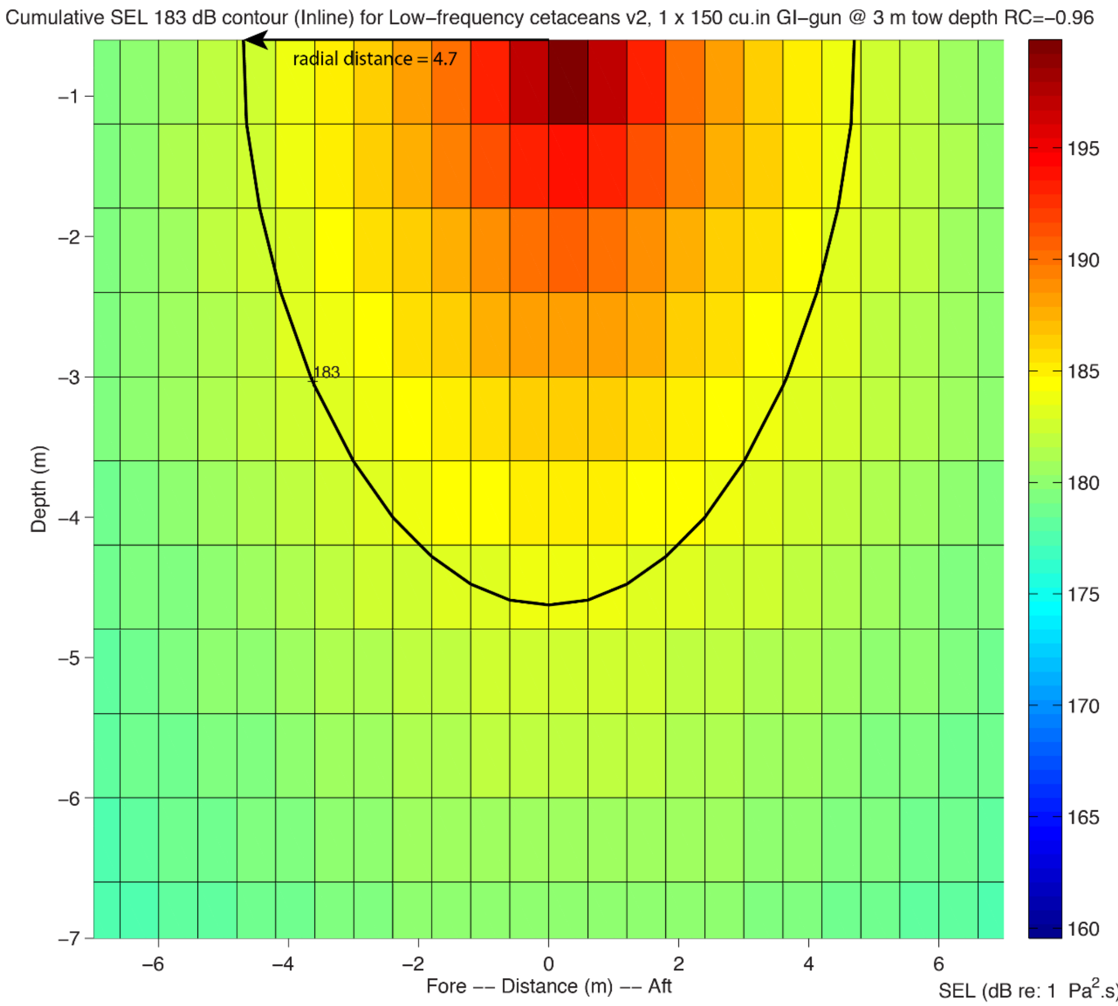


FIGURE 12: Modeled received sound exposure levels (SELs) from the one 150 cu.in GI-guns at a 3-m tow depth, after applying the auditory weighting function for the low frequency cetaceans hearing group following to the new technical guidance. The plot provides the radial distance to the 183-dB SELcum isopleth for one shot. The difference in radial distances between Fig. 4 (10.83 m) and this figure (4.74 m) allows us to estimate the adjustment in dB.

Peak Sound Pressure Level :

TABLE 8. 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 one 150 cu.in GI-gun at a 3 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)	**3.6**	**0.86**	**24.9**	**4.1**	**0.54**

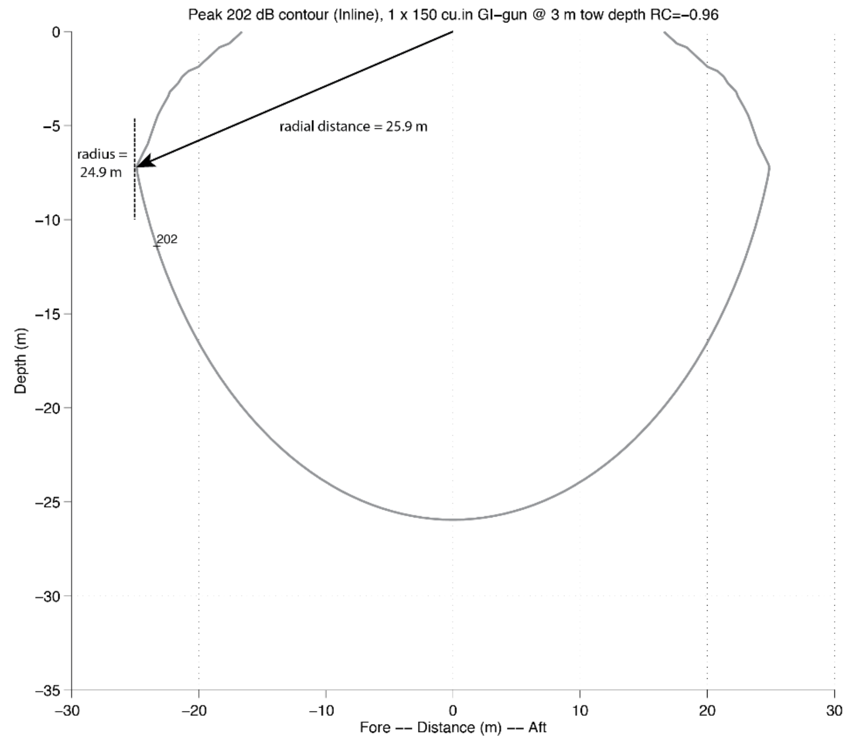


FIGURE 13: Modeled deep-water received Peak SPL from one 150 cu.in airgun at a 3-m tow depth. The plot provides the radius of the 202-dB peak isopleth (24.9 m).

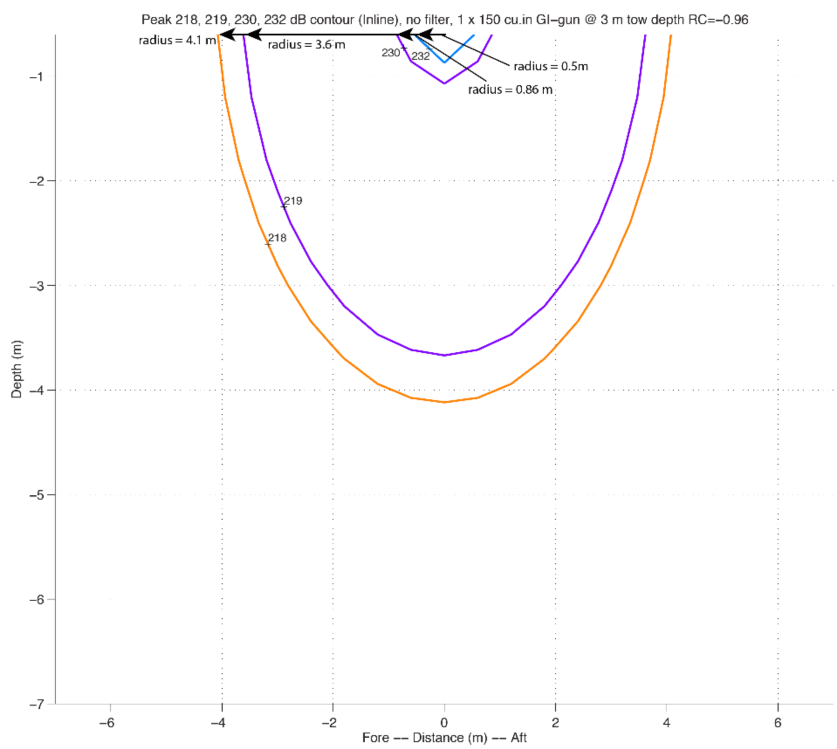


FIGURE 14: Modeled deep-water received Peak SPL from one 150 cu.in airgun at a 3-m tow depth. The plot provides the radius of the 218-219-230 and 232 dB peak isopleths.

Determination of Mitigation Zones for a Two Airgun Array with a Configuration of 1720/1720 cm^3 (2 x 105/105 in^3) (Harmonic Mode)

(2 x 210 cu.in (3 m separation) @ a 3m tow depth)

***Mitigation Zones*.—**During the planning phase, mitigation zones for the proposed marine seismic surveys were calculated based on modeling by L-DEO for both the exclusion and safety zones. 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 210-in^3 GI-guns. This modeling approach uses ray tracing for the direct wave traveling from the array to the receiver and its associated source ghost (reflection at the air-water interface in the vicinity of the array), in a constant-velocity half-space (infinite homogeneous ocean layer, unbounded by a seafloor). In addition, propagation measurements of pulses from the 36-airgun array at a tow depth of 6 m have been reported in deep water (~1600 m), intermediate water depth on the slope (~600–1100 m), and shallow water (~50 m) in the Gulf of Mexico (GoM) in 2007–2008 (Tolstoy et al. 2009; Diebold et al. 2010).

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

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

The proposed surveys would acquire data with two 210 in^3 GI-guns (separated by 3 m) at a tow depth of 3 m. For deep water (>1000 m), we use the deep-water radii obtained from L-DEO model results down to a maximum water depth of 2000 m (Fig. 15 and 16). 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).

The shallow-water radii are obtained by scaling the empirically derived measurements from the GoM calibration survey to account for the differences in volume and tow depth between the calibration survey (6600 cu.in at 6 m tow depth) and the proposed survey (420 cu.in at 3 m tow depth); whereas the shallow water GOM may not exactly replicate the shallow water environment at the proposed survey sites, it has been shown to serve as a good and very conservative proxy (Crone et al. 2014). A simple scaling factor is calculated from the ratios of the isopleths calculated by the deep-water L-DEO model, which are essentially a measure of the energy radiated by the source array:

- The 150-decibel (dB) Sound Exposure Level (SEL)[5] corresponds to deep-water maximum radii of 696 m for the two 210 in^3 GI-guns at 3 m tow depth (Fig. 15), and 7,244 m for the 6600 in^3 at 6-m tow depth (Fig. 16), yielding scaling factors of 0.096 to be applied to the shallow-water 6-m tow depth results.
- The 165-decibel (dB) Sound Exposure Level (SEL) corresponds to deep-water maximum radii of 122.6 m for the two 210 in^3 GI-guns at 3 m tow depth, and 1284 m for a 6-m tow depth, yielding a scaling factor of 0.095 to be applied to the shallow-water 6-m tow depth results.
- Similarly, the 170 dB SEL corresponds to deep-water maximum radii of 69.62 for the two 210 in^3 GI-guns at 3 m tow depth (Fig. 15) and 719 m for the 6600 in^3 at 6-m tow depth (Fig. 16), yielding a scaling factor of 0.096.
- The 185-decibel (dB) Sound Exposure Level (SEL) corresponds to deep-water maximum radii of 13.39 m for the two 210 in^3 at 3-m tow depth, and 126.3 m for a 6-m tow depth, yielding a scaling factor of 0.106 to be applied to the shallow-water 6-m tow depth results.

Measured 160-, 175-, 180-, 190- and 195-dB re 1μPa_{rms} distances in shallow water for the 36-airgun array towed at 6 m depth were 17.5 km, 2.84 km, 1.6 km, 458 m and 240 m, respectively, based on a 95th percentile fit (Tolstoy et al. 2009). Multiplying by the scaling factor to account for the tow depth and discharge volume differences between the 6600 cu.in airgun array at 6 m tow depth and the 420 cu.in GI-gun array at 3 m tow depth yields distances of 1.68 km, 269 m, 153 m, 44 m and 25.44 m, respectively.

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

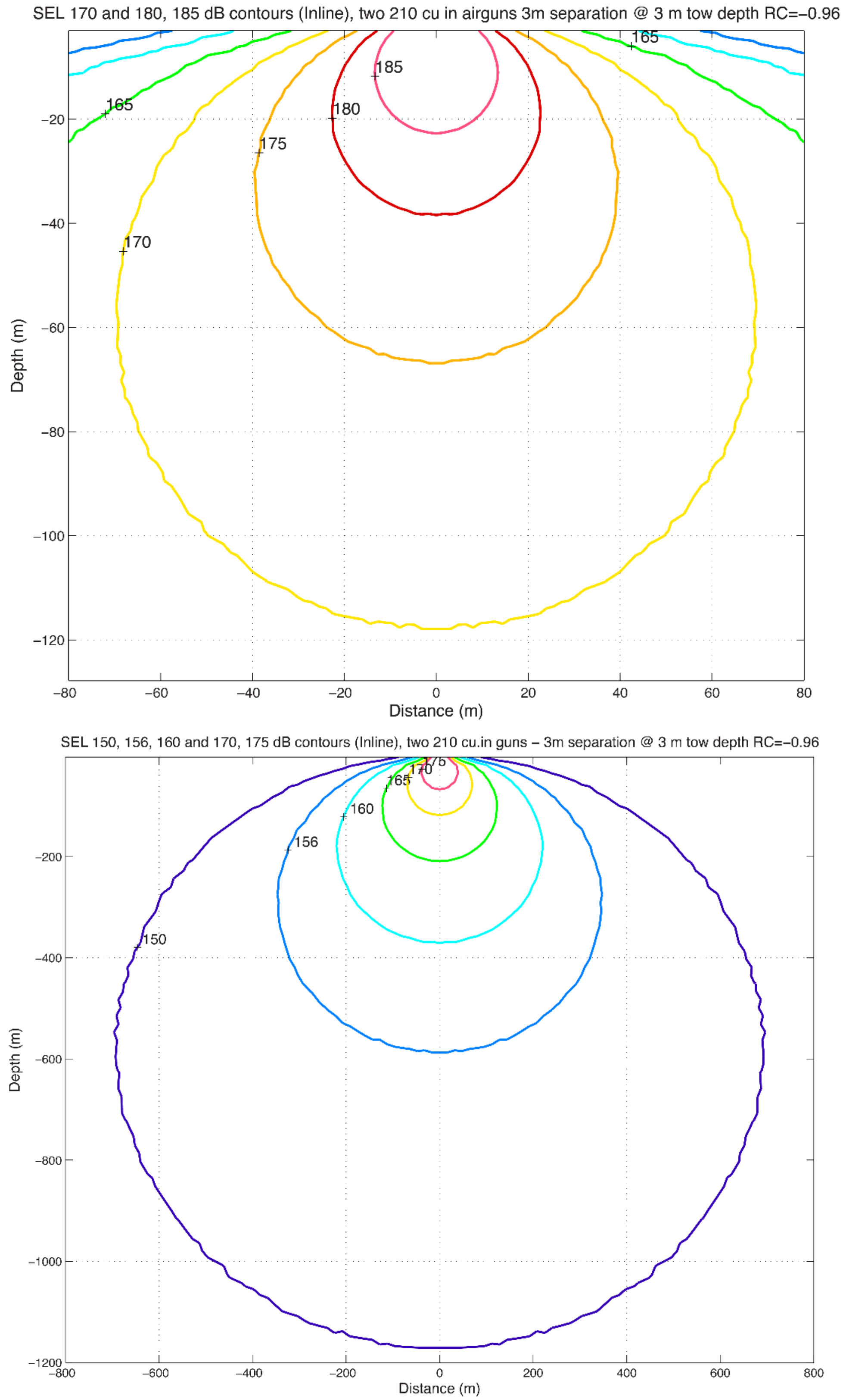


FIGURE 15. Modeled deep-water received sound exposure levels (SELs) from the two 210 in^3 GI-guns planned for use during the proposed surveys in the Antarctic at a 3-m tow depth. Received rms levels (SPLs) are expected to be ~10 dB higher. The plot at the top provides the radius to the 170-dB SEL isopleth as a proxy for the 180-dB rms isopleth, and the plot at the bottom provides the radius to the 150 and 165-dB SEL isopleths as a proxy for the 160 and 175-dB rms isopleths.

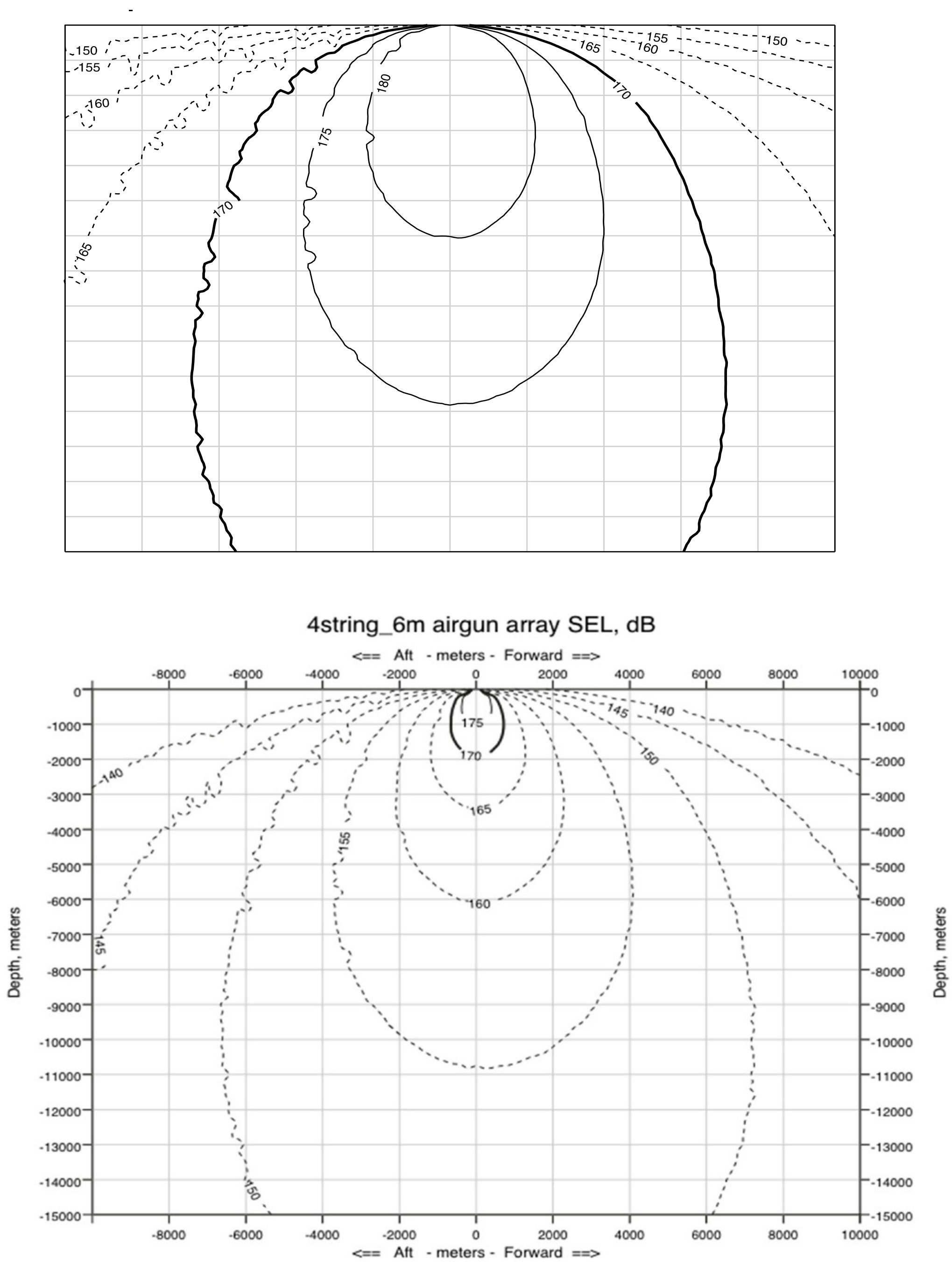


FIGURE 16. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array at a 6-m tow depth used during the GoM calibration survey. Received rms levels (SPLs) are expected to be ~10 dB higher. The plot at the top provides the radius to the 170 dB SEL isopleth as a proxy for the 180-dB rms isopleth, and the plot at the bottom provides the radius to the 150-dB SEL isopleth as a proxy for the 160-dB rms isopleth.

Table 9 shows the distances at which the 160-, 175-, 180-, 190 and 195-dB re 1µPa_{rms} sound levels are expected to be received for the two 210 in^3 GI-guns at 3 m tow depth. . The 160-dB level is the behavioral disturbance criterion (Level B) that is used by NMFS to estimate anticipated takes for marine mammals; a 175-dB level is used by the National Marine Fisheries Service (NMFS) to determine behavioral disturbance for sea turtles.

A recent retrospective analysis of acoustic propagation of *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 *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, preliminary analysis by Crone (2015, L-DEO, pers. comm., Crone et al., 2017) of data collected 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 the *Langseth* hydrophone streamer were similarly 2–3 times smaller than the predicted operational mitigation radii. In fact, five separate comparisons conducted of the L-DEO model with *in situ* received levels[6] have confirmed that the L-DEO model generated conservative exclusion zones, resulting in significantly larger EZs than necessary.

Southall et al. (2007) made detailed recommendations for new science-based noise exposure criteria. In 2018, NOAA published a revised version of its 2016 guidance for assessing the effects of anthropogenic sound on marine mammals (NOAA 2018). This assessment has been prepared in accordance with the current NOAA acoustic practices, and *also take into consideration* best practices noted by Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013), Wright (2014), and Wright and Cosentino (2015).

Enforcement of mitigation zones via power and shut downs would be implemented in the Operational Phase.

TABLE 9. Predicted distances to which sound levels ≥ 195, 190-, 180-, 175-, and 160-dB re 1 µPa_{rms} are expected to be received during the proposed surveys in the Northwest Atlantic Ocean. For the single mitigation airgun, the 100 m EZ is the conservative EZ for all low-energy acoustic sources defined in the PEIS for water depths >100 m that would be used during airgun operations and the EZ in parentheses is the modeled distance for water depths <100 m[5].

Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted rms Radii (m)				
			195 dB	190dB	180 dB	175 dB	160 dB
two 210 in^3 G-guns, 3 m separation	3	>1000 m	100[4] (13)	100[4](23)	100[4] (70)	123[1]	696[1]
		100–1000 m	100[4](20)	100[4](34)	105	185[2]	1,044[2]
		<100 m	25[3]	44[3]	153[3]	269[3]	1,680[3]

[1] Distance is based on L-DEO model results.
[2] Distance is based on L-DEO model results with a 1.5 x correction factor between deep and intermediate water depths.
[3] Distance is based on empirically derived measurements in the GoM with scaling applied to account for differences in tow depth.
[4] Modeled distances based on empirically derived measurements in the GoM are smaller.

[6] 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 2015, L-DEO, pers. comm.)

Peak and cumulative sound exposure levels (SEL) were estimated and reported in Tables 10, 11, and 12. Graphic depiction of modeled SEL are provided in Figures 15-20.

SELcum 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
** shot interval will be assume to be 5 seconds

Table 10. Table showing the results for 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 SELcum threshold is the largest. A propagation of 20 $\log_{10}$ (radial distance) is used to estimate the modified farfield SEL.

SEL_{cum} Threshold	**183**	**185**	**155**	**185**	**203**
Distance(m) (no weighting function)	21.5776	16.9734	552.7979	16.9734	2.4888
Modified Farfield SEL*	209.6801	209.5954	209.8512	209.5954	210.9198
Distance (m) (with weighting function)	10.5962	**N/A**	**N/A**	**N/A**	**N/A**
Adjustment (dB)	-6.09	**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 183dB SEL cum isopleth is the largest. We first run the modeling for one single shot without applying any weighting function. The maximum 183dB SEL cum isopleth is located at 21.58 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 10.60 m from the source. Difference between 21.58 m and 10.60 m gives an adjustment factor of -6.09 dB assuming a propagation of 20log10(R).

TABLE 11. Results for single shot SEL source level modeling for the two 210 in^3 airguns with weighting function calculations for SEL_{cum} criteria.

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	209.6801	209.5954	209.8512	209.5954	210.9198
Source Factor	1.85798E+20	1.82209E+20	1.93264E+20	1.82209E+20	2.47178E+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)	31.1	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)†	-6.09	-55.09	-64.39	-24.14	-31.05

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)	**31.1**	**0.0**	**0.0**	**0.3**	**0.0**

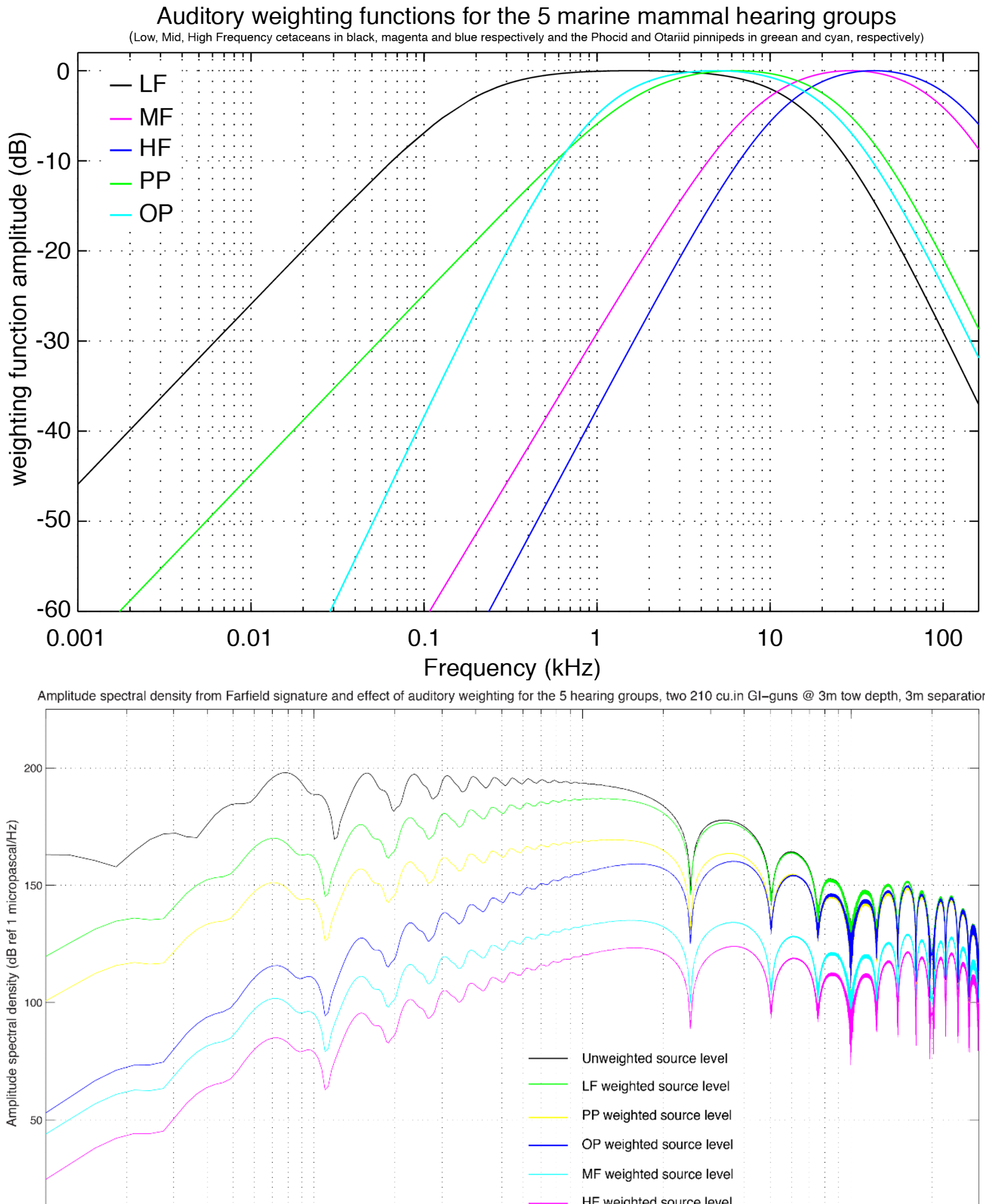


FIGURE 15: Modeled amplitude spectral density of the two 210 cu.in airgun farfield signature. Amplitude spectral density before (black) and after (green, yellow, blue, cyan, magenta) applying the auditory weighting function for the Low Frequency Cetaceans, Phocid Pinnipeds, Otariid Pinnipeds, Mid Frequency 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.

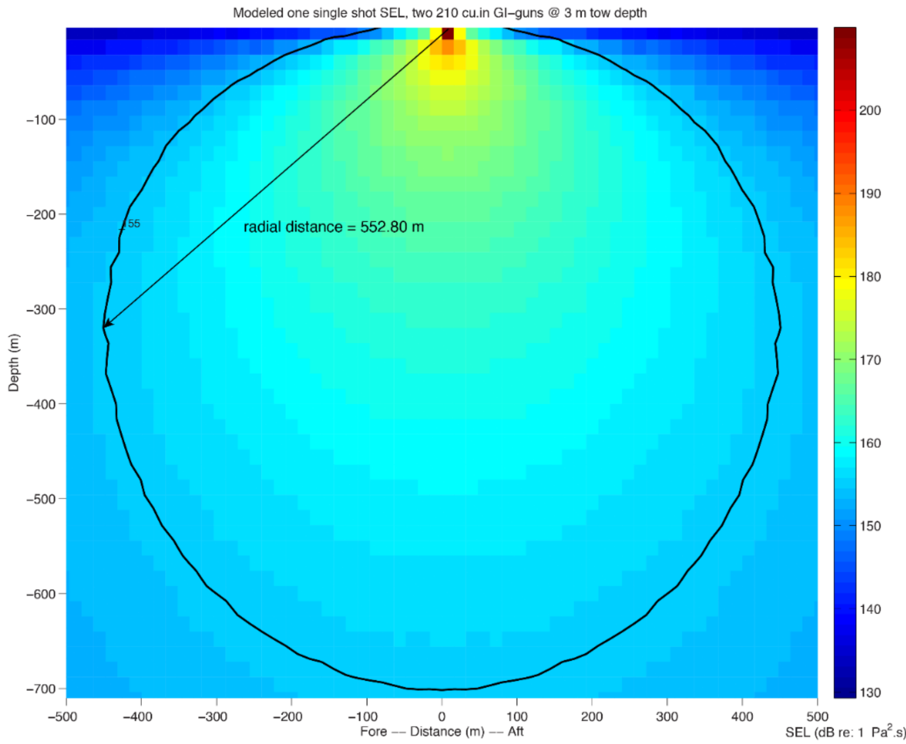


FIGURE 16: Modeled received sound levels (SELs) in deep water from the two 210 cu.in GI-guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (552.7979 m).

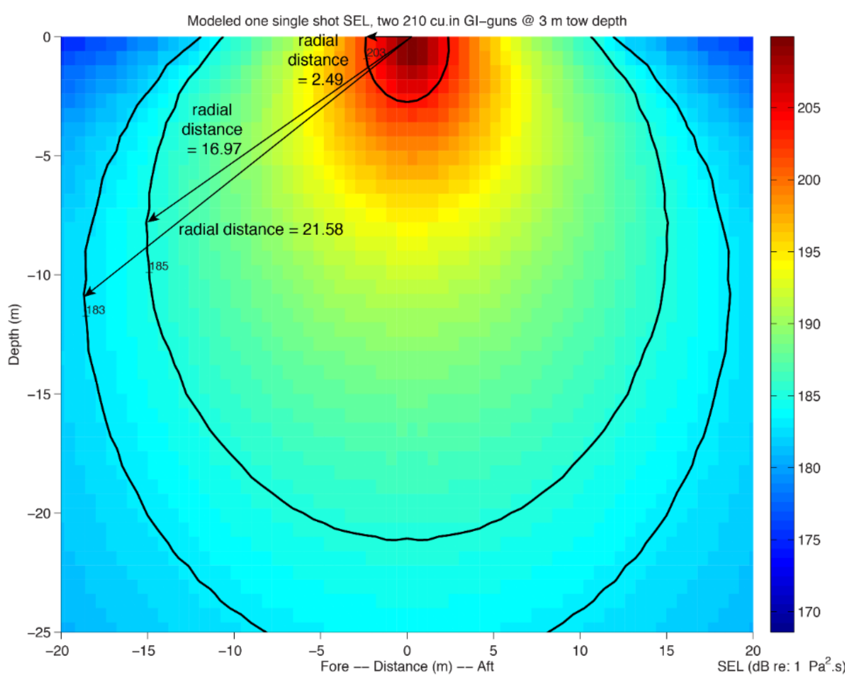


FIGURE 17. Modeled received sound levels (SELs) in deep water from the two 210 cu.in GI-guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183 and 185 dB SEL isopleths.

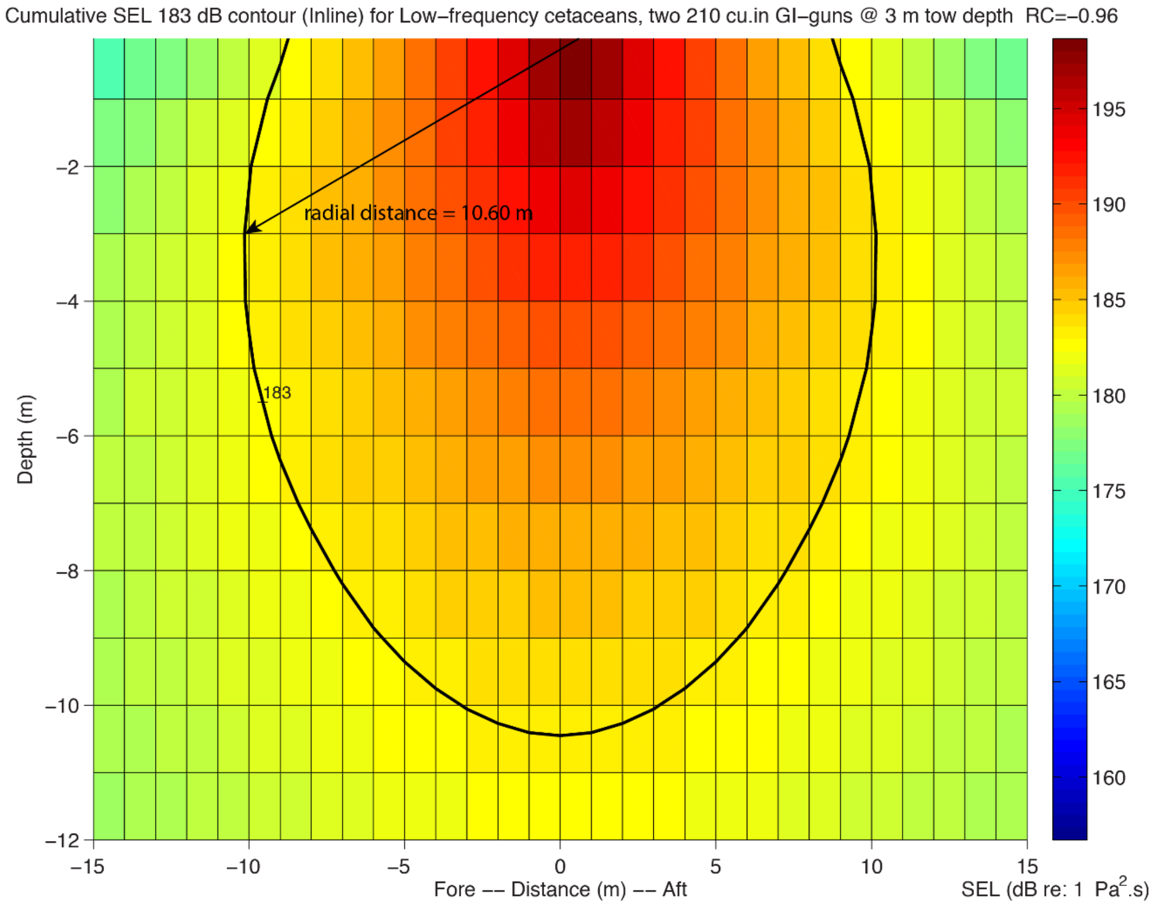


FIGURE 18. Modeled received sound exposure levels (SELs) from the two 210 cu.in GI-guns at a 3-m tow depth, after applying the auditory weighting function for the Low Frequency Cetaceans hearing group following to the new technical guidance. The plot provides the radial distance to the 183-dB SELcum isopleth for one shot. The difference in radial distances between Fig. 17 (21.58 m) and this figure (10.60 m) allows us to estimate the adjustment in dB.

Peak Sound Pressure Level

TABLE 12. 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 210 cu.in airguns at a 3 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)	**7.55**	**1.58**	**51.14**	**8.47**	**0.83**

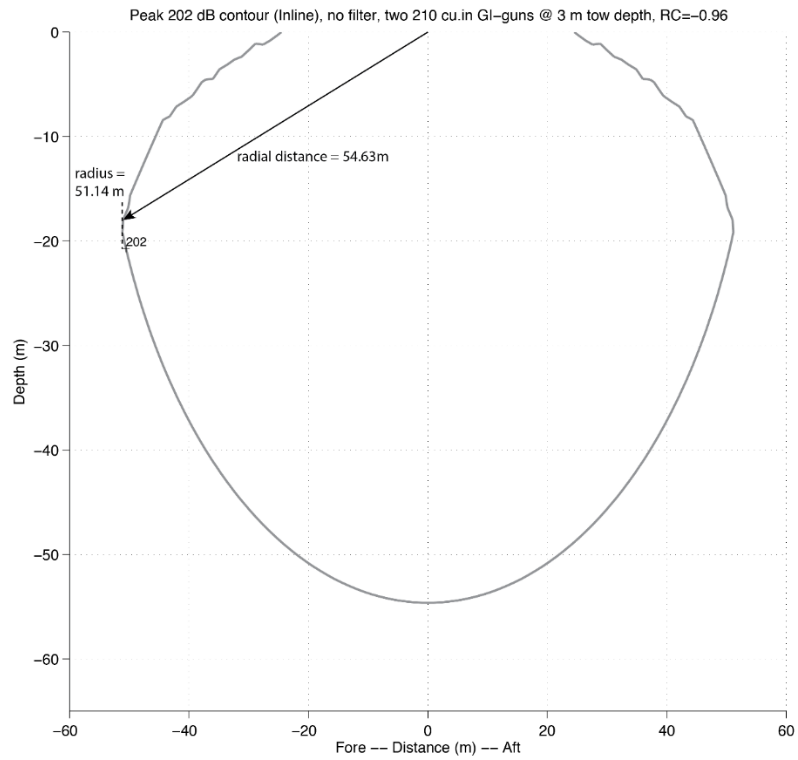


FIGURE 19. Modeled deep-water received Peak SPL from two 210 cu.in airguns at a 3-m tow depth. The plot provides the radius of the 202-dB peak isopleth (54.63 m).

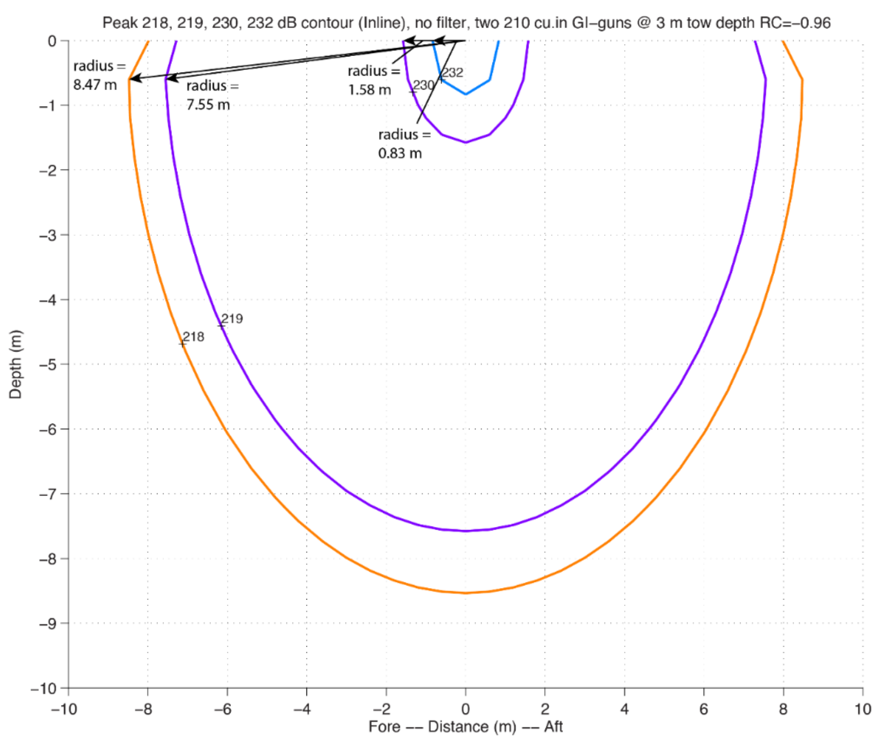


FIGURE 20. Modeled deep-water received Peak SPL from two 210 cu.in airguns at a 3-m tow depth. The plot provides the radius of the 218-219-230 and 232 dB peak isopleths.

Determination of Mitigation Zones for a One Airgun Array with a Configuration of 1720/1720 cm^3 (1 x 105/105 in^3) (Harmonic Mode)

(1 x 210 cu.in (3 m separation) @ a 3m tow depth [total volume 210])

***Mitigation Zones*.—**During the planning phase, mitigation zones for the proposed marine seismic surveys were calculated based on modeling by L-DEO for both the exclusion and safety zones. 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 one 210-in^3 GI-gun. This modeling approach uses ray tracing for the direct wave traveling from the array to the receiver and its associated source ghost (reflection at the air-water interface in the vicinity of the array), in a constant-velocity half-space (infinite homogeneous ocean layer, unbounded by a seafloor). In addition, propagation measurements of pulses from the 36-airgun array at a tow depth of 6 m have been reported in deep water (~1600 m), intermediate water depth on the slope (~600–1100 m), and shallow water (~50 m) in the Gulf of Mexico (GoM) in 2007–2008 (Tolstoy et al. 2009; Diebold et al. 2010).

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

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

The proposed surveys would acquire data with one 210 in^3 GI-gun (separated by 3 m) at a tow depth of 3 m. For deep water (>1000 m), we use the deep-water radii obtained from L-DEO model results down to a maximum water depth of 2000 m (Fig. 21 and 22). 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).

The shallow-water radii are obtained by scaling the empirically derived measurements from the GoM calibration survey to account for the differences in volume and tow depth between the calibration survey (6600 cu.in at 6 m tow depth) and the proposed survey (210 cu.in at 3 m tow depth); whereas the shallow water GOM may not exactly replicate the shallow water environment at the proposed survey sites, it has been shown to serve as a good and very conservative proxy (Crone et al. 2014). A simple scaling factor is calculated from the ratios of the isopleths calculated by the deep-water L-DEO model, which are essentially a measure of the energy radiated by the source array:

- The <u>150-decibel (dB)</u> Sound Exposure Level (SEL)[7] corresponds to deep-water maximum radii of 354.43 m for the one 210 in^3 GI-gun at 3 m tow depth (Fig. 21), and 7,244 m for the 6600 in^3 at 6-m tow depth (Fig. 22), yielding scaling factors of 0.049 to be applied to the shallow-water 6-m tow depth results.
- The <u>165-decibel (dB)</u> Sound Exposure Level (SEL) corresponds to deep-water maximum radii of 63.36 m for the one 210 in^3 GI-gun at 3 m tow depth, and 1,284 m for a 6-m tow depth, yielding a scaling factor of 0.049 to be applied to the shallow-water 6-m tow depth results.
- Similarly, <u>the 170 dB SEL</u> corresponds to deep-water maximum radii of 36.32 for the one 210 in^3 GI-gun at 3 m tow depth (Fig. 21) and 719 m for the 6600 in^3 at 6-m tow depth (Fig. 22), yielding a scaling factor of 0.050.
- The <u>185-decibel</u> (dB) Sound Exposure Level (SEL) corresponds to deep-water maximum radii of 7.736 m for the one 210 in^3 at 3-m tow depth, and 126.3 m for a 6-m tow depth, yielding a scaling factor of 0.061 to be applied to the shallow-water 6-m tow depth results.

Measured 160-, 175-, 180-, 190- and 195-dB re 1μPa_{rms} distances in shallow water for the 36-airgun array towed at 6 m depth were 17.5 km, 2.84 km, 1.6 km, 458 m and 240 m, respectively, based on a 95th percentile fit (Tolstoy et al. 2009). Multiplying by the scaling factor to account for the tow depth and discharge volume differences between the 6600 cu.in airgun array at 6 m tow depth and the 210 cu.in GI-gun at 3 m tow depth yields distances of 856 m, 140 m, 81 m, 28 m and 14.7 m, respectively.

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

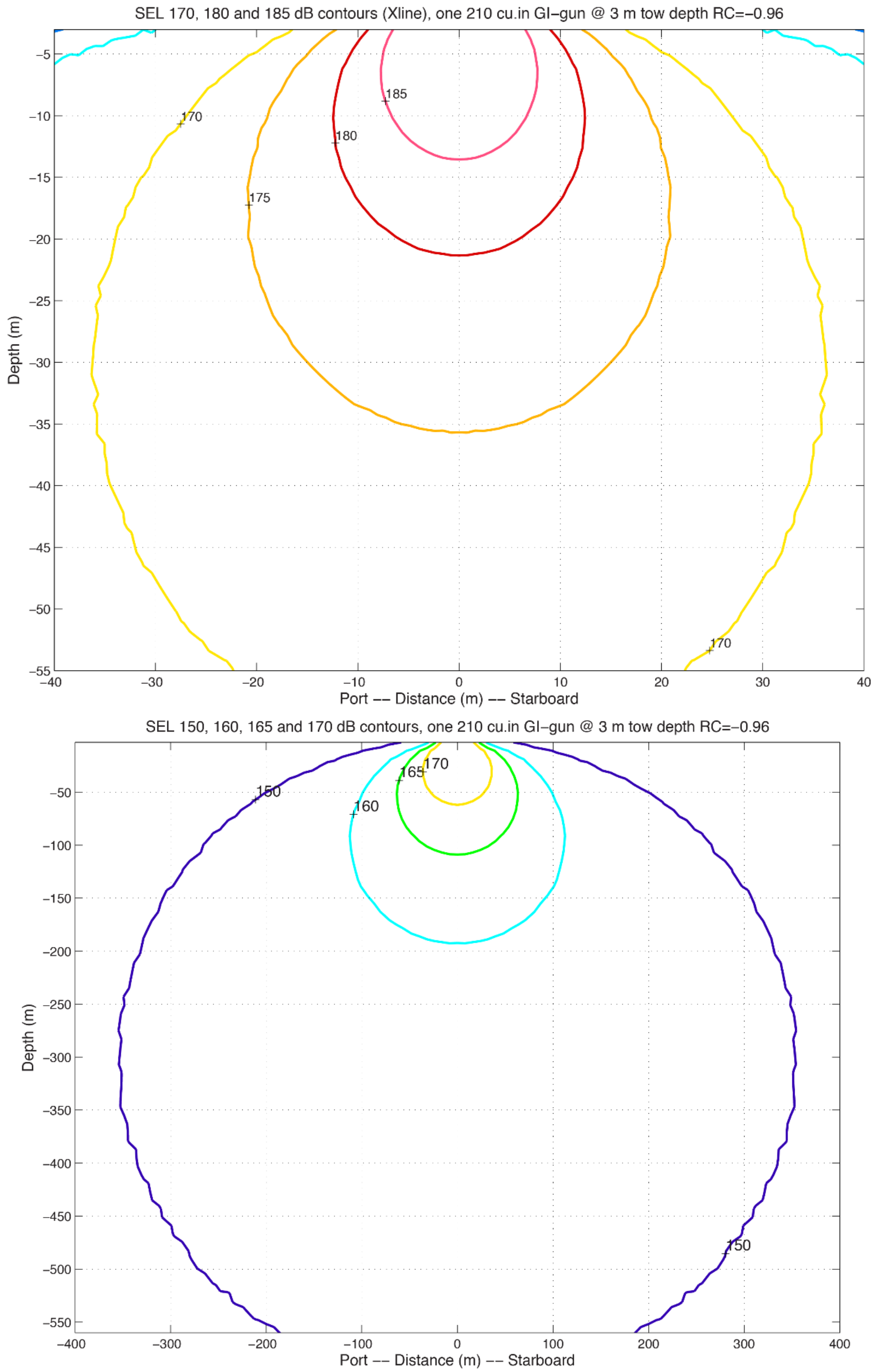


FIGURE 21. Modeled deep-water received sound exposure levels (SELs) from the one 210 in^3 GI-gun planned for use during the proposed surveys in the Antarctic at a 3-m tow depth. Received rms levels (SPLs) are expected to be ~10 dB higher. The plot at the top provides the radius to the 170-dB SEL isopleth as a proxy for the 180-dB rms isopleth, and the plot at the bottom provides the radius to the 150 and 165-dB SEL isopleths as a proxy for the 160 and 175-dB rms isopleths.

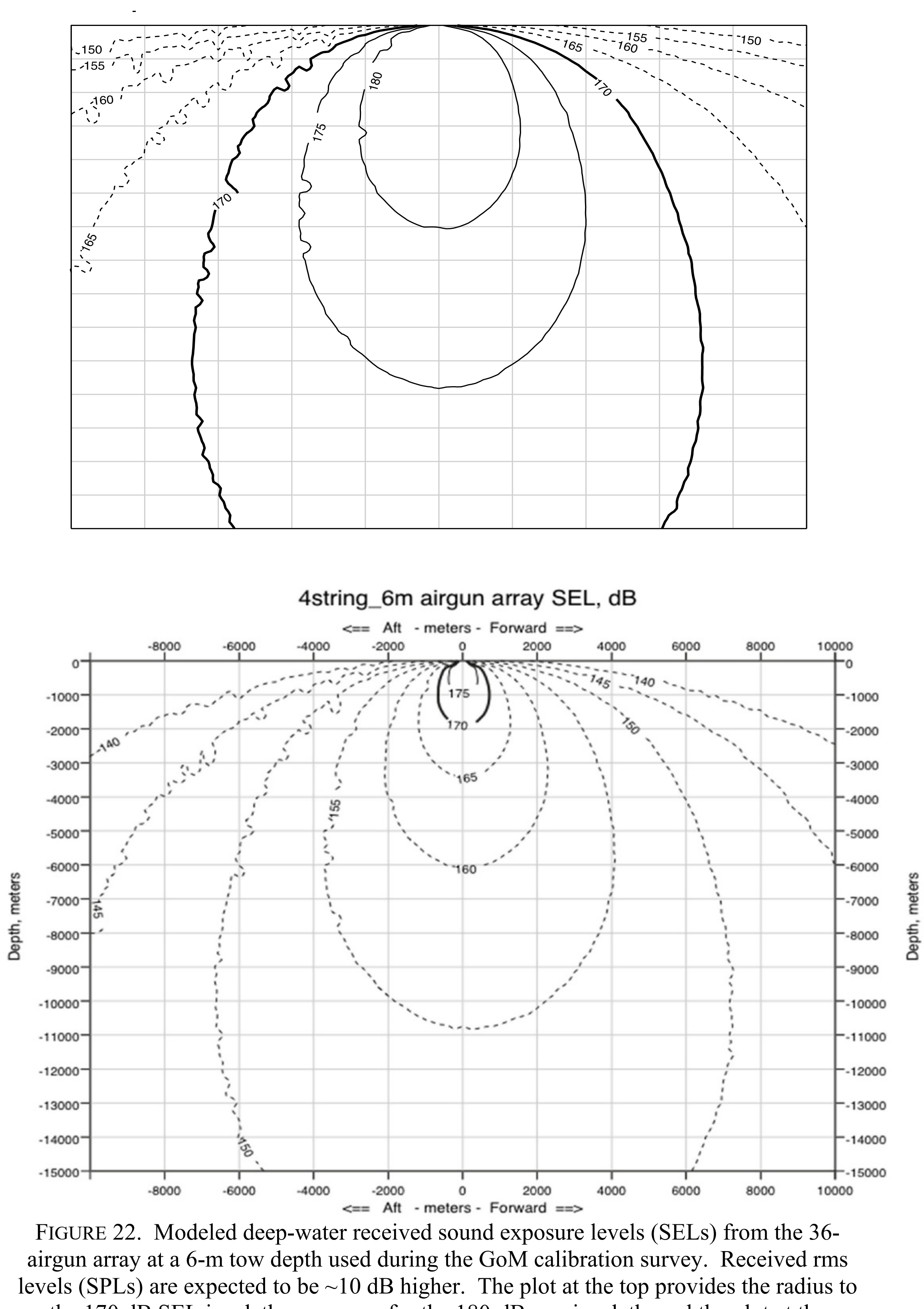


FIGURE 22. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array at a 6-m tow depth used during the GoM calibration survey. Received rms levels (SPLs) are expected to be ~10 dB higher. The plot at the top provides the radius to the 170 dB SEL isopleth as a proxy for the 180-dB rms isopleth, and the plot at the bottom provides the radius to the 150-dB SEL isopleth as a proxy for the 160-dB rms isopleth.

Table 13 shows the distances at which the 160-, 175-, 180-, 190 and 195-dB re 1μPa_{rms} sound levels are expected to be received for the one 210 in^3 GI-gun at 3 m tow depth. . The 160-dB level is the behavioral disturbance criterion (Level B) that is used by NMFS to estimate anticipated takes for marine mammals; a 175-dB level is used by the National Marine Fisheries Service (NMFS) to determine behavioral disturbance for sea turtles.

A recent retrospective analysis of acoustic propagation of *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 *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, preliminary analysis by Crone (2015, L-DEO, pers. comm., Crone et al., 2017) of data collected 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 the *Langseth* hydrophone streamer were similarly 2–3 times smaller than the predicted operational mitigation radii. In fact, five separate comparisons conducted of the L-DEO model with *in situ* received levels[8] have confirmed that the L-DEO model generated conservative exclusion zones, resulting in significantly larger EZs than necessary.

Southall et al. (2007) made detailed recommendations for new science-based noise exposure criteria. In 2018, NOAA published a revised version of its 2016 guidance for assessing the effects of anthropogenic sound on marine mammals (NOAA 2018). This assessment has been prepared in accordance with the current NOAA acoustic practices, and *also take into consideration* best practices noted by Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013), Wright (2014), and Wright and Cosentino (2015).

Enforcement of mitigation zones via power and shut downs would be implemented in the Operational Phase.

TABLE 13. Predicted distances to which sound levels ≥ 195, 190-, 180-, 175-, and 160-dB re 1 μPa_{rms} are expected to be received during the proposed surveys in the Antarctica. For the single mitigation airgun, the 100 m EZ is the conservative EZ for all low-energy acoustic sources defined in the PEIS for water depths >100 m that would be used during airgun operations and the EZ in parentheses is the modeled distance for water depths <100 m[5].

Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted rms Radii (m)				
			195 dB	190dB	180 dB	175 dB	160 dB
one 210 in^3 G-gun	3	>1000 m	100[4] (7.73)	100[4](12)	100[4] (36)	63[1]	354[1]
		100–1000 m	100[4](12)	100[4](18)	100(54)	95[2]	531[2]
		<100 m	15[3]	28[3]	81[3]	140[3]	856[3]

[1] Distance is based on L-DEO model results.
[2] Distance is based on L-DEO model results with a 1.5 x correction factor between deep and intermediate water depths.
[3] Distance is based on empirically derived measurements in the GoM with scaling applied to account for differences in tow depth.
[4] Modeled distances based on empirically derived measurements in the GoM are smaller.

[8] 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 2015, L-DEO, pers. comm.)

Peak and cumulative sound exposure levels (SEL) were estimated and reported in Tables 14, 15, and 16. Graphic depiction of modeled SEL are provided in Figures 23-28.

SELcum 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
** shot interval will be assume to be 5 seconds

Table 14. Table showing the results for 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 SELcum threshold is the largest. A propagation of 20 $\log_{10}$ (Radial distance) is used to estimate the modified farfield SEL.

SEL_{cum} Threshold	**183**	**185**	**155**	**185**	**203**
Distance(m) (no weighting function)	11.2989	9.2153	285.3444	9.2153	1.7563
Modified Farfield SEL*	204.0607	204.2902	204.1074	204.2902	207.8920
Distance (m) (with weighting function)	4.9614	**N/A**	**N/A**	**N/A**	**N/A**
Adjustment (dB)	-7.1486	**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 183dB SEL cum isopleth is the largest. We first run the modeling for one single shot without applying any weighting function. The maximum 183dB SEL cum isopleth is located at 11.30 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 4.96 m from the source. Difference between 11.30 m and 4.96 m gives an adjustment factor of -7. 1486 dB assuming a propagation of 20log10(R).

TABLE 15. Results for single shot SEL source level modeling for the one 210 in^3 airgun with weighting function calculations for SEL_{cum} criteria.

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	204.0607	204.2902	204.1074	204.2902	207.892
Source Factor	5.09448E+19	5.37094E+19	5.14956E+19	5.37094E+19	1.23092E+20

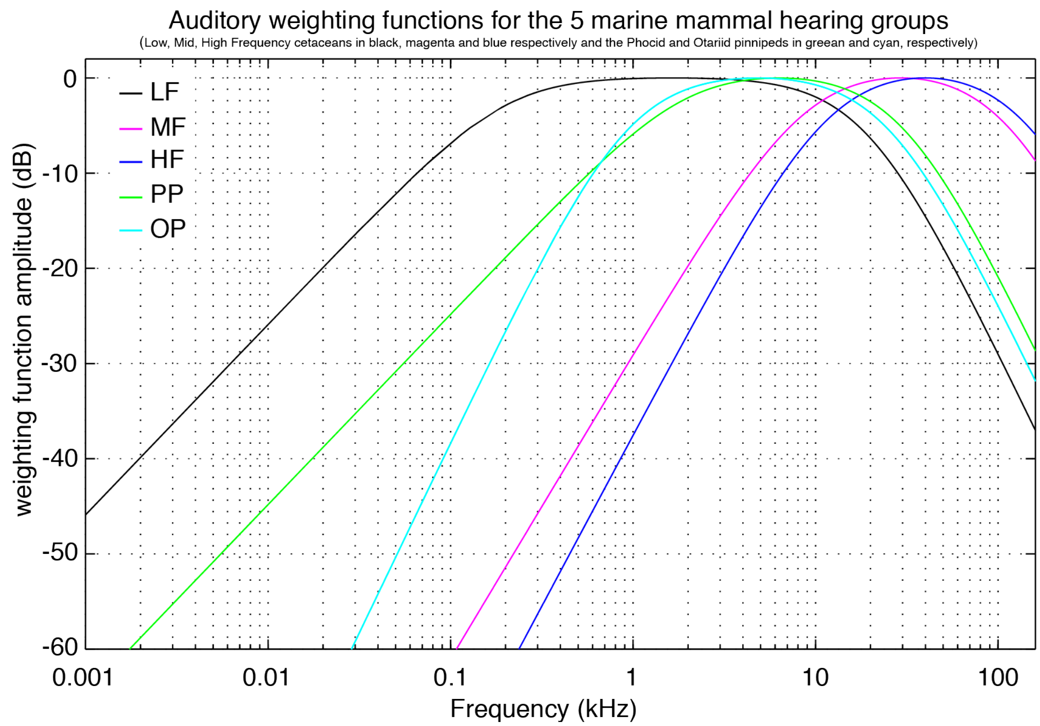
RESULTANT ISOPLETHS* *Impulsive sounds have dual metric thresholds (SELcum & PK). Metric producing largest isopleth should be used.

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)	6.7	0.0	0.0	0.1	0.0

WEIGHTING FUNCTION CALCULATIONS

Weighting Function Parameters	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	
a	1	1.6	1.8	1	2	
b	2	2	2	2	2	
f_1	0.2	8.8	12	1.9	0.94	
f_2	19	110	140	30	25	
C	0.13	1.2	1.36	0.75	0.64	
Adjustment (dB)†	-7.15	-55.39	-64.71	-24.38	-31.36	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)	**6.7**	**0.0**	**0.0**	**0.1**	**0.0**



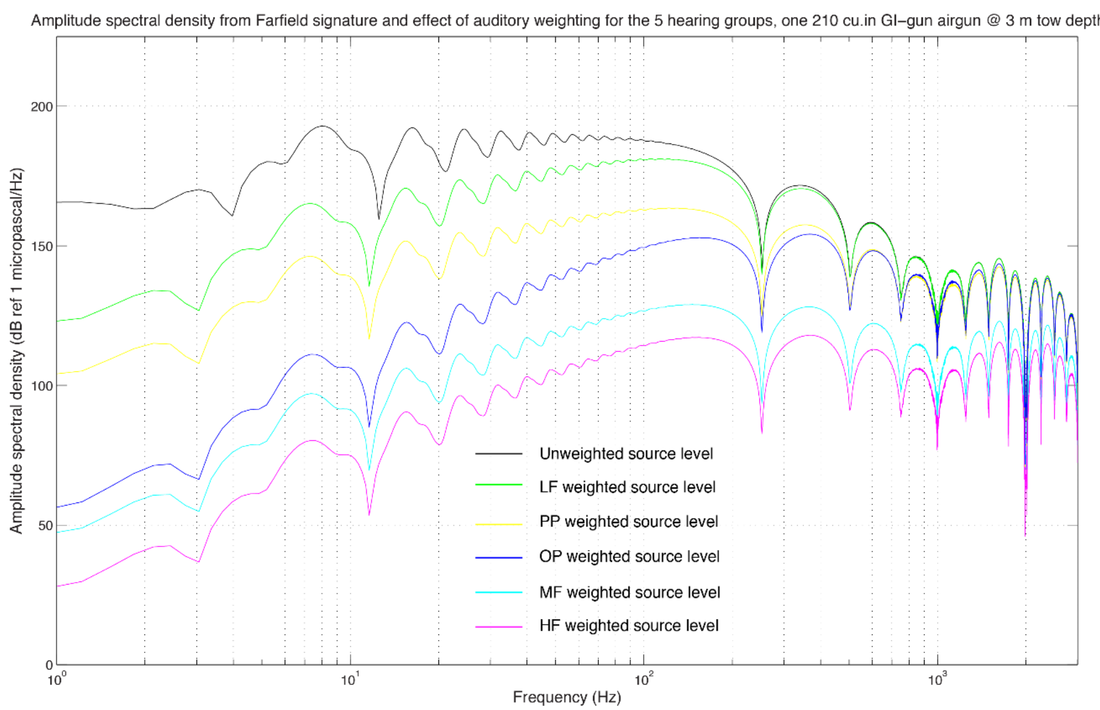


FIGURE 23. Modeled amplitude spectral density of the one 210 cu.in airgun farfield signature. Amplitude spectral density before (black) and after (green, yellow, blue, cyan, magenta) applying the auditory weighting function for the low frequency cetaceans, phocid pinnipeds, otariid pinnipeds, mid frequency 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.

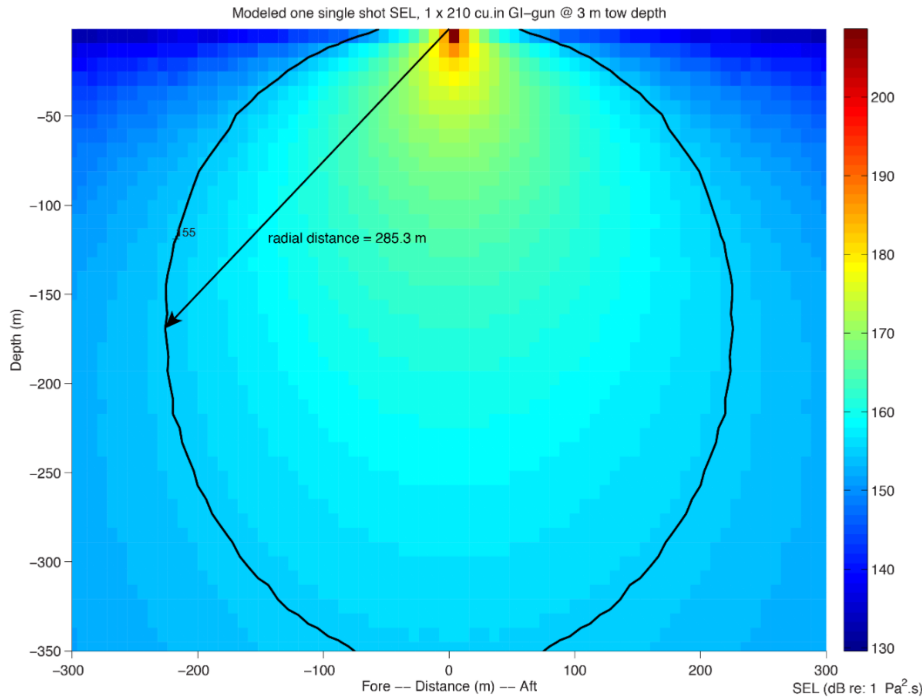


FIGURE 24. Modeled received sound levels (SELs) in deep water from the two 210 cu.in GI-guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (285.34 m).

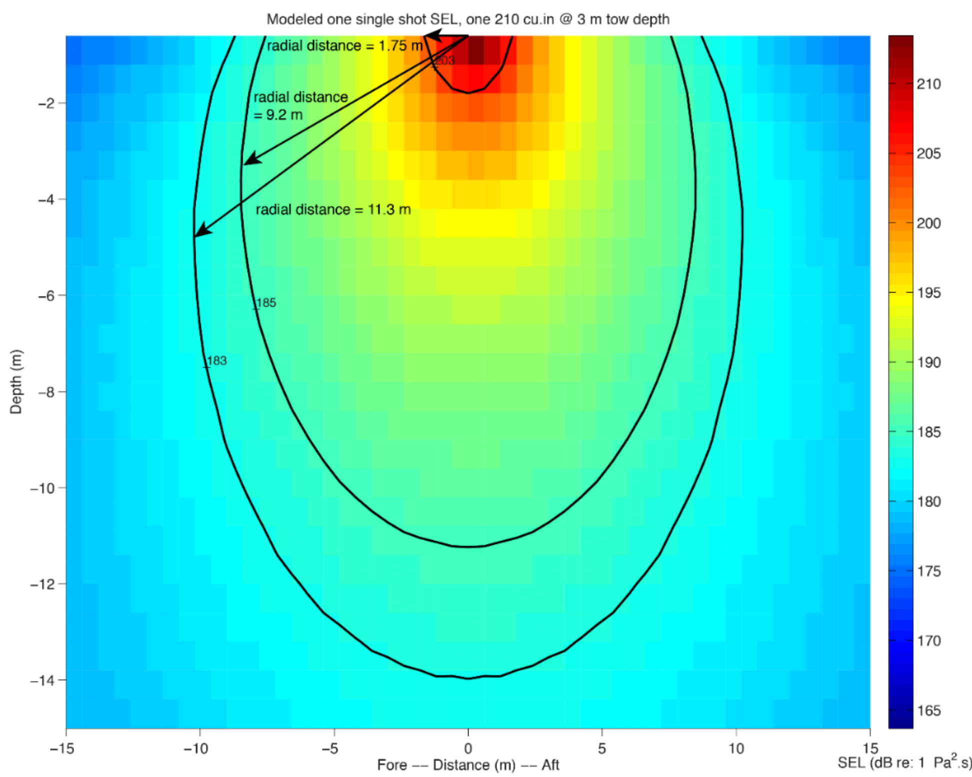


FIGURE 25. Modeled received sound levels (SELs) in deep water from the one 210 cu.in GI-guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183, 185 and 203 dB SEL isopleths.

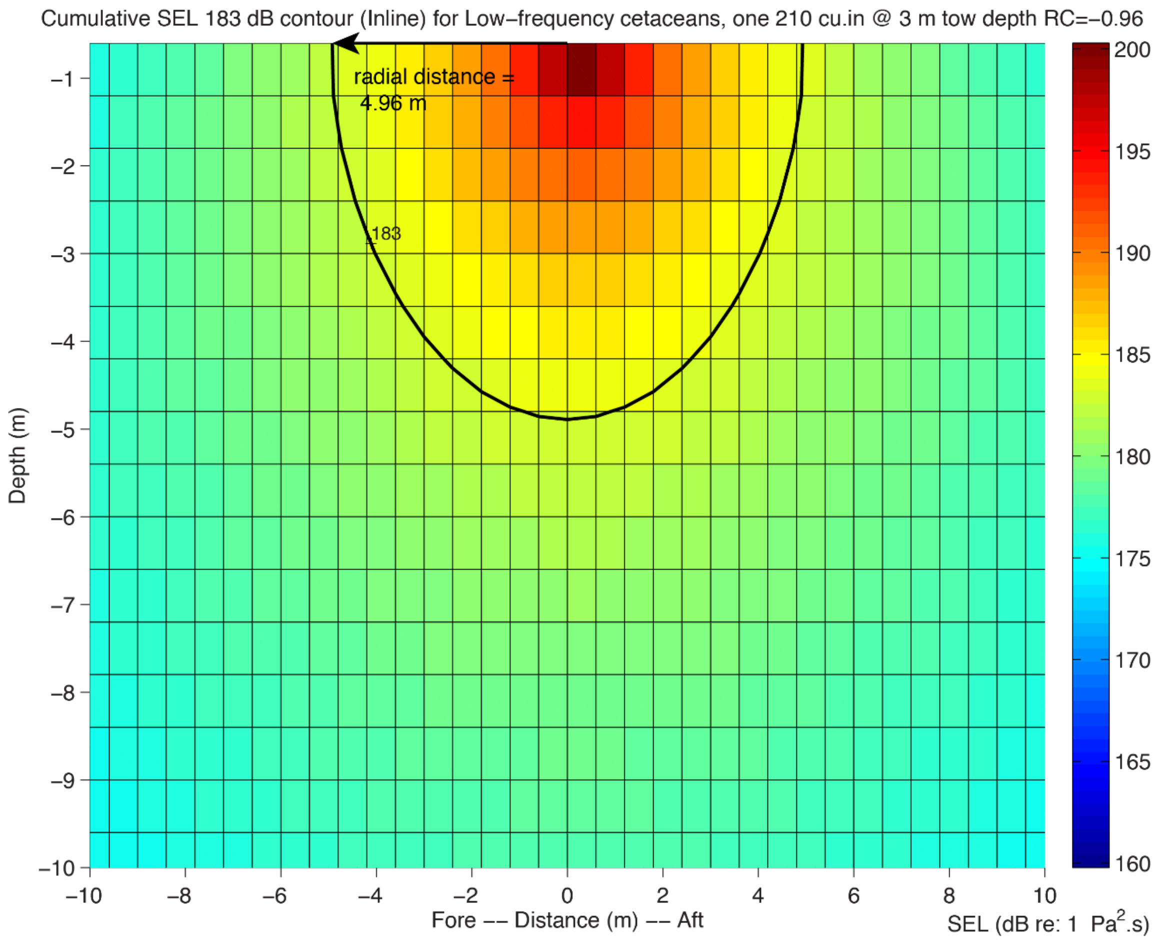


FIGURE 26. Modeled received sound exposure levels (SELs) from the one 210 cu.in GI-guns at a 3-m tow depth, after applying the auditory weighting function for the low frequency cetaceans hearing group following to the new technical guidance. The plot provides the radial distance to the 183-dB SELcum isopleth for one shot. The difference in radial distances between Fig. 25 (11.3 m) and this figure (4.96 m) allows us to estimate the adjustment in dB.

Peak Sound Pressure Level

TABLE 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 one 210 cu.in GI-gun at a 3 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)	**3.8**	**0.9**	**26.2**	**4.3**	**0.62**

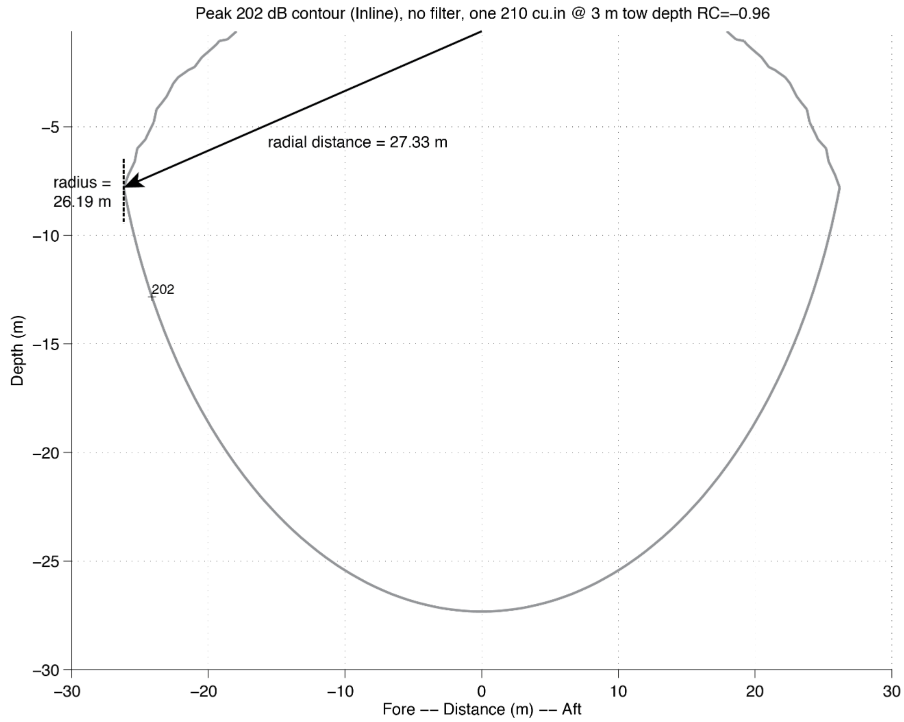


FIGURE 27. Modeled deep-water received Peak SPL from one 210 cu.in airgun at a 3-m tow depth. The plot provides the radius of the 202-dB peak isopleth (24.9 m).

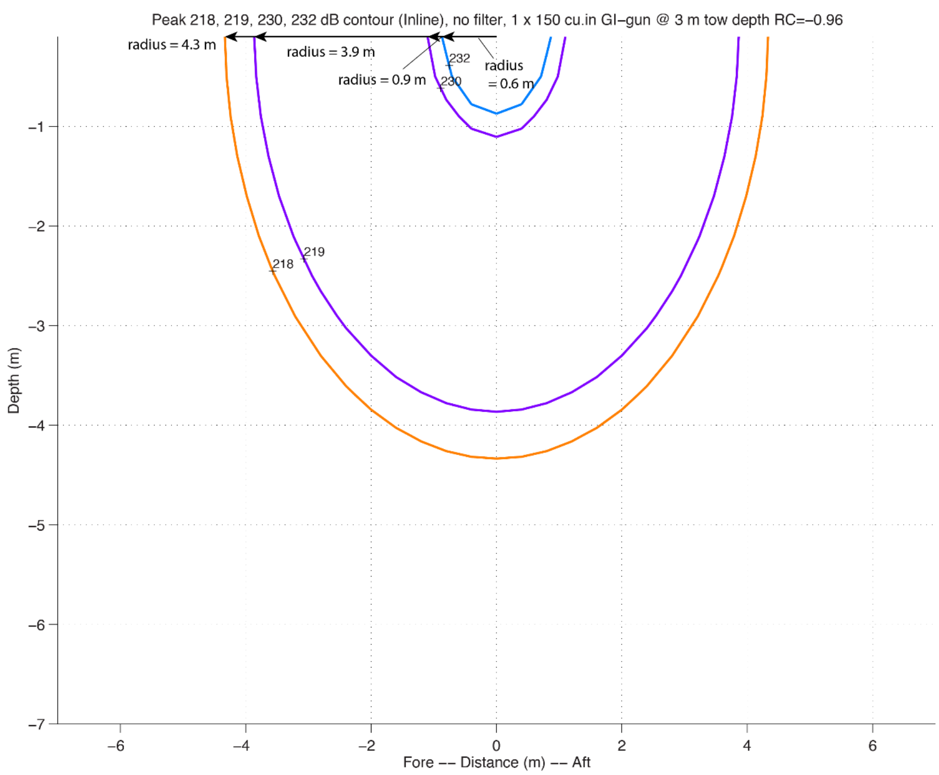


FIGURE 28. Modeled deep-water received Peak SPL from one 210 cu.in airgun at a 3-m tow depth. The plot provides the radius of the 218-219-230 and 232 dB peak isopleths.

Attachment B

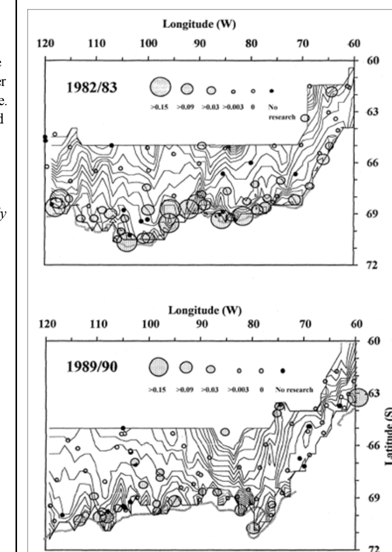
Species Cross Reference

Species / Scientific Name	Common Name
Aptenodytes forsteri	Emperor penguin
Aptenodytes patagonicus	King penguin
Arctocephalus gazella	Antarctic fur seal, Kerguelen fur seal
Balaenoptera acutorostrata	Minke whale, dwarf minke whale
Balaenoptera bonaerensis	Antarctic minke whale
Balaenoptera borealis	Sei whale
Balaenoptera edeni	Bryde's whale, Omura's whale
Balaenoptera musculus	Blue whale, sibbald's rorqual, sulphur-bottom whale
Balaenoptera physalus	Fin whale, common rorqual, fin-backed whale, finback, finner, herring whale, razorback
Berardius arnuxii	Arnoux's beaked whale, Southern four-toothed whale
Caperea marginata	Pygmy right whale
Cephalorhynchus commersonii	Commerson's dolphin
Eubalaena australis	Southern right whale
Globicephala melas	Long-finned pilot whale
Grampus griseus	Risso's dolphin
Hydrurga leptonyx	Leopard seal
Hyperoodon planifrons	Southern bottlenose whale, flatheaded bottlenose whale
Hyperoodon spp	Bottlenose whales
Indopacetus pacificus	Longman's beaked whale
Kogia breviceps	Pygmy and dwarf sperm whales
Kogia sima	Dwarf sperm whale
Lagenodelphis hosei	Fraser's dolphin
Lagenorhynchus australis	Peale's Dolphin
Lagenorhynchus cruciger	Hourglass dolphin
Lagenorhynchus obscurus	Dusky dolphin
Lagenorhyncus cruciger	Hourglass dolphin
Leptonychotes weddellii	Weddell seal
Lissodelphis peronii	Southern Right whale dolphin
Lobodon carcinophagus	Crabeater seal
Megaptera novaeangliae	Humpback whale
Mesoplodon grayi	Gray's beaked whale, southern beaked whale
Mesoplodon layardii	Layard's beaked whale, strap-toothed whale
Mirounga leonina	Southern Elephant Seal
Neophocaena phocaenoides	Finless porpoise
Ommatophoca rossiigray	Ross seal
Orcinus orca	Killer whale, Orca

Species / Scientific Name	Common Name
Oreaella brevirostris	Irrawaddy (snubfin) dolphin
Peponocephala electra	Melon-headed whale
Phocoena dioptrica (Australophocaena dioptrica)	Spectacled porpoise
Physeter macrocephalus	Sperm whale
Pseudorca crassidens	False killer whale
Pygoscelis adeliae	Adelie penguin
Pygoscelis antarcticus	Chinstrap penguin
Pygoscelis papua	Gentoo penguin
Sotalia fluviatilis	Tucuxi dolphin
Sousa chinensis	Indo-Pacific humpbacked dolphin
Steno bredanensis	Rough-toothed dolphin
Tasmacetus shepherdi	Shepherd’s beaked whale
Tursiops spp.	Bottlenose dolphins
Tursiops truncatus aduncus	Southern bottlenose dolphin
Ziphius cavirostris	Cuvier’s beaked whale

Attachment C - Species Sighting Data Sources

Amundsen Sea Marine Mammals Sightings Data Sources

Reference	Cited Observation Area	Proximity of Observation Area to Proposed Study Area (75 - 76 ° S to 108 -112 ° W in front of the Thwaites Glacier)	Object of Study	Observation Period	Methodology	Numerical Counts/Sightings	Additional Notes/Comments
Ainley et al. Cetacean Occurrence Patterns In the Amundsen and Southern Bellingshausen Sea Sector, Southern Ocean, 2007	Beginning at King Edward VII Peninsula, Marie Byrd Land, 150 ° W and ending at Marguerite Bay, Antarctic Peninsula, 70 ° W (Amundsen and Bellingshausen seas)	Data collected in proximity to the proposed study area	Cetaceans	Feb 15 to March 31 1994	A) Cetaceans counted using the methodology in Ribic et al. (1991). Two observers scanned simultaneously at 12 m above sea surface at a 90° area 800 m forward and to the side from the bridge wing whenever the ship was underway during daylight. B) Counts were continuous and partitioned into 30-min intervals as long as the ship was moving at maximum speed (21 km/hr). Such a speed resulted in segments of about 11 km long. Counts stopped when boat speed dropped to less than 5 km/hr. 517 segments were surveyed. C) Dependent variable: presence or absence of cetaceans and cetacean density (whales/km2), which was calculated by the number of animals sighted divided by area surveyed (transect width * segment distance). **The study did not correct for detectability or other factors, therefore the dependent variable was an index to density, rather than a true density estimate. Only the total density and presence/absence of cetaceans (all cetaceans detected regardless of species) was modeled.**	Surveyed 517 census segments, covering a total linear distance of 2,055 nmi (3,494 km). Minke whales were encountered on 40 occasions, totaling 104 individuals (most sightings were of single whales). 35 total killer whales were encountered on two occasions: 8 males, 12 females, and 4 juveniles in one killer whale group sighting; 4 males and 7 females in the other group. 2 beaked whales of unknown species and two groups of sperm whales, 7 in one and 12 in the other also observed.	
Ainely et al. Modeling the Relationship of Antarctic Minke Whales to Major Ocean Boundaries, 2012	South of approximately 59 °S between 140° E to 35 ° W. Included were several of the regions where sea ice is persistent year-round (e.g., eastern Ross Sea, Amundsen Sea, southern Bellingshausen Sea, and western Weddell Sea).	Data collected in proximity to the proposed study area	Antarctic minke whales	55 cruises onboard icebreakers from 1976-2005, December - February	A) Using 800-m wide strip transects, counts were made from the icebreakers' bridge wings during hours the ship travelled at speeds above 6 knots during daylight. B) In strip transects, only those whales that passed within 800m of the side of the ship (forequarter) were logged. C) Continuous surveys were broken into half-hour segments equivalent to a "transect." D) Sightings and their positions were extracted from the line transect effort. **The study modeled the probability of species occurrence using environmental data and species presence. Presence data was aggregated for each 5km cell in the study area; this resulted in a total of 300 presence locations included in the modeling.**	Ross Sea - 58 sightings, 1976-1980 Dec - Feb; Drake Passage Ant. Peninsula shelf/slope - 0 sightings, 1977-1994 Summer; Ross Sea to Bellingshausen Sea - 1 sighting, 1977 Feb; Scotia/Weddell Confluence - 25 sightings, 1983-1986 Dec - Feb; W Ant. Peninsula shelf and slope - 60 sightings, 1992 - 2005 summer; S. Indian Ocean to the ice edge (82° to 115 ° E) - 5 sightings, 1994 - 1995 Dec - Jan; Amundsen and Bellingshausen seas - 35 sightings, 1994 Feb - Mar; Ross Sea shelf and slope - 212 sightings, 2004 late summer/spring **Number of sightings is not equivalent to total whales**	
Kasamatsu et al. Distribution of Minke Whales in the Bellingshausen and Amundsen Seas with Special Reference to Environmental/Physiographic Variables, 2000	Bellingshausen and Amundsen Seas (60 ° W and 120 ° W)	Data collected in proximity to the proposed study area	Antarctic minke whales	Data collected from the IWC/IDCR sighting surveys conducted in late Dec to early Feb of 1989/90 and 1982/83. Area covered during the cruises was between the ice edge and approximately 560 km north of the ice edge.	A) 2 research vessels that operated in either closing mode or passing mode. B) In closing mode, the ship diverted course, accelerated, and approached animals to identify and count them. C) In passing mode, the vessel moved along the trackline without diverting or changing speed and all species identifications and counts were made from the trackline. **Only closing mode was applied in the 1982/83 cruise and both were applied alternatively in the 1989/90 survey.** D) Sightings were divided into two categories: primary and secondary. Primary - sightings made when full searching effort was being applied. Secondary - all other sightings. E) Minke whale density was estimated on a daily basis from the sightings data based on a line-transect method from Buckland et al. 1993 and Butterworth and Borchers (1988); density measured in schools/km2 (image from pg. 216). *Whale Density Estimate* The density of minke whales was estimated on a daily basis. The estimation of density from the sightings data was based on a line-transect method (Buckland *et al.*, 1993), using the following equation: $\hat{D}_i = n_i / 2 L_i \hat{w}$ (1) where $\hat{D}_i$ is the number of schools estimated per square km on the *i*th day, n_i is the number of schools seen (primary sightings only), L_i is distance searched (km) on the *i*th day, and $\hat{w}$ is the effective search half-width ($=1/\hat{f}(0)$, in which $\hat{f}(0)$ is the estimated probability density of perpendicular distances, evaluated at zero, calculated from fitting the Hazard rate model (Buckland, 1985). The $\hat{w}$-values by the vessel and stratum were cited from Butterworth and Borchers (1988) and Haw (unpublished observation).	A) In the 1982/83 study, areas of relatively high minke whale density (in relation to sea-surface isotherms) were primarily near the ice edge, near cold-water intrusions (approx. 71 ° S to 120 ° W). B) In the 1989/90 study, areas of relatively high minke whale density were observed near the ice edge, especially near cold-water intrusions, but these areas had lower densities than 1982/83 cruise. Also, areas with densities similar to 1982/83 cruise were observed in areas distant from ice edge, especially near tips of warm-water intrusions. **See Figure 3 - Distribution of minke whale density (schools/km2) in relation to sea-surface temperature in 1982/83 (above) and in 1989/90 (below) in cell 4H. Generally, it did not appear that minke whale densities were not observed in our study area of interest in front of the Thwaites Glacier, 75 - 76 ° S and 108 - 112 ° W.**	 **Figure 3.** Distribution of minke whale density (schools/km^2) in relation to sea-surface temperature in 1982/83 (above) and in 1989/90 (below).
De Broyer et al. Census of Antarctic Marine Life SCAR-Marine Biodiversity Information Network, Biogeographic Atlas of the Southern Ocean, Chapter 8: Biogeographic Patterns of Birds and Mammals, 2014			Cetaceans and Pinnipeds	Austral summer (roughly from October to April). Sighting data span from 1995 to 2011; majority of data collected from 1980s onward	A) A large number of freely available data and datasets were harvested from different repositories including PANGEA, OBIS, or SCAR-MarBIN; data were provided by authors or by institutions such as the IWC. At-sea sightings data were collected by different observers or on transects conducted by ships on dedicated marine science surveys. B) Different protocols of observation were used throughout the years. C) Most datasets were presence-only.		
The Expedition of the Research Vessel "Polarstern" to the Amundsen Sea, Antarctica, in 2010 (ANT - XXVI/3)	Pacific sector of the Southern Ocean, especially its western section between NE Ross and NW Amundsen seas	Data collected in proximity to the proposed study area	Cetaceans and Pinnipeds	January 29, 2010 - April 5, 2010	A) Continuous transect counts from the bridge of the ship when it was moving, visibility conditions allowing. B) No width limitation was applied	A) A total of 1,500 counts (as of March 29) - 215 cetaceans and 2,400 pinnipeds. B) In sub-tropical waters - 12 endemic Hector's dolphins, 4 common dolphins, 7 individual New Zealand fur seals ,and 1 sea lion. C) In the Antarctic domain - 2 blue whales, 1 Antarctic minke, 7 fin whales, and 17 humpbacks. 40 seals - 35 crabeaters and 5 leopards. C) Numbers of Antarctic minke whales increased eastward (eastern part of Pine Island Bay) to a total of 134. Numbers of fin and humpbacks (26 each) strongly decreased eastward. 2 sperm whales encountered. One pod of 4 orcas noted close to the ice shelf, 3 others seen from helicopter. Observed a pod of 12 Arnoux's beaked whales from helicopter, eastern Pine Bay Island. D) Crabeaters were most numerous species (2300 for a total of 2400 seals). E) Other pinniped species were 40 Weddell, 10 Leopard and 3 Ross seals (plus 1 from helicopter). Study states that numbers of these 3 species are probably underestimates due to the difficulty of detecting them in groups of 100 crabeaters or more.	

Amundsen Sea Marine Mammals Sightings Data Summary

Reference	*Ainley et al. Cetacean Occurrence Patterns In the Amundsen and Southern Bellingshausen Sea Sector, Southern Ocean, 2007*	*Ainely et al. Modeling the Relationship of Antarctic Minke Whales to Major Ocean Boundaries, 2012*	*Kasamatsu et al. Distribution of Minke Whales in the Bellingshausen and Amundsen Seas with Special Reference to Environmental/Physiographic Variables, 2000*	*De Broyer et al. Census of Antarctic Marine Life SCAR-Marine Biodiversity Information Network, Biogeographic Atlas of the Southern Ocean, Chapter 8: Biogeographic Patterns of Birds and Mammals, 2014*	*Gohl, Karsten. The Expedition of the Research Vessel "Polarstern" to the Amundsen Sea, Antarctica, in 2010 (ANT - XXVI/3)*	Navy Marine Species Density Database (NMSDD) [Note 1]
Observation period	Feb 15 to March 31 1994	55 cruises from 1976-2005, December - February	Late Dec to early Feb of 1989/90 and 1982/83	October to April, from 1995 to 2011	January 29, 2010 - April 5, 2010	various
Numerical counts reported	ü				ü	
Cetaceans						
Low-frequency Cetaceans (Mysticetes)						
Blue whale				X	X	X
Fin whale				X	X	X
Humpback whale				X	X	X
Minke whale	X	X	X	X	X	X
Sei whale				X		X
Mid-frequency cetaceans (Odontocetes)						
Arnoux's beaked whale					X	X
Grays beaked whale						X
Killer whale	X			X		X
Layard's beaked whale						X
Long-finned pilot whale						X
Southern bottlenose whale						X
Sperm whale	X			X	X	X
Unidentified beaked whales	X					
Pinnipeds						
Crabeater				X	X	
Elephant						
Leopard				X	X	
Ross				X	X	
Weddell				X	X	

Notes:

[1] NMSDD presents density data and maps, by season, for species in the Southern Ocean between 105°W and 80°E. Density values from the Amundsen Sea (between 100° W and 105° W) will be used.

Cetaceans Observed and Estimated Densities in the Amundsen Sea

Common Name	Area Surveyed (km^2) Note 1	Area Surveyed (km, linear survey)	Animals (#) Note 2	Animals (# including unidentified)	Corrected Sightings (assume only 20% reported)	Estimated Linear Density (#/km)	Half Strip-width (km)	Visual Transect Width (km) Note 4	Areal Density (#/ km^2) Note 5	Data Source	Year/Season/Area/Comments
Low-frequency Cetaceans (Mysticetes)											
Blue whale	315,000	NA	2	2	Note 3	NA	NA	NA	0.0000063	Gohl, Karsten. The Expedition of the Research Vessel "Polarstern" to the Amundsen Sea, Antarctica, in 2010 (ANT - XXVI/3)	January 29, 2010 - April 5, 2010
										De Broyer et al. Census of Antarctic Marine Life SCAR-Marine Biodiversity Information Network, Biogeographic Atlas of the Southern Ocean, Chapter 8: Biogeographic Patterns of Birds and Mammals, 2014	Austral summer (roughly from October to April). Sighting data span from 1995 to 2011; majority of data collected from 1980s onward. From the report "A large number of already freely available data were harvested from a variety of data repository centres, including PANGEA, OBIS, or SCAR-MarBIN; the rest of the data were provided by the data contributors identified in the authors list or by institutions which accepted to share them specifically with the Atlas project, like the International Whaling Commission...Most datasets were available as presence-only (i.e. absences were not specifically recorded during the surveys)."
									0.0000510	NMSDD Note 5	Annual, maximum range south of 70° S
Fin whale	315,000	NA	33	33	Note 3	NA	NA	NA	0.0001048	Gohl, Karsten. The Expedition of the Research Vessel "Polarstern" to the Amundsen Sea, Antarctica, in 2010 (ANT - XXVI/3)	January 29, 2010 - April 5, 2010
										De Broyer et al. Census of Antarctic Marine Life SCAR-Marine Biodiversity Information Network, Biogeographic Atlas of the Southern Ocean, Chapter 8: Biogeographic Patterns of Birds and Mammals, 2014	Austral summer (roughly from October to April). Sighting data span from 1995 to 2011; majority of data collected from 1980s onward. From the report "A large number of already freely available data were harvested from a variety of data repository centres, including PANGEA, OBIS, or SCAR-MarBIN; the rest of the data were provided by the data contributors identified in the authors list or by institutions which accepted to share them specifically with the Atlas project, like the International Whaling Commission...Most datasets were available as presence-only (i.e. absences were not specifically recorded during the surveys)."
									0.0072200	NMSDD Note 5	Summer, maximum range south of 70°S, west of 100^0W
Humpback whale	315,000	NA	43	43	Note 3	NA	NA	NA	0.0001365	Gohl, Karsten. The Expedition of the Research Vessel "Polarstern" to the Amundsen Sea, Antarctica, in 2010 (ANT - XXVI/3)	January 29, 2010 - April 5, 2010
										De Broyer et al. Census of Antarctic Marine Life SCAR-Marine Biodiversity Information Network, Biogeographic Atlas of the Southern Ocean, Chapter 8: Biogeographic Patterns of Birds and Mammals, 2014	Austral summer (roughly from October to April). Sighting data span from 1995 to 2011; majority of data collected from 1980s onward. From the report "A large number of already freely available data were harvested from a variety of data repository centres, including PANGEA, OBIS, or SCAR-MarBIN; the rest of the data were provided by the data contributors identified in the authors list or by institutions which accepted to share them specifically with the Atlas project, like the International Whaling Commission...Most datasets were available as presence-only (i.e. absences were not specifically recorded during the surveys)."
									0.0001000	NMSDD Note 6	Summer, maximum range south of 70°S, west of 100^0W
	NA	3,494	104	104	520	0.1488266	0.8	1.6	0.0930166	Ainley et al. Cetacean Occurrence Patterns In the Amundsen and Southern Bellingshausen Sea Sector, Southern Ocean, 2007	Feb 15 to March 31 1994
										Ainley et al. Modeling the Relationship of Antarctic Minke Whales to Major Ocean Boundaries, 2012	This study reports a summary of cruises on which minke whale data was gathered and the number of sightings (not total whales). 55 cruises on board icebreakers from 1976-2005, December - February
	60°W and 120°W	NA	NA	NA	NA	NA	NA	NA	NA	Kasamatsu et al. Distribution of Minke Whales in the Bellingshausen and Amundsen Seas with Special Reference to Environmental/Physiographic Variables, 2000	Data collected from the IWC/IDCR sighting surveys conducted from late Dec to early Feb of 1989/90 and 1982/83. Area covered during the cruises was between the ice edge and approximately 560 km north of the ice edge.

Cetaceans Observed and Estimated Densities in the Amundsen Sea

Common Name	Area Surveyed (km^2) Note 1	Area Surveyed (km, linear survey)	Animals (#) Note 2	Animals (# including unidentified)	Corrected Sightings (assume only 20% reported)	Estimated Linear Density (#/km)	Half Strip-width (km)	Visual Transect Width (km) Note 4	Areal Density (#/ km^2) Note 5	Data Source	Year/Season/Area/Comments
Minke whale										De Broyer et al. Census of Antarctic Marine Life SCAR-Marine Biodiversity Information Network, Biogeographic Atlas of the Southern Ocean, Chapter 8: Biogeographic Patterns of Birds and Mammals, 2014	Austral summer (roughly from October to April). Sighting data span from 1995 to 2011; majority of data collected from 1980s onward. From the report "A large number of already freely available data were harvested from a variety of data repository centres, including PANGEA, OBIS, or SCAR-MarBIN; the rest of the data were provided by the data contributors identified in the authors list or by institutions which accepted to share them specifically with the Atlas project, like the International Whaling Commission...Most datasets were available as presence-only (i.e. absences were not specifically recorded during the surveys)."
	315,000	NA	135	135	Note 3	NA	NA	NA	0.0004286	Gohl, Karsten. The Expedition of the Research Vessel "Polarstern" to the Amundsen Sea, Antarctica, in 2010 (ANT - XXVI/3)	January 29, 2010 - April 5, 2010
									0.0267370	NMSDD Note 6	Summer, maximum range south of 70°S, west of 100^0W
Sei whale										De Broyer et al. Census of Antarctic Marine Life SCAR-Marine Biodiversity Information Network, Biogeographic Atlas of the Southern Ocean, Chapter 8: Biogeographic Patterns of Birds and Mammals, 2014	Austral summer (roughly from October to April). Sighting data span from 1995 to 2011; majority of data collected from 1980s onward. From the report "A large number of already freely available data were harvested from a variety of data repository centres, including PANGEA, OBIS, or SCAR-MarBIN; the rest of the data were provided by the data contributors identified in the authors list or by institutions which accepted to share them specifically with the Atlas project, like the International Whaling Commission...Most datasets were available as presence-only (i.e. absences were not specifically recorded during the surveys)."
									0.0002550	NMSDD Note 6	Summer, maximum range south of 70°S, west of 100^0W
Mid-frequency Cetaceans (Odontocetes)											
Arnoux's beaked whale										De Broyer et al. Census of Antarctic Marine Life SCAR-Marine Biodiversity Information Network, Biogeographic Atlas of the Southern Ocean, Chapter 8: Biogeographic Patterns of Birds and Mammals, 2014	Austral summer (roughly from October to April). Sighting data span from 1995 to 2011; majority of data collected from 1980s onward. From the report "A large number of already freely available data were harvested from a variety of data repository centres, including PANGEA, OBIS, or SCAR-MarBIN; the rest of the data were provided by the data contributors identified in the authors list or by institutions which accepted to share them specifically with the Atlas project, like the International Whaling Commission...Most datasets were available as presence-only (i.e. absences were not specifically recorded during the surveys)."
	315,000	NA	12	12	NA	NA	NA	NA	0.0000381	Gohl, Karsten. The Expedition of the Research Vessel "Polarstern" to the Amundsen Sea, Antarctica, in 2010 (ANT - XXVI/3)	January 29, 2010 - April 5, 2010
									0.0062410	NMSDD Note 6	Summer, maximum range south of 70°S, west of 100^0W
Grays Beaked Whale									0.0000000	NMSDD Note 6	Summer, maximum range south of 70° S
Killer whale										De Broyer et al. Census of Antarctic Marine Life SCAR-Marine Biodiversity Information Network, Biogeographic Atlas of the Southern Ocean, Chapter 8: Biogeographic Patterns of Birds and Mammals, 2014	Austral summer (roughly from October to April). Sighting data span from 1995 to 2011; majority of data collected from 1980s onward. From the report "A large number of already freely available data were harvested from a variety of data repository centres, including PANGEA, OBIS, or SCAR-MarBIN; the rest of the data were provided by the data contributors identified in the authors list or by institutions which accepted to share them specifically with the Atlas project, like the International Whaling Commission...Most datasets were available as presence-only (i.e. absences were not specifically recorded during the surveys)."
	315,000	NA	7	7	Note 3	NA	NA	NA	0.0000222	Gohl, Karsten. The Expedition of the Research Vessel "Polarstern" to the Amundsen Sea, Antarctica, in 2010 (ANT - XXVI/3)	January 29, 2010 - April 5, 2010
									0.0014110	NMSDD Note 6	Summer, maximum range south of 70°S, west of 100^0W
Layard's beaked whale									0.0000000	NMSDD Note 6	Summer, maximum range south of 70° S
Long-finned pilot whale									0.0000000	NMSDD Note 6	Summer, maximum range south of 70° S
Southern bottlenose whale									0.0067570	NMSDD Note 6	Summer, maximum range south of 70°S, west of 100^0W

Cetaceans Observed and Estimated Densities in the Amundsen Sea

Common Name	Area Surveyed (km^2) Note 1	Area Surveyed (km, linear survey)	Animals (#) Note 2	Animals (# including unidentified)	Corrected Sightings (assume only 20% reported)	Estimated Linear Density (#/km)	Half Strip-width (km)	Visual Transect Width (km) Note 4	Areal Density (#/ km^2) Note 5	Data Source	Year/Season/Area/Comments
Sperm whale	NA	3,494	19	19	95	0.027189468	0.8	1.6	0.0169934	Ainley et al. Cetacean Occurrence Patterns In the Amundsen and Southern Bellingshausen Sea Sector, Southern Ocean, 2007	Feb 15 to March 31 1994
										De Broyer et al. Census of Antarctic Marine Life SCAR-Marine Biodiversity Information Network, Biogeographic Atlas of the Southern Ocean, Chapter 8: Biogeographic Patterns of Birds and Mammals, 2014	Austral summer (roughly from October to April). Sighting data span from 1995 to 2011; majority of data collected from 1980s onward. From the report "A large number of already freely available data were harvested from a variety of data repository centres, including PANGEA, OBIS, or SCAR-MarBIN; the rest of the data were provided by the data contributors identified in the authors list or by institutions which accepted to share them specifically with the Atlas project, like the International Whaling Commission...Most datasets were available as presence-only (i.e. absences were not specifically recorded during the surveys)."
	315,000	NA	2	2	NA	NA	NA	NA	0.0000063	Gohl, Karsten. The Expedition of the Research Vessel "Polarstern" to the Amundsen Sea, Antarctica, in 2010 (ANT - XXVI/3)	January 29, 2010 - April 5, 2010
									0.0000000	NMSDD Note 6	Summer, maximum range south of 70° S
High-frequency Cetaceans (true porpoises, Kogia, river dolphins, cephalorhynchid, Lagenorhynchus cruciger & L. australis)											
(all)									0.0000000	No sightings south of 60°S	

Notes:

NA = Not Available

1. Where the area surveyed was not indicated in the reference document, a value of 315,000 km^2 was used, estimate of the area of the Amundsen Sea Continental shelf (Jacobs 2012)
2. Sightings data accounts for all individuals observed in groups; corrected sightings assumes only 20% of animals present were observed and reported.
3. Assume reported number of animals has been corrected in the reference.
4. Visual transect width = half strip-width x 2, representing the total width of observations.
5. Estimated areal density [# animals/area surveyed (km2)] is provided either based on reported numbers in the reference or calculated based on the estimated linear density (#/km) x 1/visual transect width (km).

Cetacean Densities in the Amundsen Sea

	Area Surveyed (km²) Note 1	Area Surveyed (km, linear survey)	Animals (#) Note 2	Animals (# including unidentified)	Corrected Sightings (assume only 20% reported)	Estimated Linear Density (#/km)	Half Strip-width (km)	Visual Transect Width (km) Note 4	Areal Density (#/ km2) Note 5	Data Source	Comments
Low-frequency Cetaceans (Mysticetes)											
Blue whale	315,000	NA	2	2	Note 3	NA	NA	NA	0.0000063	Gohl, 2010	Based on 64 days of observations
									0.0000510	NMSDD Note 6	
Fin whale	315,000	NA	33	33	Note 3	NA	NA	NA	0.0001048	Gohl, 2010	Based on 64 days of observations
									0.0072200	NMSDD Note 6	
Humpback whale	315,000	NA	43	43	Note 3	NA	NA	NA	0.0001365	Gohl, 2010	Based on 64 days of observations
									0.0001000	NMSDD Note 6	
Minke whale	NA	3,494	104	104	520	0.1488266	0.8	1.6	**0.0930166**	Ainley et al., 2007	Based on 3,494 km linear survey observations
	315,000	NA	135	135	Note 3	NA	NA	NA	0.0004286	Gohl, 2010	
									0.0267370	NMSDD Note 6	
Sei whale									**0.0002550**	NMSDD Note 6	
Mid-frequency Cetaceans (Odontocetes)											
Arnoux's beaked whale									**0.0062410**	NMSDD Note 6	
Killer whale									**0.0014110**	NMSDD Note 6	
Southern bottlenose whale									**0.0067570**	NMSDD Note 6	
Sperm whale									**0.0169934**	Ainley et al., 2007	Based on 3,494 km linear survey observations
High-frequency Cetaceans (true porpoises, Kogia, river dolphins, cephalorhynchid, Lagenorhynchus cruciger & L. australis)											
(all)											No sightings south of 60°S

Notes:

1. Where the area surveyed was not indicated in the reference document, a value of 315,000 km² was used, estimate of the area of the Amundsen Sea Continental shelf (Jacobs 2012)
2. Sightings data accounts for all individuals observed in groups; corrected sightings assumes only 20% of animals present were observed and reported.
3. Assume reported number of animals has been corrected in the reference.
4. Visual transect width = half strip-width x 2, representing the total width of observations.
5. Most probable densities appear in **bold font;** based on sightings data and proximity to proposed study area and time of year, and will be used to estimate the number of takes.
6. Maximum density values during the austral summer for the Amundsen Sea (between 100°W-105°W and south of 70°S).

Pinnipeds Observed and Estimated Densities in the Amundsen Sea

Common Name	Area Surveyed (km^2) Note 1	Area Surveyed (km, linear survey)	Animals (#)	Correction Factor	Estimated # in the Water	Estimated Linear Density (#/km)	Half Strip-width (km)	Visual Transect Width (km)	Estimated Areal Density (#/ km^2) Note 3	Data Source	Year/Season/Area/Comments
Crabeater	315,000	NA	2,400	1	Note 2	NA	NA	NA	0.00762	Gohl, Karsten. The Expedition of the Research Vessel "Polarstern" to the Amundsen Sea, Antarctica, in 2010 (ANT - XXVI/3)	January 29, 2010 - April 5, 2010. Exerpt from the study: *"Among the pinnipeds, crabeaters were, as expected, by far the most numerous species (2300, for a total of 2400 seals). They were bound to small floes in drifted ice, and around small icebergs. A few concentrations of 100 and more on the ice were detected from ship and helicopter, while a huge concentration of 10.000 was seen twice from helicopter during 20 min of flight, i.e. covering 50 to 60 km, in the NW part of Pine Island Bay, at the northern limit of a huge ice field with medium sized pack ice floes. It seems that the extremely poor ice coverage in the bay was the cause of such a gathering. Few small groups were swimming far from any ice, often attracted by the ship. An extreme case was when tens of such groups came behind the ship from different directions during more than 10 hours (interruption of the observations due to obscurity!). The first ones arrived while seismic activity was running; they kept arriving for hours, with a "silent" streamer behind Polarstern. They did not stay long behind her, so that not more than 25 to 50 exemplars were following at any time, while the total number of arriving crabeaters was above 400 for the whole period."*
Leopard	315,000	NA	15	1	Note 2	NA	NA	NA	0.00005	Gohl, Karsten. The Expedition of the Research Vessel "Polarstern" to the Amundsen Sea, Antarctica, in 2010 (ANT - XXVI/3)	January 29, 2010 - April 5, 2010.
Ross	315,000	NA	4	1	Note 2	NA	NA	NA	1.26984E-05	Gohl, Karsten. The Expedition of the Research Vessel "Polarstern" to the Amundsen Sea, Antarctica, in 2010 (ANT - XXVI/3)	January 29, 2010 - April 5, 2010. Study notes *"3 rare Ross seals (plus 1 from helicopter)"*
Weddell	315,000	NA	40	1	Note 2	NA	NA	NA	0.000126984	Gohl, Karsten. The Expedition of the Research Vessel "Polarstern" to the Amundsen Sea, Antarctica, in 2010 (ANT - XXVI/3)	January 29, 2010 - April 5, 2010

Notes:
NA = Not Available
1. Where the area surveyed was not indicated in the reference document, a value of 315,000 km^2 was used, estimate of the area of the Amundsen Sea Continental shelf (Jacobs 2012)
2. Reported numbers provided in the reference include animals swimming near the vessel.
3. Estimated areal density [# animals/area surveyed (km2)] is provided based on reported numbers in the reference.

Pinniped Densities in the Amundsen Sea

Common Name	Area Surveyed (km^2) Note 1	Animals (#)	Animals (# including unidentified)	Correction Factor	Estimated # in the Water	Estimated Linear Density (#/km)	Half Strip-Width (km)	Visual Transect Width (km)	Areal Density (#/ km^2)	Data Source	Year/Season/Area	Comments
Crabeater	315,000	NA	2,400	1	Note 2	NA	NA	NA	0.00762	Gohl, Karsten. The Expedition of the Research Vessel "Polarstern" to the Amundsen Sea, Antarctica, in 2010 (ANT - XXVI/3)	January 29, 2010 - April 5, 2010.	Exerpt from the study: *"Among the pinnipeds, crabeaters were, as expected, by far the most numerous species (2300, for a total of 2400 seals). They were bound to small floes in drifted ice, and around small icebergs. A few concentrations of 100 and more on the ice were detected from ship and helicopter, while a huge concentration of 10.000 was seen twice from helicopter during 20 min of flight, i.e. covering 50 to 60 km, in the NW part of Pine Island Bay, at the northern limit of a huge ice field with medium sized pack ice floes. It seems that the extremely poor ice coverage in the bay was the cause of such a gathering. Few small groups were swimming far from any ice, often attracted by the ship. An extreme case was when tens of such groups came behind the ship from different directions during more than 10 hours (interruption of the observations due to obscurity!). The first ones arrived while seismic activity was running; they kept arriving for hours, with a "silent" streamer behind Polarstern. They did not stay long behind her, so that not more than 25 to 50 exemplars were following at any time, while the total number of arriving crabeaters was above 400 for the whole period."*
Leopard	315,000	NA	15	1	Note 2	NA	NA	NA	0.00005	Gohl, Karsten. The Expedition of the Research Vessel "Polarstern" to the Amundsen Sea, Antarctica, in 2010 (ANT - XXVI/3)	January 29, 2010 - April 5, 2010.	
Ross	315,000	NA	4	1	Note 2	NA	NA	NA	0.00001	Gohl, Karsten. The Expedition of the Research Vessel "Polarstern" to the Amundsen Sea, Antarctica, in 2010 (ANT - XXVI/3)	January 29, 2010 - April 5, 2010. Study notes *"3 rare Ross seals (plus 1 from helicopter)"*	
Weddell	315,000	NA	40	1	Note 2	NA	NA	NA	0.000126984	Gohl, Karsten. The Expedition of the Research Vessel "Polarstern" to the Amundsen Sea, Antarctica, in 2010 (ANT - XXVI/3)	January 29, 2010 - April 5, 2010	

Notes:

1. Where the area surveyed was not indicated in the reference document, a value of 315,000 km^2 was used, estimate of the area of the Amundsen Sea Continental shelf (Jacobs 2012)
2. Reported numbers provided in the reference include animals swimming near the vessel.

[3] Assumes 400 m half strip-width on each side of the vessel.

[4] Visual Transect Width = visual range x 2, representing the total width of observations.

Attachment D – Estimated Ensonified Area from Icebreaking Activities and Potential Marine Mammal Take

Icebreaking is considered by NOAA-Fisheries to be a continuous sound and the existing threshold for Level B harassment by continuous sounds is a received sound level of 120 dB SPL. Potential takes of marine mammals may occur from the icebreaking activity in which the USAP research vessel RVIB Nathaniel B. Palmer (NBP) is expected to engage in the Amundsen Sea region (between 75.25°S and 73.5°S, and 108.5°W and 101.0°W). The draft IHA application presents take estimates based exclusively on the seismic survey component of the project. If icebreaking does occur in the Antarctic region, it is expected to occur on a limited basis. The research activities and associated contingencies are designed to avoid areas of heavy sea ice condition since the NBP is not suited to break multi-year sea ice. If the NBP breaks ice during transit operations within the Amundsen Sea, seismic operations would not be conducted concurrently. It is noted that typical transit through areas of primarily open water and containing brash ice or pancake ice are not considered icebreaking for the purposes of this attachment.

Data characterizing the sound levels generated by icebreaking activities conducted by the NBP are not available. Therefore, data for noise generated from the USCG Cutter (USCGC) Healy was used for purposes herein. The NBP is a smaller vessel and has less icebreaking capability than the USCGC Healy, being only capable of breaking ice up to 1 m thick at speeds of 5.5 to 9.26 km/hr (3 to 5 knots). Therefore, the sound levels that may be generated by the NBP are expected to be lower than the conservative levels estimated and measured for the USCGC Healy.

The existing threshold for Level B harassment for continuous sounds is a received sound level of 120 dB SPL (NMFS 2018). Using a propagation model with a source level of 196.2 dB, the Navy Acoustic Effects Model (NAEMO) predicted the sound level range to effects for non-impulsive sources and icebreaking noise to mid-frequency cetacean and pinniped specific criteria (NMFS 2018). NAEMO predicted that sound levels would decay to 120 dB at a distance of 4.275 km from the source for cetaceans, and 4.525 m for pinnipeds.

Non-icebreaking vessels, as well as natural sounds such as those arising from sea ice motion and whale flukes hitting the ocean surface, also present similar sound impacts. Underwater noise from various vessels, including tug boats, oceanographic research vessels, and fisheries research vessels in open water, as well as icebreakers traversing sea ice, often exceed 120 dB.

The sound level and other estimates provided in this addendum are for information purposes only and do not represent any conclusions with regard to harassment. Further studies are needed before a precedent can be established.

The objectives and plans of the proposed project are described in the IHA application. The following includes the assumptions used to estimate the trackline distance for icebreaking, the area ensonified by icebreaking, and the resulting potential takes. The supplemental information has been organized in a manner consistent with the draft IHA application. The estimated takes provided in this addendum are in addition to the number of estimated takes due to seismic activities.

Only Level B takes are anticipated to be caused by icebreaking activities. NSF is not requesting Level A takes given the small area potentially ensonified to Level A take levels during icebreaking given that the sound source of 196.2 dB is lower than the non-impulsive Level A take level of 198 and 199 dB for mid- and low-frequency cetaceans, respectively (NMFS, 2018).

The number of marine mammals that may be present and potentially disturbed are presented below based on available data of mammal sightings in the area. Level B takes are calculated by multiplying the expected presence of marine mammals within an area where the received sound levels due to icebreaking would be equal to or exceed 120 dB. It is anticipated that the linear distance of icebreaking operations would not exceed 445 km (48 hrs at 9.26 km/hr). Assuming the maximum distance that would receive a sound level of 120 dB or greater would be 4.275 km for cetaceans and 4.525 km for pinnipeds; the total area potentially ensonified by icebreaking would be 3805 km^2 (2 x 4.275 km x 445 km) for cetaceans and 4207.25 km^2 (2 x 4.525 km x 445 km) for pinnipeds.

Table D-1 summarizes the estimated number of cetacean and pinniped takes anticipated during icebreaking operations. The estimated number of takes for pinnipeds accounts for both seals that may be in the water and those hauled-out on ice surfaces. While the number of cetaceans that may be encountered within the ice margin habitat would be expected to be less than open water, the estimates below utilize the estimated densities for the open water and therefore; represent conservative estimates.

At least one Protected Species Observer (PSO) would stand watch at all times while the NBP is conducting icebreaking. We expect that PSOs would observe few cetaceans during icebreaking activities, and would be limited to those species in proximity to the ice margin habitat. Observations would use the proposed exclusion zone (EZ) of 100 m described in Section 11.0 of the IHA application and the 4.275 km (for cetaceans) and 4.525 km (for pinnipeds) distances for Level B take during icebreaking. Observations would also include searching for pinnipeds that may be present on the surface of the sea ice (i.e., hauled out) and that could potentially dive into the water as the vessel approaches, indicating disturbance from noise generated by icebreaking activities.

Table D-1. Projected Number of Cetacean and Pinniped Takes in the Proposed Study Areas from Icebreaking Operations

Common Name	Estimated Density of Animals (no/km^2)[no/mi^2]	Number of Estimated Takes and Requested Authorization [2]	Species Population Estimate[3]	Level B Take as % of Population
Low-frequency Cetaceans (Mysticetes) [1]				
Blue whale (e)	0.0000510 [0.0000197]	1	1700	0.059%
Fin whale (e)	0.0072200 [0.0027877]	28	1735	1.614%
Humpback whale (e)	0.0001000 [0.0000386]	1	42,000	0.002%
Minke whale	0.0930166 [0.0359139]	354	360,000	0.098%
Sei whale (e)	0.0002550 [0.0000985]	1	626	0.160%
Mid-frequency Cetaceans (Odontocetes) [1]				
Arnoux's beaked whale	0.0062410 [0.0024097]	24	599,300	0.004%
Killer whale	0.0014110 [0.0005448]	6	80,000	0.008%
Lanyard's beaked whale	0.000638 [0.000186]	3	599,300	0.001%
Long-finned pilot whale	0.007859 [0.002291]	30	200,000	0.015%
Southern bottlenose whale	0.0067570 [0.0026089]	26	500,000	0.005%
Sperm whale (e)	0.0169934 [0.0065612]	65	12,069	0.539%
Gray's beaked whale	0.000281 [0.000082]	2	599,300	0.0003%
Pinnipeds [1]				
Crabeater seal	0.0076190 [0.0029417]	31	5,000,000	0.001%
Leopard seal	0.0000476 [0.0000184]	1	220,000	0.0005%
Ross seal	0.0000127 [0.0000049]	1	20,000	0.005%
Weddell seal	0.0001270 [0.0000490]	1	500,000	0.0002%

Notes:
(e) = Endangered species
[1] Conservatively assumes all sightings could result in Level B harassment
[2] Calculated take is estimated using areal density of organisms multiplied by the area ensonified to 120 dB (rms) (3805 km^2 and 4027.25 km^2, for cetaceans and pinnipeds, respectively).
[3] Population estimates are provided in Section 4 of the IHA application

POTENTIAL IMPACTS FROM ICEBREAKING

A description of the potential effects of airgun sounds are described in Section 7.0 of the IHA application. These effects to marine mammals as result of icebreaking operations are expected to be similar.

The NBP is designed for continuous passage at 5.5 to 9.26 km/hr (3 to 5 knots) through ice 1 m thick. During this project, the NBP would typically encounter first- or second-year ice while avoiding thicker ice floes, particularly large intact multi-year ice, whenever possible. In addition, the vessel would follow leads when possible while following the survey route. As the vessel passes through the ice, the ship causes the ice to part and travel alongside the hull. This ice typically returns to fill the wake as the ship passes. The effects are transitory, hours at most, and localized, constrained to a relatively narrow swath perhaps 10 m to each side of the vessel.

The NBP's maximum beam is 18.3 m. Applying the maximum estimated amount of icebreaking, i.e. 500 km, to the corridor opened by the ship, we anticipate that a maximum of approximately 24.7 km^2 of ice may be disturbed. This represents a very small amount of the total ice present in the Amundson Sea.

Icebreaking may damage seal breathing holes and would also reduce the haulout area in the immediate vicinity of the ship's track. Icebreaking along a maximum of 445 km of trackline would alter local ice conditions in the immediate vicinity of the vessel. This has the potential to temporarily lead to a reduction of suitable seal haul-out habitat. However, the dynamic sea-ice environment requires that seals be able to adapt to changes in sea, ice, and snow conditions, and therefore, they create new breathing holes and lairs throughout winter and spring. In addition, seals often use open 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 and no significant impact on marine mammals is anticipated by icebreaking during the proposed project.

LITERATURE CITED

National Marine Fisheries Service (NMFS). 2018. Takes of marine mammals incidental to specified activities; taking marine mammals incidental to U.S. Navy's Office of Naval Research Arctic research activities. Federal Register. 83: 48799-48809. Available from: https://www.federalregister.gov/documents/2018/09/27/2018-21070/takes-of-marine-mammals-incidental-to-specified-activities-taking-marine-mammals-incidental-to-us