Request by Lamont-Doherty Earth Observatory for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during Marine Geophysical Surveys by the R/V *Marcus G. Langseth* in the Gulf of Alaska, 2019

submitted by

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to

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SUMMARY

Researchers from Lamont-Doherty Earth Observatory (L-DEO), Cornell University, Colgate University, University of Washington, University of California Santa Cruz, University of Colorado Boulder, University of New Mexico, Washington University in St. Louis, and the United States Geological Survey (USGS), with funding from the U.S. National Science Foundation (NSF), propose to conduct a high-energy seismic survey from the Research Vessel (R/V) *Marcus G. Langseth* (*Langseth*) in the Gulf of Alaska (GOA) during 2019. The NSF-owned *Langseth* is operated by Columbia University's L-DEO under an existing Cooperative Agreement. The proposed seismic survey would likely occur off the Alaska Peninsula and the eastern Aleutian islands during late spring 2019 and would use a 36-airgun towed array with a total discharge volume of ~6600 in^3. The survey would take place within the U.S. Exclusive Economic Zone (EEZ), in water ~15 to ~6184 m deep. This request is submitted pursuant to Section 101 (a)(5)(D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371(a)(5).

Numerous species of marine mammals inhabit the GOA. Several of these are listed as ***endangered*** under the ESA, including North Pacific right, sperm, sei, fin, and blue whales, the Cook Inlet Distinct Population Segment (DPS) of beluga whales, the Western North Pacific DPSs of humpback and gray whales, and the Western DPS of Steller sea lions. The Mexico DPS of humpback whales, which is known to feed in Alaska, is listed as ***threatened***. Critical habitat for the North Pacific right whale and Steller sea lion is also found within the survey area. Other ESA-listed species that could occur in the area are the ***endangered*** short-tailed albatross, the ***threatened*** Steller's eider, the ***endangered*** leatherback turtle, and the ***threatened*** Central North Pacific DPS and East Pacific DPS of green turtle.

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.

I. OPERATIONS TO BE CONDUCTED

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

Overview of the Activity

Researchers from L-DEO, Cornell University, Colgate University, University of Washington, University of California Santa Cruz, University of Colorado Boulder, University of New Mexico, Washington University in St. Louis, and USGS (herein collectively referred to as the Proposing Institutions), have proposed to conduct a seismic survey using the Research Vessel (R/V) *Marcus G.*

Langseth (the *Langseth*) in the western GOA in the Northeast Pacific Ocean (Figure 1). The main goal of the seismic program is to conduct a 2D survey along the Alaska Peninsula subduction zone using airguns. A 4-km long streamer would be used for a portion of the survey to collect seismic reflection data. To achieve the project goals, the Principal Investigator (PI) Dr. G. Abers (Cornell University) and co-PIs Drs. A. Adams (Colgate University), E. Roland (University of Washington), S. Schwartz (University of California Santa Cruz), A. Sheehan (University of Colorado Boulder), D. Shillington (L-DEO), S. Webb (L-DEO), L. Worthington (University of New Mexico), D. Wiens (Washington University in St. Louis), and P. Haeussler (USGS) propose to collect 2D wide-angle seismic reflection/refraction data off the Alaska Peninsula. Dr. A. Bécel would be Chief Scientist.

The proposed survey would take advantage of passive seismic equipment already deployed in support of the Alaska Amphibious Community Seismic Experiment (AACSE). AACSE deployed 75 ocean bottom seismometers (OBSs) offshore of the Alaska Peninsula in spring 2017 (Figure 2), and this array will remain on the seafloor for 15 months until the end of summer 2019. A 4-km long hydrophone streamer would be towed through approximately the first third of the survey, consisting of the first six NW-SE trending lines and the connecting lines between them. The proposed study consists of a 19-day cruise to collect a wide-angle reflection/refraction dataset using a subset of the AACSE array. The proposed activity, however, has utility independent from the AACSE and would provide unique higher resolution imaging of the subduction zone that is not possible with the AACSE data alone.

This project focuses on two subduction zone segments — the Semidi segment and the SW Kodiak Aperity. The addition of active sources (airguns) to the AACSE would directly contribute to the overall project goals of imaging the architecture for the subduction zone and understanding the structures controlling how and where the planet's largest earthquakes occur. In particular, the 3D P-wave velocity model derived from this seismic experiment would be beneficial for future AACSE passive array studies by providing the structure underneath a subset of the AACSE ocean bottom seismometer array. Data collected would be in support of research that meets NSF program priorities and NSF's critical need to foster an understanding of Earth processes. Data from this project would be made available for general scientific community use, referred to as "open access". The seismic data could be used to evaluate earthquake and tsunami hazards. Another major objective of the cruise is educational. Early career scientists would participate in the cruise and receive training in marine geophysics and subduction zone processes. The open access data obtained by this project would also be very useful for educational purposes after the cruise, since this cutting edge data would be openly available.

The project consists of a number of tracklines that cross the trench onto the Pacific plate and shorter connecting tracklines. The representative tracklines shown in Figure 1 have a total length of 4400 km. There could be additional seismic operations associated with turns, airgun testing, and repeat coverage of any areas where initial data quality is sub-standard. In the calculations for all areas (see § VII), 25% has been added in the form of operational days, which is equivalent to adding 25% to the proposed line km to be surveyed. During the survey, approximately 13% of the line km would take place in shallow water (<100 m), 27% would occur in intermediate water depths (100–1000 m), and the rest (60%) would occur in deep water (>1000 m).

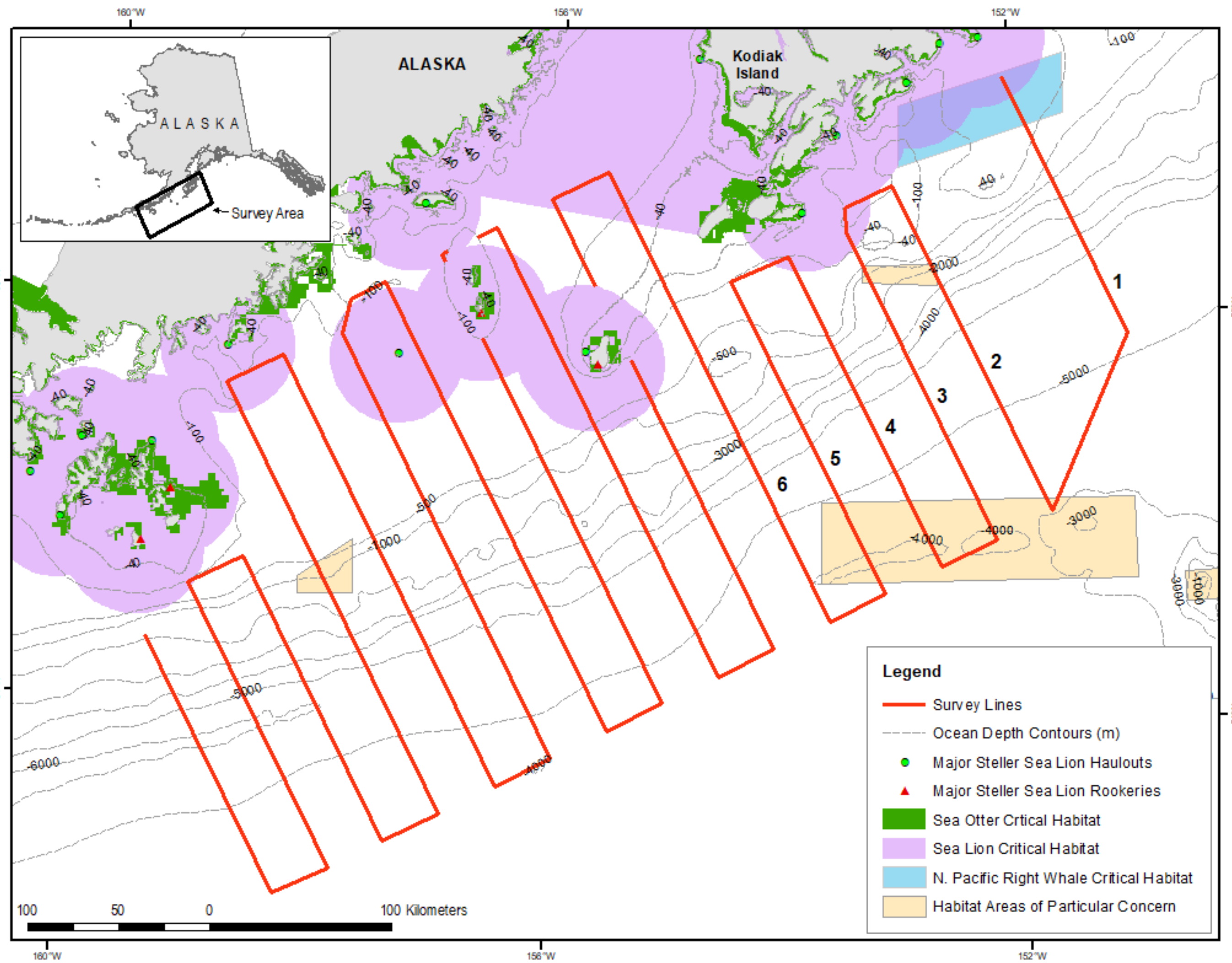

FIGURE 1. Map of the proposed 2019 seismic survey off the Alaskan Peninsula showing representative survey lines.

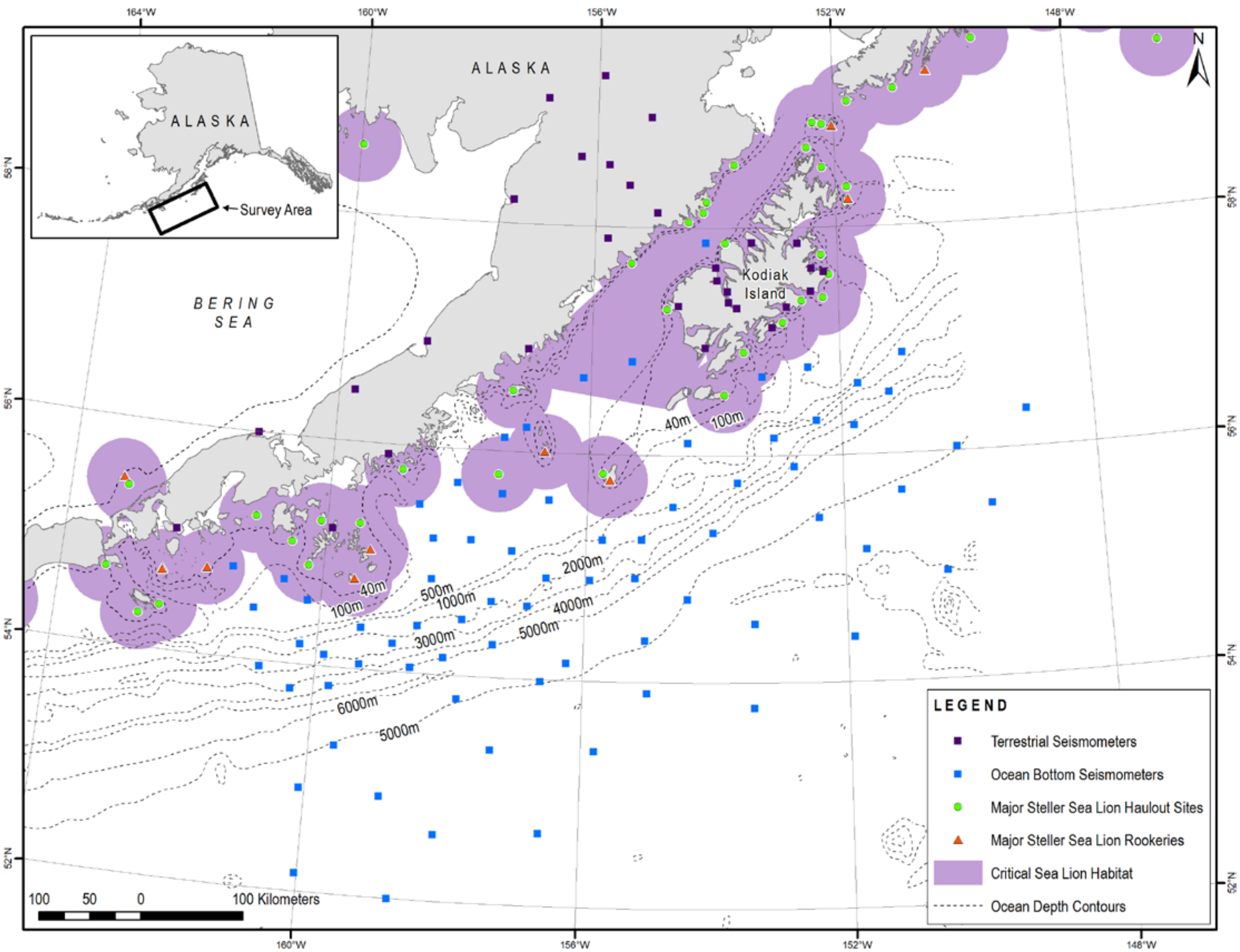

FIGURE 2. Map of previously deployed seismic receiver locations along the Alaskan Peninsula, including both terrestrial and ocean bottom seismometers.

In addition to the operations of the airgun array, a multibeam echosounder (MBES), a sub-bottom profiler (SBP), and an Acoustic Doppler Current Profiler (ADCP) would be operated from the *Langseth* continuously during the seismic surveys, but not during transit to and from the survey areas. All planned geophysical data acquisition activities would be conducted by L-DEO with on-board assistance by the scientists who have proposed the studies. The vessel would be self-contained, and the crew would live aboard the vessel. Adjustments to the survey procedures and plans described in this and other sections may be determined necessary during operations for reasons such as science drivers, poor data quality, inclement weather, or mechanical issues with the research vessel and/or equipment.

Source Vessel Specifications

The *Langseth* is described in § 2.2.2.1 of the PEIS. The vessel speed during all seismic operations would be ~5 kts (~9.3 km/h).

Airgun Description

The *Langseth* would tow the full array, consisting of four strings with 36 airguns (plus 4 spares) and a total volume of ~6600 in^3. The airgun array is described in § 2.2.3.1 of the PEIS, and the airgun configuration is illustrated in Figures 2-11 to 2-12 of the PEIS. The 4-string array would be towed at a depth of 12 m, and the shot interval would be 399.3 m.

Predicted Sound Levels

During the planning phase, mitigation zones for the proposed marine seismic survey were not derived from the farfield signature but calculated based on modeling by L-DEO for both the exclusion zones (EZ) for Level A takes and safety zones (160 dB re $1µPa_{rms}$) for Level B takes. The background information and methodology for this are provided in Appendix A.

The proposed survey would acquire data with the 36-airgun array at a maximum tow depth of 12 m. L-DEO model results are used to determine the 160-dB_{rms} radius for the 36-airgun array and 40-in^3 airgun at a 12-m tow depth in deep water (>1000 m) down to a maximum depth of 2000 m. The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor of 1.5. For shallow water (<100 m), radii are based on empirically derived measurements in the Gulf of Mexico (GoM) with scaling applied to account for differences in tow depth (see Appendix A). Table 1 shows the distances at which the 160-dB re $1µPa_{rms}$ sound levels are expected to be received for the 36-airgun array and the single (mitigation) airgun. The 160-dB level is the behavioral disturbance criterion (Level B) that is used by NMFS to estimate anticipated takes for marine mammals.

TABLE 1. Level B. Predicted distances to which sound levels ≥160-dB re 1 μPa$_{rms}$ could be received during the proposed survey in the GOA. The 160-dB criterion applies to all hearing groups of marine mammals.

Source and Volume	**Tow Depth (m)**	**Water Depth (m)**	**Predicted distances (in m) to the 160-dB Received Sound Level**
Single Bolt airgun, 40 in^3	12	>1000 m	431[1]
		100–1000 m	647[2]
		<100 m	1,041[3]
4 strings, 36 airguns, 6600 in^3	12	>1000 m	6,733[1]
		100–1000 m	10,100[2]
		<100 m	25,494[3]

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

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

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

	Level A Threshold Distances (m) for Various Hearing Groups				
36-airgun array; 6600 in^3	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
PTS SEL_{cum}	**40.1**	0	0.1	1.3	0
PTS Peak	38.9	**13.6**	**268.3**	**43.7**	**10.6**

Table 3 shows the distances at which the 175- and 195-dB re 1μPa$_{rms}$ sound levels are expected to be received for the 36-airgun array and a single airgun, based on L-DEO modeling; the 195-dB distance would be used as the EZ for sea turtles, as required by NMFS, and the 175-dB level is used by NMFS, as well as USN (2017), to determine behavioral disturbance for turtles.

This document has been prepared in accordance with the current National Oceanic and Atmospheric Administration (NOAA) acoustic practices, and the monitoring and mitigation procedures are based on best practices noted by Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013a), Wright (2014), Wright and Cosentino (2015), and Acosta et al. (2017). At the time of preparation of this document, how the technical guidance would be implemented operationally, along with other potential monitoring and mitigation measures, remains somewhat uncertain. For other recent high-energy seismic surveys conducted by L-DEO, NMFS required protected species observers (PSOs) to establish and monitor a 500-m EZ for power downs and to monitor an additional 500-m buffer zone beyond the EZ. A power down required the reduction of the full array to a single 40-in^3 airgun; a 100-m EZ was established and monitored for shut downs of the single airgun. Enforcement of mitigation zones via power and shut downs would be implemented as described below

TABLE 3. Sea turtle thresholds recommended by NMFS. Predicted distances to which sound levels ≥195- and 175-dB re 1 μPa$_{rms}$ could be received during the proposed survey in the GOA.

Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted distances (in m) to Received Sound Levels	
			195 dB	**175 dB**
Single Bolt airgun, 40 in^3	12	>1000 m	8[1] (100[3])	77[1]
		100–1000 m	11[2] (100[3])	116[2]
		<100 m	14[4](100[3])	170[4]
4 strings, 36 airguns, 6600 in^3	12	>1000 m	181[1]	1,864[1]
		100–1000 m	272[1]	2,796[2]
		<100 m	344[4]	4,123[4]

[1] Distance is based on L-DEO model results.
[2] Distance is based on L-DEO model results with a 1.5 × correction factor between deep and intermediate water depths.
[3] An EZ of 100 m would be used as the shut-down distance for sea turtles, consistent with PEIS low-energy source requirements.
[4] Distance is based on empirically derived measurements in the GoM with scaling applied to account for differences in tow depth.

Description of Operations

The procedures to be used for the proposed marine geophysical survey would be similar to those used during previous surveys by L-DEO and would use conventional seismic methodology. The survey would involve one source vessel, the *Langseth*. The *Langseth* would tow an array of 36 airguns at a depth of 12 m as an energy source with a total volume of ~6600 in^3. The receiving system would consist of previously deployed OBSs and onshore seismometers (Figure 2); a 4-km hydrophone streamer would be towed during a portion of the survey, as described in Section I above. As the airgun arrays are towed along the survey lines, the seismometers would receive and store the returning acoustic signals internally for later analysis. The shot interval would be 399.3 m (~155 s) at a speed of 5 kts.

A total of ~4400 km of transect lines would be surveyed in the GOA. There could be additional seismic operations associated with turns, airgun testing, and repeat coverage of any areas where initial data quality is sub-standard. In the take calculations for all areas (see § VII), 25% has been added in the form of operational days, which is equivalent to adding 25% to the proposed line km to be surveyed. During the survey, approximately 13% of the line km would take place in shallow water (<100 m), 27% would occur in intermediate water depths (100–1000 m), and the rest (60%) would occur in deep water (>1000 m). In addition to the operations of the airgun array, the ocean floor would be mapped with a Kongsberg EM 122 MBES and a Knudsen Chirp 3260 SBP. A Teledyne RDI 75 kHz Ocean Surveyor ADCP would be used to measure water current velocities. These sources are described in § 2.2.3.1 of the PEIS.

II. DATES, DURATION, AND REGION OF ACTIVITY

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

The proposed survey would occur within the area of ~52–58°N, ~150–162°W, within the EEZ of Alaska in water depths ranging from ~15 to ~6184 m. Representative survey tracklines are shown in Figure 1. These representative lines reflect modifications made to reduce the potential acoustic exposure of nearshore habitats in areas occupied by sea otters. As described further in this document, however, deviation in actual track lines, including order of survey operations, could be necessary for reasons such as science drivers, poor data quality, inclement weather, or mechanical issues with the research vessel and/or equipment. Thus, within the constraints of any federal authorizations issued for the activity, tracklines may shift from those shown in Figure 1 and could occur anywhere within the coordinates noted above and illustrated by the box in the inset map on Figure 1.

The survey needs to be conducted while the AACSE OBSs are on the sea floor (before 6 August 2019). The most value-added time window is mid-May through mid-June, when an on-shore, 400–450 element nodal seismic array will also be deployed on Kodiak Island and which could record an unprecedented ship-to-shore dataset.

The survey is expected to consist of up to 18 days of seismic operations and ~1 day of transit. The *Langseth* would leave from and return to port in Kodiak, likely during late spring (end of May/early June) 2019. Tentative sail dates are 1–19 June 2019. As the *Langseth* is a national asset, NSF and L-DEO strive to schedule its operations in the most efficient manner possible; schedule efficiencies are achieved when regionally occurring research projects are scheduled consecutively and non-operational transits are minimized. Because of the nature of the NSF merit review process and the long timelines associated with the ESA Section 7 consultation and IHA processes, not all research projects or vessel logistics will have been identified at the time the consultation documents are submitted to federal regulators; typically, however, these types of details, such as port arrival/departure locations, are not a substantive component of the consultations.

Seasonality of the proposed survey operations does not affect the ensuing analysis (including take estimates), because the best available species densities for any time of the year have been used.

III. SPECIES AND NUMBERS OF MARINE MAMMALS IN AREA

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

The marine mammals that occur in the proposed survey area belong to four taxonomic groups: odontocetes (toothed cetaceans, such as dolphins), mysticetes (baleen whales), and pinnipeds (seals, sea lions, and walrus). Eighteen cetacean species and six pinniped species are known to or could occur in the western GOA study area (Table 4).

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

TABLE 4. The habitat, abundance, and conservation status of marine mammals that could occur in or near the proposed seismic survey areas in the North Pacific Ocean.

Species	Habitat	Occurrence in/near Study Area	Abundance (Alaska)	Regional Abundance	ESA[1]	IUCN[2]	CITES[3]	Notes on Abundance Estimates
Mysticetes North Pacific right whale	Coastal, shelf	Rare	28–31[4]	400-500[5]	EN	EN	I	[4] Bering Sea/Aleutian Islands (Wade et al. 2011b). [5] North Pacific (Jefferson et al. 2015).
Gray whale	Coastal	Uncommon	N.A.	20,990[6]	DL	LC	I	[6] Eastern North Pacific (Carretta et al. 2016).
Humpback whale	Coastal, banks	Common	2215[7]	21,063[8]	EN/T/DL*	LC	I	[7] NW GOA, Kodiak to ~142°W (Rone et al. (2017). [8] North Pacific, 2004–2006 (Barlow et al. 2011).
Common minke whale	Coastal, shelf	Uncommon	1233[9]	25,000[10]	NL	LC	I	[9] W. GOA and E. Aleutians (Zerbini et al. 2006). [10] NW Pacific and Okhotsk Sea (IWC 2018).
Sei whale	Pelagic	Rare	N.A.	27,197[11]	EN	EN	I	[11] Central and Eastern North Pacific (Hakamada and Matsuoka 2015).
Fin whale	Pelagic	Common	3168[7]	13,620-18,680[12]	EN	EN	I	[7] NW GOA, Kodiak to ~142°W (Rone et al. (2017). [12] North Pacific (Ohsumi and Wada 1974).
Blue whale	Pelagic, shelf, coastal	Rare	63[7]	1647[13]	EN	EN	I	[7] NW GOA, Kodiak to ~142°W (Rone et al. (2017). [13] Eastern North Pacific Stock (Calambokidis and Barlow 2013).
Odontocetes Sperm whale	Pelagic	Uncommon	129[7]	26,300[14]	EN	VU	I	[7] NW GOA, Kodiak to ~142°W (Rone et al. (2017). [14] NW Temperate Pacific; estimate based on visual sightings (Barlow and Taylor 2005).
Cuvier's beaked whale	Pelagic	Common	N.A.	20,000[15]	NL	LC	II	[15] ETP (Wade and Gerrodette 1993).
Baird's beaked whale	Pelagic	Rare	N.A.	25,300[16] 5029[17] 10,190[18]	NL	DD	I	[16] Includes all species of the genus *Mesoplodon* in the ETP (Wade and Gerrodette 1993). [17] Pacific coast of Japan (Kasuya 2009). [18] Western Pacific Ocean (Okamura et al. 2012).
Stejneger's beaked whale	Likely pelagic	Common	N.A	N.A	NL	DD	II	
Pacific white-sided dolphin	Pelagic, shelf, coastal	Common	26,880[19]	988,333[20]	NL	LC	II	[19] North Pacific Stock (Muto et al. 2016). [20] North Pacific Ocean (Miyashita 1993b).
Risso's dolphin	Pelagic, shelf, coastal	Extralimital	N.A.	838,000[21]	NL	LC	II	[21] Western North Pacific Ocean (Miyashita 1993a).
Killer whale	Pelagic, shelf, coastal	Common	2934[22]	8500[23]	NL‡	DD	II	[22] Minimum abundance in Alaska, includes 2347 residents and 587 transients (Muto et al. 2017). [23] ETP (Ford 2009).
Harbor porpoise	Coastal	Uncommon	31,046[24]	79,261[25]	NL	LC	II	[24] GOA stock (Muto et al. 2018). [25] GOA plus Bering Sea stocks (Muto et al. 2018).

Species	Habitat	Occurrence in/near Study Area	Abundance (Alaska)	Regional Abundance	ESA[1]	IUCN[2]	CITES[3]	Notes on Abundance Estimates
Dall's porpoise	Pelagic, shelf	Common	83,400[26]	1,186,000[27]	NL	LC	II	[26] Alaska stock (Muto et al. 2016). [27] North Pacific Ocean and Bering Sea (Houck and Jefferson 1999).
Pinnipeds Northern fur seal	Pelagic, breeds coastally	Uncommon	626,734[28]	1.1 million[29]	NL	VU	NL	[28] Eastern Pacific Stock (Muto et al. 2017). [29] North Pacific (Gelatt and Lowry 2008).
Steller sea lion	Coastal, offshore	Common	41,638[30] 53,303[31]	N.A.	EN/DL[†]	NT	NL	[30] Eastern U.S. Stock (Muto et al. 2017). [31] Western U.S. Stock (Muto et al. 2018).
California sea lion	Coastal	Uncommon	N.A.	296,750[32]	NL	LC	NL	[32] Carretta et al. (2015).
Harbor seal	Coastal	Uncommon	54,906[33]	205,090[34]	NL	LC	NL	[33] Total of North Kodiak, South Kodiak, and Cook Inlet/Shelikof Strait Stocks (Muto et al. 2016). [34] Alaska statewide (Muto et al. 2016).
Northern elephant seal	Coastal, offshore	Uncommon	N.A.	210,000-239,000[35]	NL	LC	NL	[35] U.S. and Mexico (Lowry et al. 2014).

N.A. = data not available.
[1] U.S. Endangered Species Act. EN = Endangered; T = Threatened; DL = Delisted; NL = Not listed.
[2] Codes for IUCN (2018) classifications: EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient.
[3] Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES-UNEP 2017): Appendix I = threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled; Appendix III = trade of species regulated but cooperation from other countries needed to prevent unsustainable or illegal exploitation.
* The Western North Pacific DPS is listed as endangered and the Mexico DPS is listed as threatened; the Hawaii DPS was delisted in 2016 (81 FR 62259, 8 September 2016). Both the Central and Western North Pacific stock are considered depleted under the MMPA (Muto et al. 2018).
[†] Stocks in Alaska are not listed, but the southern resident DPS is listed as endangered. AT1 transient in Alaska is considered depleted and a strategic stock (NOAA 2004a).
[‡] The Western DPS is listed as endangered; the Eastern DPS was delisted in 2013 (78 FR 66139, 4 November 2013).
[¶] Southwest Alaska DPS.

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

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

Sections III and IV are integrated here to minimize repetition.

Several of the marine mammal species/populations that could occur in the area are listed under the ESA as ***endangered***, including the North Pacific right whale, sperm whale, Western North Pacific DPSs of humpback and gray whales, fin, sei, and blue whales and the Western DPS of Steller sea lions. Individuals from the Cook Inlet DPS of beluga whales are not expected to occur in the survey area. The Mexico DPS of the humpback whale is listed as ***threatened***.

Several other North Pacific cetacean species are not included here because they do not typically occur in this part of the GOA. These are: the Bryde's whale; pygmy and dwarf sperm whales; Blainville's, gingko-toothed, and Longman's beaked whales; pygmy and false killer whales; beluga whale; short-finned pilot whale; melon-headed whale; northern right whale dolphin, long- and short-beaked common dolphins, Fraser's dolphin; pantropical spotted dolphin; striped and spinner dolphins; rough-toothed dolphin; and common bottlenose dolphin. Additionally, three pinniped species are not included. The Guadalupe fur seal, which only ranges as far north as California, and spotted and ribbon seals. Although the range of the two latter can extend into the Gulf of Alaska, they are strongly associated with sea ice and likely to be much further north as the ice recedes in the spring when the proposed survey is planned to occur.

Mysticetes

North Pacific Right Whale (*Eubalaena japonica*)

North Pacific right whales summer in the northern North Pacific, primarily in the Okhotsk Sea (Brownell et al. 2001) and in the Bering Sea (Shelden et al. 2005; Wade et al. 2006). This species is divided into western and eastern North Pacific stocks. The eastern North Pacific stock that occurs in U.S. waters numbers only ~31 individuals (Wade et al. 2011b), and critical habitat has been designated in the eastern Bering Sea and in the GOA, south of Kodiak Island (NMFS 2017b). Wintering and breeding areas are unknown, but have been suggested to include the Hawaiian Islands, Ryukyu Islands, and Sea of Japan (Allen 1942; Banfield 1974; Gilmore 1978; Reeves et al. 1978; Herman et al. 1980; Omura 1986).

Since the 1960s, North Pacific right whale sightings have been relatively rare (e.g., Clapham et al. 2004; Shelden et al. 2005). In the eastern North Pacific, south of 50ºN, only 29 reliable sightings were recorded from 1900 to 1994 (Scarff 1986, 1991; Carretta et al. 1994). Starting in 1996, right whales have been sighted regularly in the southeast Bering Sea, including calves in some years (Goddard and Rugh 1998; LeDuc et al. 2001; Moore et al. 2000, 2002b; Wade et al. 2006; Zerbini et al. 2009); they have also been detected acoustically when sonobuoys were deployed (McDonald and Moore 2002; Munger et al. 2003, 2005, 2008; Berchok et al. 2009). Right whales are known to occur in the southeast Bering Sea from May to December (e.g., Tynan et al. 2001; Hildebrand and Munger 2005; Munger et al. 2005, 2008). Call frequencies tended to be higher in July–October than from May–June or November–December (Munger et al. 2008). Right whales seem to pass through the middle-shelf areas, without remaining there longer than a few days (Munger et al. 2008).

Shelden et al. (2005) reported that the slope and abyssal plain in the western GOA were important areas for right whales until the late 1960s, but sightings and acoustic detections in this region in recent decades are rare. In March 1979, a group of four right whales was seen in Yakutat Bay (Waite et al. 2003), but there were no further reports of right whale sightings in the GOA until July 1998, when a single whale was seen southeast of Kodiak Island (Waite et al. 2003). Three sightings and one acoustic detection of right whales were made in Barnabas Trough south of Kodiak Island during NOAA surveys in 2004 to 2006 in areas with high densities of zooplankton (Wade et al. 2011a). Those authors also report a fourth opportunistic sighting by a commercial fisher during that time in the same area. One right whale was sighted in the Aleutian Islands south of Unimak Pass in September 2004 (Wade et al. 2011b). A BIA for feeding for North Pacific right whales was designated east of the Kodiak Archipelago, encompassing the GOA critical habitat and extending south of 56° N and north of 58° N and beyond the shelf edge (Ferguson et al. 2015).

Right whale acoustic detections were made south of the Alaska Peninsula and to the east of Kodiak Island in 2000 during August and September (see Waite et al. 2003; Mellinger et al. 2004b), but no acoustic detections were made from April to August 2003 (Munger et al. 2008) or in April 2009 (Rone et al. 2010). Three right whales were acoustically detected in the Barnabas Trench area during a towed-PAM survey of the U.S. Navy training area east of Kodiak in the summer of 2013 but none were observed visually (Rone et al. 2014). Right whales were not detected acoustically in any year (2011-2015) of the fixed PAM monitoring in this region (Baumann-Pickering et al. 2012; Debich et al. 2013; Rice et al. 2015). No right whales were visually observed during the three years of surveys (2009, 2013, and 2015) in this military area east of Kodiak (Rone et al. 2017). The DoN assigned a year-round density of 0.00001/km^2 for right whales in this region (DoN 2014). There was one sighting of a single North Pacific right whale during the NSF/L-DEO seismic survey conducted in the summer of 2011 in the same area as the currently proposed survey (RPS 2011). Thus, it is possible that a right whale could be seen during the proposed survey.

Gray Whale (*Eschrichtius robustus*)

Two separate populations of gray whales have been recognized in the North Pacific (LeDuc et al. 2002): the eastern North Pacific and western North Pacific (or Korean-Okhotsk) stocks. However, the distinction between these two populations has been recently debated owing to evidence that whales from the western feeding area also travel to breeding areas in the eastern North Pacific (Weller et al. 2012, 2013; Mate et al. 2015). Thus, it is possible that whales from both the *endangered* Western North Pacific and the delisted Eastern North Pacific DPS could occur in the proposed survey area in the eastern North Pacific.

Gray whale populations were severely reduced by whaling, but the eastern North Pacific population is considered to have recovered. Punt and Wade (2012) estimated the eastern North Pacific population to be at 85% of its carrying capacity in 2009. The eastern North Pacific gray whale breeds and winters in Baja, California, and migrates north to summer feeding grounds in the northern Bering Sea, Chukchi Sea, and western Beaufort Sea (Rice and Wolman 1971; Rice 1998; Jefferson et al. 2015). Most of the eastern Pacific population makes a round-trip annual migration of more than 18,000 km. From late May to early October, the majority of the population concentrates in the northern and western Bering Sea and in the Chukchi Sea. However, some individuals spend the summer months scattered along the coasts of southeast Alaska, B.C., Washington, Oregon, and northern California (Rice and Wolman 1971; Nerini 1984; Darling et al. 1998; Dunham and Duffus 2001, 2002; Calambokidis et al. 2002). Gray whales are found primarily in shallow water; most follow the coast during migration, staying close to the shoreline except when crossing major bays, straits, and inlets (Braham 1984).

It is difficult to determine precisely when the southbound migration begins; whales near Barrow were moving predominantly south in August (Maher 1960; Braham 1984). Gray whales leave the Bering Sea through Unimak Pass from late October through January (Braham 1984). From October to January, the main part of the population moves down the west coast of North America. Rugh et al. (2001) analyzed data collected from two sites in California to estimate the timing of the gray whale southward migration. They estimated that the median date for the migration past various sites was 1 December in the central Bering

Sea (a nominal starting point), 12 December at Unimak Pass, 18 December at Kodiak Island, and 5 January for Washington.

By January and February, most of the whales are concentrated in the lagoons along the Pacific coast of the Baja Peninsula, Mexico. From late February to June, the population migrates northward to arctic and subarctic seas (Rice and Wolman 1971). The peak of northward migration in the GOA occurs in mid-April (Braham 1984). Most gray whales follow the coast during migration and stay within 2 km of the shoreline, except when crossing major bays, straits, and inlets from southeast Alaska to the eastern Bering Sea (Braham 1984). Gray whales use the nearshore areas of the Alaska Peninsula during the spring and fall migrations, and are often found within the bays and lagoons, primarily north of the peninsula, during the summer (Brueggeman et al. 1989 *in* Waite et al. 1999). However, gray whales are known to move further offshore between the entrance to Prince William Sound (PWS) and Kodiak Island and between Kodiak Island and the southern part of the Alaska Peninsula (Consiglieri et al. 1982). During May–October, primary occurrence extends seaward 28 km from the shoreline. This is the main migratory corridor for gray whales.

In the summer, gray whales are seen in the southeast Bering Sea (Moore et al. 2002b) and in the GOA, including around Kodiak Island (e.g., Wade et al. 2003; Calambokidis et al. 2004; Calambokidis 2007; Moore et al. 2007). In fact, gray whales have been seen feeding off southeast Kodiak Island, in particular near Ugak Bay, year-round (Moore et al. 2007). Moore et al. (2007) noted monthly sighting rates that exceeded 100 sightings/h in January, June, September, and November, and >20 sightings/h in most other months. One feeding aggregation in July consisted of 350-400 animals, clustered in groups of 10–20 animals, from the mouth of Ugak Bay to 100 km ESE of Ugak Island (Moore et al. 2007). Wade et al. (2003) reported a group size of 5.6 in the western GOA. A biologically important area (BIA) for feeding for gray whales has been identified in the waters east of the Kodiak Archipelago, with the greatest densities of gray whales occurring from June through August (Ferguson et al. 2015). Additionally, a gray whale migratory corridor BIA has been established extending from Unimak Pass in the western GOA to the Canadian border in the eastern GOA (Ferguson et al. 2015), including much of the landward side of the survey area. Gray whales occur in this area in high densities during November through January (southbound) and March through May (northbound).

Rone et al. (2017) sighted gray whales off Ugak Island, Kodiak, in all three years (2009, 2013, and 2015) of surveys in the military training area east of Kodiak. The US Department of the Navy (DoN 2014) estimated gray whale densities of 0.0485724/km^2 within 2.25 nmi of the coast and 0.0024276/km^2 for waters 2.25 to 20 nmi from shore for this area. Gray whales were detected acoustically throughout the summer and fall at fixed hydrophones on the shelf off Kenai Peninsula and near Kodiak Island in this military training area in a 2014-2015 study (Rice et al. 2015), but they were not detected at deeper slope or seamount sites and they were detected only once in prior years of study from 2011 to 2013 (Baumann-Pickering et al. 2012; Debich et al. 2013). Gray whales were neither observed visually nor detected acoustically during the NSF/L-DEO seismic survey conducted in the summer of 2011 in the same area as the currently proposed survey (RPS 2011). Gray whales could be encountered during the proposed seismic survey in the GOA.

Humpback Whale (*Megaptera novaeangliae*)

The humpback whale is found throughout all oceans of the World (Clapham 2009), with recent genetic evidence suggesting three separate subspecies: North Pacific, North Atlantic, and Southern Hemisphere (Jackson et al. 2014). Nonetheless, genetic analyses suggest some gene flow (either past or present) between the North and South Pacific (e.g., Jackson et al. 2014; Bettridge et al. 2015). Although considered to be mainly a coastal species, the humpback whale often traverses deep pelagic areas while migrating (e.g., Mate et al. 1999; Garrigue et al. 2015).

North Pacific humpback whales migrate between summer feeding grounds along the Pacific Rim and the Bering and Okhotsk seas and winter calving and breeding areas in subtropical and tropical waters (Pike and MacAskie 1969; Rice 1978; Winn and Reichley 1985; Calambokidis et al. 2000, 2001, 2008). In the North Pacific, humpbacks winter in four different breeding areas: (1) along the coast of Mexico; (2) along the coast of Central America; (3) around the Main Hawaiian Islands; and (4) in the western Pacific, particularly around the Ogasawara and Ryukyu islands in southern Japan and the northern Philippines (Calambokidis et al. 2008; Fleming and Jackson 2011; Bettridge et al. 2015). These breeding areas are recognized as the Mexico, Central America, Hawaii, and Western Pacific DPSs (NMFS 2016b). Hawaii is the primary wintering area for whales from summer feeding areas in the Gulf of Alaska (Calambokidis et al. 2008). Individuals from the Hawaii, Western Pacific, and Mexico DPSs could occur in the proposed survey area to feed.

There is potential for mixing of the western and eastern North Pacific humpback populations on their summer feeding grounds, and several sources suggest that this occurs to a limited extent (Muto et al. 2018). NMFS is currently reviewing the global humpback whale stock structure in light of the recent revision to their ESA listing and identification of 14 DPSs (81 FR 62259, 8 September 2016). Currently, two stocks of humpback whales are recognized as occurring in Alaskan waters. The Central North Pacific Stock occurs from southeast Alaska to the Alaska Peninsula and the Western North Pacific Stock occurs from the Aleutians to the Bering Sea and Russia. These two stocks overlap on feeding grounds in the eastern Bering Sea and the western Gulf of Alaska (Muto et al. 2018), encompassing the entire proposed survey area. BIAs for humpback whale feeding have been designated surrounding Kodiak Island and the Shumagin Islands (Ferguson et al. 2015). The highest densities of humpback whales occur during July through September around Kodiak Island and during July through August in the Shumagin Islands.

Humpback whales are commonly sighted within the proposed survey area. Waite (2003) reported that 117 humpbacks were seen in 41 groups during their surveys in the western GOA in 2003, with aggregations seen off northeast Kodiak Island. During summer surveys from the Kenai Fjords to the central Aleutian Islands in 2001–2003, humpbacks were most abundant near Kodiak Island, the Shumagin Islands, and north of Unimak Pass (Zerbini et al. 2006). Sightings of humpbacks around the Kodiak Islands were made most frequently in the fall, and aggregations were seen off Shuyak and Sitkalidak islands (Wynne and Witteveen 2005), as well as in Marmot and Chiniak bays (Baraff et al. 2005). Waite et al. (1999) noted another aggregation area north of Unalaska Island. Offshore sightings of humpbacks have also been made south of the Alaska Peninsula, including ~280 km south of the Shumagin Islands (e.g., Forney and Brownell 1996; Waite et al. 1999). Humpback whales were sighted a total of 220 times (637 animals) during the three years of surveys (2009, 2013, and 2015) in and near the U.S. Navy training area east of Kodiak (Rone et al. 2017). Humpback whales were also frequently detected acoustically during all years (2011-2015) of fixed-PAM studies in this area, with peak detections during late fall through early winter and detections at all shelf, slope, and seamount sites (Baumann-Pickering et al. 2012; Debich et al. 2013; Rice et al. 2015). Using sightings data from the June–July 2013 survey, density estimates for humpback whales were calculated for four different habitat strata: 0.093/km^2 for the inshore stratum (shelf waters), 0.001/km^2 for the offshore stratum (pelagic waters), 0.001/km^2 for the seamount stratum, and 0.0000/km^2 for the slope stratum (Rone et al. 2017). Humpback whales were the most frequently sighted cetacean during the NSF/L-DEO seismic survey conducted in the summer of 2011 in the same area as the currently proposed survey, comprising 50% of all cetacean sightings (RPS 2011). There were 92 sightings of this species, representing 288 animals during the 37 days of monitoring. The average group size was three and the maximum group size was 37. This species is likely to be common in the proposed survey area.

Calambokidis et al. (2008) reported an abundance estimate of 3000–5000 for the GOA. Rone et al. (2017) calculated an abundance estimate of 2,215 (uncorrected for missed animals) from a June–July 2013 survey in the U.S. Navy training area east of Kodiak Island, with the bulk of this estimate (2,927) found in the inshore stratum. NMFS provides best estimates of 1,107 for the Western North Pacific Stock and 10,103 for the Eastern North Pacific Stock (Muto et al. 2018). The entire North Pacific population has been estimated to number 21,063 individuals (Barlow et al. 2011).

Common Minke Whale (*Balaenoptera acutorostrata*)

The common minke whale has a cosmopolitan distribution ranging from the tropics and subtropics to the ice edge in both hemispheres (Jefferson et al. 2015). In the Northern Hemisphere, minke whales are usually seen in coastal areas, but can also be seen in pelagic waters during northward migrations in spring and summer, and southward migration in autumn (Stewart and Leatherwood 1985). In the North Pacific, the summer range extends to the Chukchi Sea; in the winter, minke whales move further south to within 2º of the Equator (Perrin and Brownell 2009). The International Whaling Commission (IWC) recognizes three stocks in the North Pacific: the Sea of Japan/East China Sea, the rest of the western Pacific west of 180ºN, and the remainder of the Pacific (Donovan 1991). NMFS recognizes a single stock in Alaskan waters and a second California/Oregon/Washington Stock (Muto et al. 2016).

The minke whale tends to be solitary or in groups of 2–3 but can occur in much larger aggregations around prey resources (Jefferson et al. 2008). Predominantly solitary animals were seen during surveys in Alaska (Wade et al. 2003; Waite 2003; Zerbini et al. 2006). The small size, inconspicuous blows, and brief surfacing times of minke whales mean that they are easily overlooked in heavy sea states, although they are known to approach vessels in some circumstances (Stewart and Leatherwood 1985). Little is known about the diving behavior of minke whales, but they are not known to make prolonged deep dives (Leatherwood and Reeves 1983).

Minke whales are relatively common in the Bering and Chukchi seas and in the inshore waters of the GOA (Mizroch 1992), but they are not considered abundant in any other part of the eastern Pacific (Brueggeman et al. 1990). Waite (2003) sighted four minke whales in three groups during surveys in the western GOA in 2003, south of the Kenai Peninsula and south of PWS. Moore et al. (2002b) reported a minke whale sighting south of the Sanak Islands. Baraff et al. (2005) reported a single sighting near Kodiak Island in July 2002. During surveys in the western GOA and eastern Aleutians, minke whales occurred primarily in the Aleutians; a few sightings were made south of the Alaska Peninsula and near Kodiak Island (Zerbini et al. 2006). Rone et al. (2017) reported two sightings totaling three minke whales in 2009, three sightings totaling six minke whales in 2013, and no sightings of minke whales in 2015 in the U.S. Navy training area east of Kodiak. In 2009 the DoN derived a year-round density of 0.0006/km^2 for minke whales for this area, which they consider the best available estimate given the scarce sightings of this species in this area. Minke whales were not detected acoustically during any year (2011-2015) of the fixed-PAM studies in the DoN area east of Kodiak (Baumann-Pickering et al. 2012; Debich et al. 2013; Rice et al. 2015). There was one sighting of a single common minke whale during the NSF/L-DEO seismic survey conducted in the summer of 2011 in the same area as the currently proposed survey (RPS 2011).

Sei Whale (*Balaenoptera borealis*)

The sei whale occurs in all ocean basins (Horwood 2009) but appears to prefer mid-latitude temperate waters (Jefferson et al. 2015). It undertakes seasonal migrations to feed in subpolar latitudes during summer and returns to lower latitudes during winter to calve (Horwood 2009). The sei whale is pelagic and generally not found in coastal waters (Harwood and Wilson 2001). It occurs in deeper waters characteristic of the continental shelf edge region (Hain et al. 1985) and in other regions of steep bathymetric relief such as seamounts and canyons (Kenney and Winn 1987; Gregr and Trites 2001). On feeding grounds, sei whales associate with oceanic frontal systems (Horwood 1987) such as the cold eastern currents in the North Pacific (Perry et al. 1999). Sei whales are frequently seen in groups of 2–5 (Jefferson et al. 2008), although larger groups sometimes form on feeding grounds (Gambell 1985a).

In the U.S. Pacific, an Eastern North Pacific and a Hawaii stock are recognized (Carretta et al. 2017). During summer in the North Pacific, the sei whale can be found from the Bering Sea to the northern GOA and south to California, and in the western Pacific from Japan to Korea. Its winter distribution is concentrated at about 20°N, and sightings have been made between southern Baja California and the Islas Revilla Gigedo (Rice 1998). No breeding grounds have been identified for sei whales; however, calving is thought to occur from September to March.

Moore et al. (2002b) made four sightings of six sei whales during summer surveys in the eastern Bering Sea, and one sighting south of the Alaska Peninsula between Kodiak and the Shumagin Islands. No sei whales were seen during surveys of the GOA by Wade et al. (2003), Waite (2003), or Zerbini et al. (2006). Rone et al. (2017) reported no sei whale sightings in 2009 or 2013 and a single sei whale sighting of one animal in 2015 in the U.S. Navy training area east of Kodiak. DoN (2014; see Figs. 5-24 and 5.25) estimated densities in the range of 0.000000-0.000102/km^2 for this area during the spring, summer, and fall. There was one sighting of two sei whales during the NSF/L-DEO seismic survey conducted in the summer of 2011 in the same area as the currently proposed survey (RPS 2011). Sei whale sightings are likely to be uncommon in the proposed survey area.

Fin Whale (*Balaenoptera physalus*)

The fin whale is widely distributed in all the World's oceans (Gambell 1985b), although it is most abundant in temperate and cold waters (Aguilar 2009). Nonetheless, its overall range and distribution are not well known (Jefferson et al. 2015). A recent review of fin whale distribution in the North Pacific noted the lack of sightings across the pelagic waters between eastern and western winter areas (Mizroch et al. 2009). The fin whale most commonly occurs offshore but can also be found in coastal areas (Aguilar 2009). Most populations migrate seasonally between temperate waters where mating and calving occur in winter, and polar waters where feeding occurs in summer (Aguilar 2009). However, recent evidence suggests that some animals may remain at high latitudes in winter or low latitudes in summer (Edwards et al. 2015).

The fin whale is known to use the shelf edge as a migration route (Evans 1987). Sergeant (1977) suggested that fin whales tend to follow steep slope contours, either because they detect them readily, or because the contours are areas of high biological productivity. However, fin whale movements have been reported to be complex (Jefferson et al. 2015). Stafford et al. (2009) noted that sea-surface temperature is a good predictor variable for fin whale call detections in the North Pacific.

North Pacific fin whales summer from the Chukchi Sea to California and winter from California southwards (Gambell 1985b). In the U.S., three stocks are recognized in the North Pacific: California/Oregon/Washington, Hawaii, and Alaska (Northeast Pacific) (Carretta et al. 2017). Information about the seasonal distribution of fin whales in the North Pacific has been obtained from the detection of fin whale calls by bottom-mounted, offshore hydrophone arrays along the U.S. Pacific coast, in the central North Pacific, and in the western Aleutian Islands (Moore et al. 1998, 2006; Watkins et al. 2000a,b; Stafford et al. 2007, 2009). Fin whale calls are recorded in the North Pacific year-round, including the GOA (e.g., Moore et al. 2006; Stafford et al. 2007, 2009; Edwards et al. 2015). Near the Alaska Peninsula in the western GOA, the number of calls received peaked in May–August, with few calls during the rest of the year (Moore et al. 1998). In the central North Pacific, the GOA, and the Aleutian Islands, call rates peak during fall and winter (Moore et al. 1998, 2006; Watkins et al. 2000a,b; Stafford et al. 2009).

Rice and Wolman (1982) encountered 19 fin whales during surveys in the GOA, including 10 aggregated near Middleton Island on 1 July 1980. During surveys from the Kenai Peninsula to the central

Aleutian Islands, fin whales were most abundant near the Semidi Islands and Kodiak Island (Zerbini et al. 2006). Numerous sightings of fin whales were also seen between the Semidi Islands and Kodiak Island during surveys by Waite (2003). Fin whale sightings around Kodiak Island were most numerous along the western part of the island in Uyak Bay and Kupreanof Straits, and in Marmot Bay (Wynne and Witteveen 2005; Baraff et al. 2005). Fin whales were sighted around Kodiak Island year-round, but most sightings were made in the spring and summer (Wynne and Witteveeen 2005). A BIA for fin whale feeding has been designated southward from the Kenai Peninsula inshore of the Kodiak Archipelago and along the Alaska Peninsula to include the Semidi Islands (Ferguson et al. 2015), overlapping with a proportion of the proposed survey area. Densities of fin whales are highest in this area during June through August.

Rone et al. (2017) reported 24 fin whale sightings (64 animals) in 2009, two hundred fin whale sightings (392 animals) in 2013, and 48 fin whale sightings (69 animals) in 2015 in the U.S. Navy training area east of Kodiak. They used the 2013 data to calculate densities of fin whales for four habitat areas: 0.068/km^2 for the inshore stratum, 0.016/km^2 for the offshore stratum, 0.003/km^2 for the seamount stratum, and 0.013/km^2 for the slope stratum. That study also provided an abundance estimate of 3168 for this area. The density and abundance estimates were not corrected for missed animals. Fin whales were also frequently detected acoustically throughout the year during all years (2011-2015) of fixed-PAM studies in this area and detections occurred at all shelf, slope, and seamount sites (Baumann-Pickering et al. 2012; Debich et al. 2013; Rice et al. 2015). Fin whales were the second most freqently sighted cetacean during the NSF/L-DEO seismic survey conducted in the summer of 2011 in the same area as the currently proposed survey, comprising 15.2% of all cetacean sightings (RPS 2011). There were 28 sightings of this species, representing 79 animals during the 37 days of monitoring. The average group size was three and the maximum group size was 10. Fin whales are likely to be common in the proposed survey area.

Blue Whale (*Balaenoptera musculus*)

The blue whale has a cosmopolitan distribution and tends to be pelagic, only coming nearshore to feed and possibly to breed (Jefferson et al. 2015). Blue whale migration is less well defined than for some other rorquals, and their movements tend to be more closely linked to areas of high primary productivity, and hence prey, to meet their high energetic demands (Branch et al. 2007). Generally, blue whales are seasonal migrants between high latitudes in the summer, where they feed, and low latitudes in the winter, where they mate and give birth (Lockyer and Brown 1981). Some individuals may stay in low or high latitudes throughout the year (Reilly and Thayer 1990; Watkins et al. 2000b).

Although it has been suggested that there are at least five subpopulations in the North Pacific (Reeves et al. 1998), analysis of calls monitored from the U.S. Navy Sound Surveillance System (SOSUS) and other offshore hydrophones (e.g., Stafford et al. 1999, 2001, 2007; Watkins et al. 2000a; Stafford 2003) suggests that there are two separate populations: one in the eastern and one in the central North Pacific (Carretta et al. 2017). The Eastern North Pacific Stock includes whales that feed primarily off California from June–November and winter off Central America (Calambokidis et al. 1990; Mate et al. 1999). The Central North Pacific Stock feeds off Kamchatka, south of the Aleutians and in the Gulf of Alaska during summer (Stafford 2003; Watkins et al. 2000b), and migrates to the western and central Pacific (including Hawaii) to breed in winter (Stafford et al. 2001; Carretta et al. 2017). The status of these two populations could differ substantially, as little is known about the population size in the western North Pacific (Branch et al. 2016).

In the North Pacific, blue whale calls are detected year-round (Stafford et al. 2001, 2009; Moore et al. 2002a, 2006; Monnahan et al. 2014). Stafford et al. (2009) reported that sea-surface temperature is a good predictor variable for blue whale call detections in the North Pacific. In the GOA, no detections of blue whales had been made since the late 1960s (NOAA 2004b; Calambokidis et al. 2009) until blue whale calls were recorded in the area during 1999–2002 (Stafford 2003; Stafford and Moore 2005; Moore et al. 2006; Stafford et al. 2007). Call types from both northeastern and northwestern Pacific blue whales were recorded from July through December in the GOA, suggesting that two stocks used the area at that time (Stafford 2003; Stafford et al. 2007). Call rates peaked from August through November (Moore et al. 2006). More recent acoustic studies using fixed PAM have confirmed the presence of blue whales from both the Central and Northeast Pacific stocks in the Gulf of Alaska concurrently (Baumann-Pickering et al. 2012; Debich et al. 2013; Rice et al. 2015). Blue whale calls were recorded in all months; at all shelf, slope, and seamount sites; and during all years (2011-2015) of those studies.

In July 2004, three blue whales were sighted in the GOA. The first blue whale was seen on 14 July ~185 km southeast of PWS. Two more blue whales were seen ~275 km southeast of PWS (NOAA 2004b; Calambokidis et al. 2009). These whales were thought to be part of the California feeding population (Calambokidis et al. 2009). Western blue whales are more likely to occur in the western portion of the GOA, southwest of Kodiak, where their calls have been detected (see Stafford 2003). Two blue whale sightings were also made in the Aleutians in August 2004 (Calambokidis et al. 2009). No blue whales were seen during surveys of the western GOA by Zerbini et al. (2006).

Rone et al. (2017) reported no blue whale sightings in 2009, five blue whale sightings (seven animals) in 2013, and 13 blue whale sightings (13 animals) in 2015 in the U.S. Navy training area east of Kodiak. Rone et al. (2017) used the June–July 2013 sightings data to calculate a blue whale density of 0.0014/km^2 for the seamount stratum and an abundance estimate of 63 for that area. These density and abundance estimates were not corrected for missed animals. The DoN considers blue whale densities to be in the range of 0.001651–0.002644/km^2 for the seamount stratum and 0.000010–0.000826/km^2 for the other areas in the region year-round (see Fig. 5-36 of DoN 2014). Blue whales were not observed during the NSF/L-DEO seismic survey conducted in the summer of 2011 in the same area as the currently proposed survey (RPS 2011).

Odontocetes

Sperm Whale (*Physeter macrocephalus*)

The sperm whale is the largest of the toothed whales, with an extensive worldwide distribution from the edge of the polar pack ice to the Equator (Whitehead 2009). Sperm whale distribution is linked to its social structure: mixed groups of adult females and juveniles of both sexes generally occur in tropical and subtropical waters at latitudes less than ~40° (Whitehead 2009). After leaving their female relatives, males gradually move to higher latitudes, with the largest males occurring at the highest latitudes and only returning to tropical and subtropical regions to breed. Sperm whales generally are distributed over large areas that have high secondary productivity and steep underwater topography, in waters at least 1000 m deep (Jaquet and Whitehead 1996). They are often found far from shore but can be found closer to oceanic islands that rise steeply from deep ocean waters (Whitehead 2009).

Most of the information regarding sperm whale distribution in the GOA (especially the eastern GOA) and southeast Alaska has come from anecdotal observations from fishermen and reports from fisheries observers aboard commercial fishing vessels (e.g., Dahlheim 1988). Fishery observers have identified interactions (e.g., depredation) between longline vessels and sperm whales in the GOA and southeast Alaska since at least the mid-1970s (e.g., Hill et al. 1999; Straley et al. 2005; Sigler et al. 2008), with most interactions occurring in the West Yakutat and East Yakutat/Southeast regions (Perez 2006; Hanselman et al. 2008). Sigler et al. (2008) noted high depredation rates in West Yakutat, East Yakutat/Southeast region, as well as the central GOA. Hill et al. (1999) found that most interactions in the GOA occurred to the east of Kodiak Island, even though there was substantial longline effort in waters to the west of Kodiak. Mellinger et al. (2004a) also noted that sperm whales occurred less often west of Kodiak Island.

Sperm whales are commonly sighted during surveys in the Aleutians and the central and western GOA (e.g., Forney and Brownell 1996; Moore 2001; Waite 2003; Wade et al. 2003; Zerbini et al. 2004; Barlow and Henry 2005; Ireland et al. 2005; Straley et al. 2005). Waite (2003) and Wade et al. (2003) noted an average group size of 1.2 in the western GOA. In contrast, there are fewer reports on the occurrence of sperm whales in the eastern GOA (e.g., Rice and Wolman 1982; Mellinger et al. 2004a; MacLean and Koski 2005; Rone et al. 2010). Rone et al. (2017) reported no sperm whale sightings in 2009, 19 sperm whale sightings (22 animals) in 2013, and 27 sperm whale sightings (45 animals) in 2015 in the U.S. Navy training area east of Kodiak. Additionally, there were 241 acoustic encounters with sperm whales during the 2013 towed-hydrophone survey in that study (Rone et al. 2014). Sperm whales were also frequently detected acoustically throughout the year during all years (2011-2015) of fixed-PAM studies in this area and detections occurred at all shelf, slope, and seamount sites, but they were less common at the shelf site near Kenai Peninsula and most common on the slope (Baumann-Pickering et al. 2012; Debich et al. 2013; Rice et al. 2015).

Rone et al. (2017) used the June–July 2013 sightings data to calculate sperm whale densities of $0.0000/km^2$ for the seamount stratum and $0.003/km^2$ for the slope stratum, with an overall density of $0.0003/km^2$ for the area. They also provided an abundance estimate (uncorrected for missed animals) for the area of 129 sperm whales, most of which were found in slope waters. Sperm whales were not observed during the NSF/L-DEO seismic survey conducted in the summer of 2011 in the same area as the currently proposed survey (RPS 2011).

Cuvier's Beaked Whale (*Ziphius cavirostris*)

Cuvier's beaked whale is the most widespread of the beaked whales, occurring in almost all temperate, subtropical, and tropical waters and even some sub-polar and polar waters (MacLeod et al. 2006). It is likely the most abundant of all beaked whales (Heyning and Mead 2009). Cuvier's beaked whale is found in deep water over and near the continental slope (Jefferson et al. 2015).

Cuvier's beaked whale ranges north to the GOA, including southeast Alaska, the Aleutian Islands, and the Commander Islands (Rice 1986, 1998). Most reported sightings have been in the Aleutian Islands (e.g., Leatherwood et al. 1983; Forney and Brownell 1996; Brueggeman et al. 1987). Waite (2003) reported a single sighting of four Cuvier's beaked whales at the shelf break east of Kodiak Island during the summer of 2003 and one stranded on Kodiak Island in January 1987 (Foster and Hare 1990). There was one sighting of a single Cuvier's beaked whale during a 2013 survey in the U.S. Navy training area east of Kodiak, but none during the 2009 and 2015 surveys in that region (Rone et al. 2017). There were also five sightings (eight animals) of unidentified beaked whales during the 2013 survey and none during the other years. Additionally, there were 34 acoustic encounters with Cuvier's beaked whales during the 2013 towed-hydrophone survey in that study (Rone et al. 2014). Cuvier's beaked whales were detected occasionally at deep-water sites (900-1000 m) during the 2011-2015 fixed-PAM studies in the U.S. Navy training area. They were infrequently detected on the slope site but more commonly detected at Pratt and Quinn seamounts. Detections occurred May to July 2014 at Pratt Seamount and October 2014 to March 2015 at Quinn Seamount in one of those studies (Rice et al. 2015). The U.S. DoN (2014) used Waite (2003) sightings data for this species to calculate a density estimate of $0.0022/km^2$ for their GOA training area east of Kodiak year-round. Beaked whales were not observed during the NSF/L-DEO seismic survey conducted in the summer of 2011 in the same area as the currently proposed survey (RPS 2011).

Stejneger's Beaked Whale (*Mesoplodon stejnegeri*)

Stejneger's beaked whale occurs in subarctic and cool temperate waters of the North Pacific (Mead 1989). Most records are from Alaskan waters, and the Aleutian Islands appear to be its center of distribution (Mead 1989; Wade et al. 2003). There have been no confirmed sightings of Stejneger's beaked whale in the GOA since 1986 (Wade et al. 2003). However, they have been detected acoustically in the Aleutian Islands during summer, fall, and winter (Baumann-Pickering et al. 2014) and were detected year-round at deep-water sites during the 2011-2015 fixed-PAM studies in the U.S. Navy training area east of Kodiak (Baumann-Pickering et al. 2012; Debich et al. 2013; Rice et al. 2015). In contrast to Cuvier's beaked whales, which were more prevalent at seamounts, Stejneger's beaked whales were detected most frequently at the slope site, with peak detections in September and October (Debich et al. 2013; Rice et al. 2015). There were no sightings of Stejneger's beaked whales during three years of surveys (2009, 2013, 2015) in this area (Rone et al. 2017). However, there were five sightings (eight animals) of unidentified beaked whales during the 2013 survey. Additionally, there were six acoustic encounters with Stejneger's beaked whales during the 2013 towed-hydrophone survey in that study (Rone et al. 2014). Beaked whales were not observed during the NSF/L-DEO seismic survey conducted in the summer of 2011 in the same area as the currently proposed survey (RPS 2011).

Baird's Beaked Whale (*Berardius bairdii*)

Baird's beaked whale has a fairly extensive range across the North Pacific north of 30˚N, and strandings have occurred as far north as the Pribilof Islands (Rice 1986). Two forms of Baird's beaked whales have been recognized – the common slate-gray form and a smaller, rare black form (Morin et al. 2017). The gray form is seen off Japan, in the Aleutians, and on the west coast of North America, whereas the black from has been reported for northern Japan and the Aleutians (Morin et al. 2017). Recent genetic studies suggest that the black form could be a separate species (Morin et al. 2017).

Baird's beaked whale is currently divided into three distinct stocks: Sea of Japan, Okhotsk Sea, and Bering Sea/eastern North Pacific (Balcomb 1989; Reyes 1991). Baird's beaked whales sometimes are seen close to shore, but their primary habitat is over or near the continental slope and oceanic seamounts in waters 1000–3000 m deep (Jefferson et al. 1993; Kasuya and Ohsumi 1984; Kasuya 2009).

Baird's beaked whale is migratory, arriving in the Bering Sea in the spring, and remaining there throughout the summer; the winter distribution is unknown (Kasuya 2002). There are numerous sighting records from the central GOA to the Aleutian Islands and the southern Bering Sea (Leatherwood et al. 1983; Kasuya and Ohsumi 1984; Forney and Brownell 1996; Brueggeman et al. 1987; Moore et al. 2002b; Waite 2003; Wade et al. 2003). There were seven sightings of Baird's beaked whales (58 animals) during a 2013 survey in the U.S. Navy training area east of Kodiak (Rone et al. 2017). Additionally, there were nine acoustic encounters with Baird's beaked whales during the 2013 towed-hydrophone survey in that study (Rone et al. 2014). There were also five sightings (eight animals) of unidentified beaked whales during that survey. No beaked whales were observed in 2009 or 2015 surveys in the same area (Rone et al. 2017). Baird's beaked whales were detected acoustically during fixed-PAM studies in this area during the 2011-2012 and 2012-2013 studies but not in 2014-2015 (Baumann-Pickering et al. 2012; Debich et al. 2013; Rice et al. 2015). They were detected regularly at the slope site from November through and January and at the Pratt Seamount site during most months. The U.S. DoN (2014) used Waite (2003) sightings data for this species to calculate a density estimate of 0.0005/km^2 for their GOA training area east of Kodiak year round. Beaked whales were not observed during the NSF/L-DEO seismic survey conducted in the summer of 2011 in the same area as the currently proposed survey (RPS 2011).

Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*)

The Pacific white-sided dolphin is found throughout the temperate North Pacific, in a relatively narrow distribution between 38°N and 47°N (Brownell et al. 1999). It is common both on the high seas and along the continental margins (Leatherwood et al. 1984; Dahlheim and Towell 1994; Ferrero and Walker 1996). Pacific white-sided dolphins often associate with other species, including cetaceans (especially Risso's and northern right whale dolphins; Green et al. 1993), pinnipeds, and seabirds.

Pacific white-sided dolphins were seen throughout the North Pacific during surveys conducted during 1983–1990 (Buckland et al. 1993; Miyashita 1993b). During winter, this species is most abundant in California slope and offshore areas; as northern marine waters begin to warm in the spring, it appears to move north to slope and offshore waters off Oregon/Washington (Green et al. 1992, 1993; Forney 1994; Forney et al. 1995; Buchanan et al. 2001; Barlow 2003). During the summer, Pacific white-sided dolphins occur north into the GOA and west to Amchitka in the Aleutian Islands, but rarely in the southern Bering Sea (Allen and Angliss 2010). Moore et al. (2002b) documented a single sighting of eight Pacific white-sided dolphins in the southeast Bering Sea along the Alaska Peninsula. Sightings in the GOA and Aleutian Islands have been documented in the summer by Waite (2003) and Wade et al. (2003), and in the spring to the southeast of Kodiak Island by Rone et al. (2010). Dahlheim and Towell (1994) reported sightings for southeast Alaska. There was one sighting of 60 Pacific white-sided dolphins in 2009, no sightings in 2013, and 10 sightings of Pacific white-sided dolphins (986 animals) in 2015 during surveys in the U.S. Navy training area east of Kodiak (Rone et al. 2017). The DoN (2014) has assigned this species a year-round density estimate of 0.0208/km^2 in this region. Pacific white-sided dolphins were not observed during the NSF/L-DEO seismic survey conducted in the summer of 2011 in the same area as the currently proposed survey (RPS 2011), but there was one sighting of two unidentified small odontocetes.

Risso's Dolphin (*Grampus griseus*)

Risso's dolphin is primarily a tropical and mid-temperate species distributed worldwide (Kruse et al. 1999). It occurs between 60ºN and 60ºS, where surface water temperatures are at least 10ºC (Kruse et al. 1999). Water temperature appears to be an important factor affecting its distribution (Kruse et al. 1999). Although it occurs from coastal to deep water, it shows a strong preference for mid-temperate waters of the continental shelf and slope (Jefferson et al. 2014).

Throughout the region from California to Washington, the distribution and abundance of Risso's dolphins are highly variable, presumably in response to changing oceanographic conditions on both annual and seasonal time scales (Forney and Barlow 1998; Buchanan et al. 2001; Becker 2007). Water temperature appears to be an important factor affecting their distribution (Kruse et al. 1999; see also Becker 2007). Like the Pacific white-sided dolphin, Risso's dolphin is believed to make seasonal north-south movements related to water temperature, spending colder winter months off California and moving north to waters off Oregon/Washington during the spring and summer as northern waters begin to warm (Green et al. 1992, 1993; Buchanan et al. 2001; Barlow 2003; Becker 2007). Risso's dolphins are uncommon to rare in the GOA. Risso's dolphins have been sighted near Chirikof Island (southwest of Kodiak Island) and offshore in the GOA (Consiglieri et al. 1980; Braham 1983). They were detected acoustically once, in January 2013, near Pratt Seamount during fixed-PAM studies from 2011-2015 in the U.S. Navy training area (Debich et al. 2013). The DoN (2014) considers this species to be only an occasional visitor to their GOA training area and has assigned them a year-round density of 0.00001/km^2 in this region. Risso's dolphins were not observed during the NSF/L-DEO seismic survey conducted in the summer of 2011 in the same area as the currently proposed survey (RPS 2011). There was one sighting of two unidentified small odontocetes.

Killer Whale (*Orcinus orca*)

The killer whale is cosmopolitan and globally fairly abundant; it has been observed in all oceans of the World (Ford 2009). It is very common in temperate waters and also frequents tropical waters, at least seasonally (Heyning and Dahlheim 1988). High densities of the species occur in high latitudes, especially in areas where prey is abundant. Killer whale movements generally appear to follow the distribution of their prey, which includes marine mammals, fish, and squid.

Of eight killer whale stocks currently recognized in the Pacific U.S., six occur in Alaskan waters: (1) the Eastern North Pacific Alaska Resident Stock, from southeast Alaska to the Aleutians and Bering Sea,

(2) the Eastern North Pacific Northern Resident Stock, from B.C. through parts of southeast Alaska, (3) the Eastern North Pacific Gulf of Alaska, Aleutian Islands, and Bering Sea Transient Stock, from PWS through to the Aleutians and Bering Sea, (4) the AT1 Transient Stock, from PWS through the Kenai Fjords, (5) the West Coast Transient Stock, from California through southeast Alaska, and (6) the Offshore Stock, from California through Alaska. The AT1 Transient Stock is considered depleted under the MMPA and therefore a strategic stock. Movements of resident groups between different geographic areas have also been documented (Leatherwood et al. 1990; Dahlheim et al. 1997; Matkin et al. 1997, 1999 *in* Allen and Angliss 2010). In the proposed study area, individuals from one resident stock (Eastern North Pacific Alaska Resident Stock), the North Pacific Offshore Stock, and two transient stocks (Eastern North Pacific Gulf of Alaska, Aleutian Islands, and Bering Sea Transient Stock and the depleted AT1 transient stock), could be encountered during the survey.

During surveys of the western GOA and Aleutian Islands, transient killer whale densities were higher south of the Alaska Peninsula between the Shumagin Islands and the eastern Aleutians than in other areas (Wade et al. 2003; Zerbini et al. 2007). They were not seen between the Shumagin Islands and the eastern side of Kodiak Island during surveys in 2001–2003, but they were sighted there during earlier surveys (e.g., Dahlheim 1997 *in* Zerbini et al. 2007). Resident killer whales were most abundant near Kodiak Island, around Umnak and Unalaska Islands in the eastern Aleutians, and in Seguam Pass in the central Aleutians (Wade et al. 2003; Zerbini et al. 2007). No residents were seen between 156ºW and 164ºW, south of the Alaska Peninsula (Zerbini et al. 2007).

Little is known about offshore killer whales in the GOA, but they could be encountered during the proposed survey. During summer surveys of the western GOA and Aleutian Islands in 2001–2003, two sightings of offshore killer whales were made, one northeast of Unalaska Island and another one south of Kodiak Island near the Trinity Islands (Wade et al. 2003; Zerbini et al. 2007). As the groups sighted were large, it suggests the number of offshore killer whales in the area is relatively high (Zerbini et al. 2007). Dahlheim et al. (2008b) encountered groups of 20–60 killer whales in western Alaska; offshore killer whales encountered near Kodiak Island and the eastern Aleutians were also sighted in southeast Alaska and California. A group of at least 54 offshore killer whales was sighted in July 2003 during a survey in the eastern Aleutian Islands (Matkin et al. 2007).

Rone et al. (2017) reported six killer whale sightings (119 animals) in 2009, 21 killer whale sightings (138 animals) in 2013, and 10 killer whale sightings (73 animals) in 2015 in the U.S. Navy training area east of Kodiak. Additionally, there were 32 acoustic encounters with killer whales and three acoustic encounters with offshore killer whales (based on known differences in their acoustic signals) during the 2013 towed-hydrophone survey in that study (Rone et al. 2014). Killer whales were detected acoustically sporadiacally throughout the year at shelf, slope, and seamount sites in the U.S. Navy training area (Baumann-Pickering et al. 2012; Debich et al. 2013). Rone et al. (2017) used the June–July 2013 sightings data to calculate killer whale densities of 0.005/km^2 for the inshore stratum, 0.002/km^2 for the seamount stratum, and 0.019/km^2 for the slope stratum, with an overall density of 0.0023/km^2 for the area. They also provided an abundance estimate (uncorrected for missed animals) for the area of 899 killer whales, most of which were found in slope waters. There was one sighting of a single killer whale during the NSF/L-DEO seismic survey conducted in the summer of 2011 in the same area as the currently proposed survey (RPS 2011).

Dall's Porpoise (*Phocoenoides dalli*)

Dall's porpoise is only found in the North Pacific and adjacent seas. It is widely distributed across the North Pacific over the continental shelf and slope waters, and over deep (>2500 m) oceanic waters (Hall 1979), ranging from ~30–62ºN (Jefferson et al. 2015). In general, this species is common throughout its range (Buckland et al. 1993). It is know to approach vessels to bowride (Jefferson 2009).

Dall's porpoise occurs throughout Alaska; the only apparent gaps in distribution in Alaskan waters south of the Bering Strait are for upper Cook Inlet and the Bering Sea shelf. Using a population estimate based on vessel surveys during 1987–1991, and correcting for the tendency of this species to approach vessels, which Turnock and Quinn (1991) suggested resulted in inflated abundance estimates perhaps by as much as five times, a population estimate of 83,400 was calculated for the Alaska stock of Dall's porpoise. Because this estimate is more than eight years old, NMFS considers it to be unreliable and reported that there are no reliable abundance estimates available for the Alaska Stock of this species when it was last reviewed (Muto et al. 2016).

Numerous studies have documented the occurrence of Dall's porpoise in the Aleutian Islands and western GOA (Forney and Brownell 1996; Moore 2001; Wade et al. 2003; Waite 2003; Baraff et al. 2005; Ireland et al. 2005) as well as in the Bering Sea (Moore et al. 2002b). Dall's porpoise was one of the most frequently sighted species during summer seismic surveys in the central and eastern GOA and southeast Alaska (MacLean and Koski 2005; Hauser and Holst 2009). Rone et al. (2017) reported 10 Dall's porpoise sightings (59 animals) in 2009, 337 Dall's porpoise sightings (907 animals) in 2013, and 98 Dall's porpoise sightings (391 animals) in 2015 in the U.S. Navy training area east of Kodiak. Additionally, there were three acoustic encounters with Dall's porpoise during the 2013 towed-hydrophone survey in that study (Rone et al. 2014). Rone et al. (2017) used the June–July 2013 sightings data to calculate Dall's porpoise densities for four habitat strata – 0.218/km^2 for the inshore stratum, 0.037/km^2 for the offshore stratum, 0.024/km^2 for the seamount stratum, and 0.196/km^2 for the slope stratum, with an overall density of 0.0398/km^2 for this area. They also provided an abundance estimate for the area of 15,423 Dall's porpoises. This estimate was uncorrected for missed animals and did not account for their propensity to approach vessels. Dall's porpoise was the second most freqently sighted cetacean during the NSF/L-DEO seismic survey conducted in the summer of 2011 in the same area as the currently proposed survey, comprising 14.1% of all cetacean sightings (RPS 2011). There were 26 sightings of this species, representing 227 animals during the 37 days of monitoring. The average group size was nine and the largest group size was 35.

Harbor Porpoise (*Phocoena phocoena*)

The harbor porpoise inhabits temperate, subarctic, and arctic waters. It is typically found in shallow water (<100 m) nearshore but is occasionally sighted in deeper offshore water (Jefferson et al. 2015); abundance declines linearly as depth increases (Barlow 1988). In the eastern North Pacific, its range extends from Point Barrow, Alaska, to Point Conception, California.

In Alaska, there are three separate stocks of harbor porpoise: Southeast Alaska, GOA, and Bering Sea. The Southeast Alaska Stock occurs from northern B.C. to Cape Suckling, and the GOA Stock ranges from Cape Suckling to Unimak Pass. The population estimates for the Southeast Alaska, GOA, and Bering Sea stocks are 11,146, 31,046, and 48,215, respectively (Muto et al. 2016).

Harbor porpoise are seen regularly in the western GOA and Aleutian Islands (e.g., Wade et al. 2003; Waite 2003; Baraff et al. 2005; Ireland et al. 2005) and Bering Sea (Moore et al. 2002b). Harbor porpoises are also sighted in the eastern and central GOA and southeast Alaska (Dahlheim et al. 2000, 2008a; MacLean and Koski 2005; Rone et al. 2010). There were 30 sightings (89 animals) of harbor porpoise in 2009, eight sightings (11 animals) of harbor porposie in 2013, and a single sighting of one harbor porpoise in 2015 during surveys in the U.S. Navy training area east of Kodiak (Rone et al. 2017). Harbor porpoise were not observed during the NSF/L-DEO seismic survey conducted in the summer of 2011 in the same area as the currently proposed survey (RPS 2011), but there was one sighting of two unidentified small odontocetes.

Pinnipeds

Northern Fur Seal (*Callorhinus ursinus*)

The northern fur seal is endemic to the North Pacific Ocean and occurs from southern California to the Bering Sea, Okhotsk Sea, and Honshu Island, Japan (Muto et al. 2018). During the breeding season, most of the worldwide population of northern fur seals inhabits the Pribilof Islands in the southern Bering Sea (Lee et al. 2014; Muto et al. 2018). The rest of the population occurs at rookeries on Bogoslof Island in the Bering Sea, in Russia (Commander Islands, Robben Island, Kuril Islands), on San Miguel Island in southern California (NMFS 1993; Lee et al. 2014), and on the Farallon Islands off central California (Muto et al. 2018). In the U.S., two stocks are recognized—the Eastern Pacific and the California stocks (Muto et al. 2018). The Eastern Pacific stock ranges from the Pribilof Islands and Bogoslof Island in the Bering Sea during summer to California during winter (Muto et al. 2018).

When not on rookery islands, northern fur seals are primarily pelagic but occasionally haul out on rocky shorelines (Muto et al. 2018). During the breeding season, adult males usually come ashore in May–August and may sometimes be present until November; adult females are found ashore from June–November (Carretta et al. 2017; Muto et al. 2018). After reproduction, northern fur seals spend the next 7–8 months feeding at sea (Roppel 1984). Once weaned, juveniles spend 2–3 years at sea before returning to rookeries. Animals may migrate to the GOA, off Japan, and the west coast of the U.S. (Muto et al. 2018). Pups travel through Aleutian passes and spend the first two years at sea before returning to their islands of origin.

In November, adult females and pups leave the Pribilof Islands and migrate into the North Pacific Ocean to areas including offshore Oregon and Washington (Ream et al. 2005). Males usually migrate only as far south as the GOA (Kajimura 1984). Ream et al. (2005) showed that migrating females moved over the continental shelf as they migrated southeasterly. Instead of following depth contours, their travel corresponded with movements of the Alaska Gyre and the North Pacific Current (Ream et al. 2005). Their foraging areas were associated with eddies, the subarctic-subtropical transition region, and coastal mixing (Ream et al. 2005; Alford et al. 2005). Some juveniles and non-pregnant females may remain in the GOA throughout the summer (Calkins 1986).

Robson et al. (2004) reported that female fur seals from St. Paul and St. George islands traveled in different directions. They also observed habitat separation among breeding sites on the same island (Robson et al. 2004). Lactating females from the same breeding site share a foraging area, whereas females from different sites tend to forage in different areas (Robson et al. 2004). Females from both islands traveled for similar durations and maximum distances (Robson et al. 2004).

Northern fur seals were seen throughout the North Pacific during surveys conducted during 1987–1990 (Buckland et al. 1993). Tracked adult male fur seals that were tagged on St. Paul Island in the Bering Sea in October 2009, wintered in the Bering Sea or northern North Pacific Ocean; females migrated to the GOA and the California Current (Sterling et al. 2014).

A total of 42 northern fur seals was seen during 3767 km of shipboard surveys in the northwestern GOA during June–July 1987 (Brueggeman et al. 1988). Leatherwood et al. (1983) reported 14 sightings of 34 northern fur seals away from the breeding islands in the southeast Bering Sea during aerial surveys in 1982, mostly during July and August. No fur seals were seen during summer surveys in the GOA in 2004 and 2008 (MacLean and Koski 2005; Hauser and Holst 2009) or during spring surveys in 2009 (Rone et al. 2010). None of the 42 female northern fur seals tagged on St Paul Island between August–October 2007 and 2008 traveled south of the Aleutian Islands (Kuhn et al. 2010). Rone et al. (2014) reported 78 northern fur seal sightings (83 animals) in 2013 in the U.S. Navy training area east of Kodiak and calculated densities for four habitat strata: 0.015/km^2 for the inshore stratum, 0.017/km^2 for the offshore stratum, 0.006/km^2 for the seamount stratum, and 0.004/km^2 for the slope stratum, with an overall density of 0.011/km^2 for the area. They also provided an abundance estimate (uncorrected for missed animals) for the area of 1770 northern fur seals. There were seven sightings, representing 7 northern fur seals, during the NSF/L-DEO seismic survey conducted in the summer of 2011 in the same area as the currently proposed survey (RPS 2011).

Steller Sea Lion (*Eumetopias jubatus*)

The Steller sea lion occurs along the North Pacific Rim from northern Japan to California (Loughlin et al. 1984). They are distributed around the coasts to the outer shelf from northern Japan through the Kuril Islands and Okhotsk Sea, through the Aleutian Islands, central Bering Sea, southern Alaska, and south to California (NMFS 2016c). There are two stocks, or DPSs, of Steller sea lions – the Western and Eastern DPSs, which are divided at 144°W longitude (NMFS 2016c). The Western DPS is listed as *endangered* and includes animals that occur in Japan and Russia (NMFS 2016c; Muto et al. 2017); the Eastern DPS was delisted from *threatened* in 2013 (NMFS 2013a). Critical habitat has been designated 20 n.mi. around all major haulouts and rookeries, as well as three large foraging areas (NMFS 2017b). The critical habitat of both stocks is currently under review in light of the delisting of the Eastern DPS (Muto et al. 2018). Critical habitat as well as "no approach" zones occur within the proposed study area. "No approach" zones are restricted areas wherein no vessel may approach within 3 n.mi. (5.6 km) of listed rookeries (50 CFR 223.202). Only individuals from the Western DPS are expected to occur in the proposed survey area. The Eastern DPS is estimated at 41,638 (Muto et al. 2017) and appears to have increased at an annual rate of 4.76% between 1989 and 2015 (Muto et al. 2018).

Rookeries of Steller sea lions from the Western DPS are located on the Aleutian Islands and along the Gulf of Alaska, as well as the east coast of Kamchatka, Commander Islands, and Kuril Islands (Burkanov and Loughlin 2005; Fritz et al. 2016; Muto et al. 2017). Breeding adults occupy rookeries from late-May to early-July (NMFS 2008). Non-breeding adults use haulouts or occupy sites at the periphery of rookeries during the breeding season (NMFS 2008). Pupping occurs from mid-May to mid-July (Pitcher and Calkins 1981) and peaks in June (Pitcher et al. 2002). Territorial males fast and remain on land during the breeding season (NMFS 2008). Females with pups generally stay within 30 km of the rookeries in shallow (30–120 m) water when feeding (NMFS 2008). Tagged juvenile sea lions showed localized movements near shore (Briggs et al. 2005). Loughlin et al. (2003) reported that most (88%) at-sea movements of juvenile Steller sea lions in the Aleutian Islands were short (<15 km) foraging trips. The mean distance of juvenile sea lion trips at sea was 16.6 km and the maximum trip distance recorded was 447 km. Long-range trips represented 6% of all trips at sea, and trip distance and duration increase with age (Loughlin et al. 2003; Call et al. 2007). Although Steller sea lions are not considered migratory, foraging animals can travel long distances outside of the breeding season (Loughlin et al. 2003; Raum-Suryan et al. 2002).

Steller sea lions are present in Alaska year-round, with centers of abundance in the GOA and Aleutian Islands. There are five major rookery sites within the study area in the northern GOA: Chirikof, Chowiet, Atkins, Chernabura islands, and Pinnacle Rock. There are also numerous haulout sites located within the study area (see Fig. 1); most haulout sites on Kodiak Island (and within the study area) are used year-round (e.g., Wynne 2005). Counts are highest in late summer (Wynne 2005). Sea lion counts in the central GOA, including Kodiak Island, were reported to be declining between 1999 and 2003 (Sease and Gudmundson 2002; Wynne 2005). Evidence suggests that counts in Alaska were lowest in 2002 and 2003, but between 2003 and 2016 pup and non-pup counts have increased by 2.19%/year and 2.24%/year, respectively (Muto et al. 2018). These rates vary regionally, with the highest rates of increase in the eastern Gulf of Alaska and a steadily decreasing rate of increase heading west to the Aleutian Islands.

Steller sea lions are an important subsistence resource for Alaska Natives from southeast Alaska to the Aleutian Islands. There are numerous communities along the shores of the GOA that participate in subsistence hunting. In 2008, 19 sea lions were taken in the Kodiak Island region and 9 were taken along the South Alaska Peninsula (Wolfe et al. 2009). As of 2009, data on community subsistence harvests are no longer being collected consistently so no data are available. The most recent 5 years of data available (2004–2008) show an annual average catch of 172 steller sea lions for all areas in Alaska combined except the Pribilof Islands in the Bering Sea (Muto et al. 2018).

The U.S. DoN (2014) estimates a density of 0.0098/km^2 for this species year-round in its training area east of Kodiak. There was one sighting of 18 Steller sea lions during the NSF/L-DEO seismic survey conducted in the summer of 2011 in the same area as the currently proposed survey (RPS 2011).

Northern Elephant Seal (*Mirounga angustirostris*)

Northern elephant seals breed in California and Baja California, primarily on offshore islands (Stewart et al. 1994), from December–March (Stewart and Huber 1993). Adult elephant seals engage in two long northward migrations per year, one following the breeding season, and another following the annual molt, with females returning earlier to molt (March–April) than males (July–August) (Stewart and DeLong 1995). Juvenile elephant seals typically leave the rookeries in April or May and head north, traveling an average of 900–1000 km. Hindell and Perrin (2009) noted that traveling likely takes place in water depths >200 m.

When not breeding, elephant seals feed at sea far from the rookeries, ranging as far north as 60°N, into the GOA and along the Aleutian Islands (Le Boeuf et al. 2000). Some seals that were tracked via satellite-tags for no more than 224 days traveled distances in excess of 10,000 km during that time (Le Beouf et al. 2000). Northern elephant seals that were satellite-tagged at a California rookery have been recorded traveling as far west as ~166.5–172.5°E (Le Boeuf et al. 2000; Robinson et al. 2012; Robinson 2016 *in* OBIS 2018; Costa 2017 *in* OBIS 2018). Post-molting seals traveled longer and farther than post-breeding seals (Robinson et al. 2012). Rone et al. (2014) reported 16 northern fur seal sightings (16 animals) in a June–July 2013 survey in the U.S. Navy training area east of Kodiak. The U.S. DoN (2014) estimates a cold water (winter/spring) density of 0.0024/km^2 and warm water (summer/fall) density of 0.0022/km^2 for this species in its GOA training area east of Kodiak. Northern elephant seal males could occur in the GOA throughout the year (Calkins 1986).

California Sea Lion (*Zalophus californianus*)

The primary range of the California sea lion includes the coastal areas and offshore islands of the eastern North Pacific Ocean from BC, Canada, to central Mexico, including the Gulf of California (Jefferson et al. 2015). However, its distribution is expanding (Jefferson et al. 2015), and its secondary range extends into the GOA where it is occasionally recorded (Maniscalco et al. 2004) and southern Mexico (Gallo-Reynoso and Solórzano-Velasco 1991). California sea lions are coastal animals that often haul out on shore throughout the year. King (1983) noted that sea lions are rarely found more than 16 km offshore. During fall and winter surveys off Oregon/Washington, mean distance from shore was ~13 km (Bonnell et al. 1992).

California sea lion rookeries are on islands located in southern California, western Baja California, and the Gulf of California (Carretta et al. 2016). A single stock is recognized in U.S. waters: the U.S. Stock. Five genetically distinct geographic populations have been identified: (1) Pacific Temperate (includes rookeries in U.S. waters and the Coronados Islands to the south), (2) Pacific Subtropical, (3) Southern Gulf of California, (4) Central Gulf of California, and (5) Northern Gulf of California (Schramm et al. 2009). Animals from the Pacific Temperate population occur in the proposed project area. California sea lions that are sighted in Alaska are typically seen at Steller sea lion rookeries or haulouts, with most sightings occurring between March and May, although they can be found in the GOA year-round (Maniscalco et al. 2004). The U.S. DoN (2014) estimates a density of 0.00001/km^2 for this species year-round in its training area east of Kodiak

Harbor Seal (*Phoca vitulina*)

The harbor seal is distributed in the North Atlantic and North Pacific. Two subspecies occur in the Pacific: *P.v. stejnegeri* in the northwest Pacific Ocean and *P.v. richardii* in the eastern Pacific Ocean. Eastern Pacific harbor seals occur in nearshore, coastal, and estuarine areas ranging from Baja California, Mexico, north to the Pribilof Islands in Alaska (Muto et al. 2016). Harbor seals inhabit estuarine and coastal waters, hauling out on rocks, reefs, beaches, and glacial ice flows. They are generally non-migratory, but move locally with the tides, weather, season, food availability, and reproduction (Scheffer and Slipp 1944; Fisher 1952; Bigg 1969, 1981). Twelve stocks of harbor seals are recognized in Alaska (Muto et al. 2016). The proposed survey would take place within the range of three of these stocks: North Kodiak, South Kodiak, and Cook Inlet/Shelikof Strait stocks. Nearby stocks are the Aleutian Islands, Prince William Sound, and Glacier Bay/Icy Strait stocks. There are two stocks in the Bering Sea (Bristol Bay and Pribilof Islands) and four stocks in southeast Alaska.

Female harbor seals give birth to a single pup while hauled out on shore or on glacial ice flows; pups are born from May to mid-July. The mother and pup remain together until weaning occurs at 3–6 weeks (Bishop 1967; Bigg 1969). When molting, which occurs primarily in late August, seals spend the majority of the time hauled out on shore, glacial ice, or other substrates. Juvenile harbor seals can travel significant distances (525 km) to forage or disperse, whereas adults were generally found within 190 km of their tagging location in Prince William Sound, Alaska (Lowry et al. 2001). The smaller home range used by adults is suggestive of a strong site fidelity (Pitcher and Calkins 1979; Pitcher and McAllister 1981; Lowry et al. 2001). Pups tagged in the GOA most commonly undertook multiple return trips of more than 75 km from natal areas, followed by movements of <25 km from the natal area (Small et al. 2005). Pups tagged in Prince William Sound traveled a mean maximum distance of 43.2 km from their tagging location, whereas those tagged in the GOA moved a mean maximum distance of 86.6 km (Small et al. 2005).

Harbor seals are an important subsistence resource for Alaska Natives in the northern GOA. In 2011–2012, 37 harbor seals were taken from the North Kodiak Stock and 126 harbor seals were taken from the South Kodiak Stock by communities on Kodiak Island (Muto et al. 2016). The number taken from the Cook Inlet/Shelikof Strait Stock for 2011–2012 is unknown, but an average of 233 were taken from this stock annually during 2004-2008 (Muto et al. 2016).

The U.S. DoN (2014) estimates a density of 0.00001/km^2 for this species year-round in its training area east of Kodiak. There was one sighting of nine harbor seals during the NSF/L-DEO seismic survey conducted in the summer of 2011 in the same area as the currently proposed survey (RPS 2011). Harbor seals could be encountered in the proposed survey area.

V. TYPE OF INCIDENTAL TAKE AUTHORIZATION REQUESTED

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

L-DEO requests an IHA pursuant to Section 101 (a)(5)(D) of the MMPA for incidental take by harassment during its planned seismic surveys in the Gulf of Alaska in 2019. The operations outlined in § I have the potential to take marine mammals by harassment. Sounds would be generated by the airguns used during the survey, by echosounders, and by general vessel operations. "Takes" by harassment would potentially result when marine mammals near the activity are exposed to the pulsed sounds, such as those generated by the airguns. The effects would depend on the species of marine mammal, the behavior of the animal at the time of reception of the stimulus, as well as the distance and received level of the sound (see § VII). Disturbance reactions are likely amongst some of the marine mammals near the tracklines of the source vessel.

At most, effects on marine mammals would be anticipated as falling within the MMPA definition of "Level B Harassment" for those species managed by NMFS. No take by serious injury is expected, given the nature of the planned operations and the mitigation measures that are planned (see § XI, MITIGATION MEASURES), and no lethal takes are expected. However, per NMFS requirement, L-DEO and NSF are also requesting small numbers of Level A takes for the remote possibility of low-level physiological effects. Because of the characteristics of the proposed study and the proposed monitoring and mitigation measures, in addition to the general avoidance by marine mammals of loud sounds, Level A takes are considered highly unlikely. However, during the Gulf of Alaska survey, where they could be present, Dall's porpoise could be more susceptible to exposure to sound levels that exceed the PTS threshold than other marine mammals, because this species is known to approach vessels to bowride.

VI. NUMBERS OF MARINE MAMMALS THAT COULD BE TAKEN

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

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

VII. ANTICIPATED IMPACT ON SPECIES OR STOCKS

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

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

- First we summarize the potential impacts on marine mammals of airgun operations, as called for in § VII. A more comprehensive review of the relevant background information appears in § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS.
- Then we summarize the potential impacts of operations by the echosounders. A more comprehensive review of the relevant background information appears in § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS.
- Finally, we estimate the numbers of marine mammals that could be affected by the proposed surveys in the Gulf of Alaska. As called for in § VI, this section includes a description of the rationale for the estimates of the potential numbers of harassment "takes" during the planned surveys, as well Level A "takes", as required by NMFS. Acoustic modeling was conducted by L-DEO, determined to be acceptable by NMFS to use in the calculation of estimated takes under the MMPA.

Summary of Potential Effects of Airgun Sounds

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

Permanent hearing impairment (PTS), in the unlikely event that it occurred, would constitute injury, but TTS is not considered an injury (Southall et al. 2007; Le Prell 2012). Rather, the onset of TTS has been considered an indicator that, if the animal is exposed to higher levels of that sound, physical damage is ultimately a possibility. Nonetheless, research has shown that sound exposure can cause cochlear neural degeneration, even when threshold shifts and hair cell damage are reversible (Kujawa and Liberman 2009; Liberman et al. 2016). These findings have raised some doubts as to whether TTS should continue to be considered a non-injurious effect (Weilgart 2014; Tougaard et al. 2015, 2016). Although the possibility cannot be entirely excluded, it is unlikely that the proposed survey would result in any cases of temporary or permanent hearing impairment, or any significant non-auditory physical or physiological effects. If marine mammals encounter a survey while it is underway, some behavioral disturbance could result, but this would be localized and short-term.

Tolerance

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

Masking

Masking effects of pulsed sounds (even from large arrays of airguns) on marine mammal calls and other natural sounds are expected to be limited, although there are few specific data on this. Because of the intermittent nature and low duty cycle of seismic pulses, animals can emit and receive sounds in the relatively quiet intervals between pulses. However, in exceptional situations, reverberation occurs for much or all of the interval between pulses (e.g., Simard et al. 2005; Clark and Gagnon 2006), which could mask calls. Situations with prolonged strong reverberation are infrequent. However, it is common for reverberation to cause some lesser degree of elevation of the background level between airgun pulses (e.g., Gedamke 2011; Guerra et al. 2011, 2016; Klinck et al. 2012; Guan et al. 2015), and this weaker reverberation presumably reduces the detection range of calls and other natural sounds to some degree. Guerra et al. (2016) reported that ambient noise levels between seismic pulses were elevated as a result of reverberation at ranges of 50 km from the seismic source. Based on measurements in deep water of the Southern Ocean, Gedamke (2011) estimated that the slight elevation of background levels during intervals between pulses reduced blue and fin whale communication space by as much as 36–51% when a seismic survey was operating 450–2800 km away. Based on preliminary modeling, Wittekind et al. (2016) reported that airgun sounds could reduce the communication range of blue and fin whales 2000 km from the seismic source. Nieukirk et al. (2012) and Blackwell et al. (2013) noted the potential for masking effects from seismic surveys on large whales.

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

Disturbance Reactions

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

Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors (Richardson et al. 1995; Wartzok et al. 2004; Southall et al. 2007; Weilgart 2007; Ellison et al. 2012). If a marine mammal does react briefly to an underwater sound by changing its behavior or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or population (e.g., New et al. 2013a). However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on individuals and populations could be significant (Lusseau and Bejder 2007; Weilgart 2007; New et al. 2013b; Nowacek et al. 2015; Forney et al. 2017). Some studies have attempted modeling to assess consequences of effects from underwater noise at the population level (e.g., King et al. 2015; Costa et al. 2016a,b; Ellison et al. 2016; Harwood et al. 2016; Nowacek et al. 2016; Farmer et al. 2017).

Given the many uncertainties in predicting the quantity and types of impacts of noise on marine mammals, it is common practice to estimate how many marine mammals would be present within a particular distance of industrial activities and/or exposed to a particular level of industrial sound. In most cases, this approach likely overestimates the numbers of marine mammals that would be affected in some biologically important manner.

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

Baleen Whales.—Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to pulses from large arrays of airguns at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, baleen whales exposed to strong noise pulses from airguns often react by deviating from their normal migration route and/or interrupting their feeding and moving away. In the cases of migrating gray and bowhead whales, the observed changes in behavior appeared to be of little or no biological consequence to the animals. They simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors (Malme et al. 1984; Malme and Miles 1985; Richardson et al. 1995).

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

Dunlop et al. (2015) reported that migrating humpback whales in Australia responded to a vessel operating a 20 in^3 airgun by decreasing their dive time and speed of southward migration; however, the same responses were obtained during control trials without an active airgun, suggesting that humpbacks responded to the source vessel rather than the airgun. A ramp up was not superior to triggering humpbacks to move away from the vessel compared with a constant source at a higher level of 140 in^3, although an increase in distance from the airgun(s) was noted for both sources (Dunlop et al. 2016a). Avoidance was also shown when no airguns were operational, indicating that the presence of the vessel itself had an effect on the response (Dunlop et al. 2016a,b). Overall, the results showed that humpbacks were more likely to avoid active small airgun sources (20 and 140 in^3) within 3 km and received levels of at least 140 dB re 1 $\mu Pa^2 \cdot s$ (Dunlop et al. 2017a). Responses to ramp up and use of a large 3130 in^3 array elicited greater behavioral changes in humpbacks when compared with small arrays (Dunlop et al. 2016c). Humpbacks reduced their southbound migration, or deviated from their path thereby avoiding the active array, when they were within 4 km of the active large airgun source, where received levels were >135 dB re 1 $\mu Pa^2 \cdot s$ (Dunlop et al. 2017b). These results are consistent with earlier studies (e.g., McCauley et al. 2000).

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

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

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

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

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

There was no indication that *western gray whales* exposed to seismic sound were displaced from their overall feeding grounds near Sakhalin Island during seismic programs in 1997 (Würsig et al. 1999) and in 2001 (Johnson et al. 2007; Meier et al. 2007; Yazvenko et al. 2007a). However, there were indications of subtle behavioral effects among whales that remained in the areas exposed to airgun sounds (Würsig et al. 1999; Gailey et al. 2007; Weller et al. 2006a) and localized redistribution of some individuals within the nearshore feeding ground so as to avoid close approaches by the seismic vessel (Weller et al. 2002, 2006b; Yazvenko et al. 2007a). Despite the evidence of subtle changes in some quantitative measures of behavior and local redistribution of some individuals, there was no apparent change in the frequency of feeding, as evident from mud plumes visible at the surface (Yazvenko et al. 2007b). Similarly, no large changes in gray whale movement, respiration, or distribution patterns were observed during the seismic programs conducted in 2010 (Bröker et al. 2015; Gailey et al. 2016). Although sighting distances of gray whales from shore increased slightly during a 2-week seismic survey, this result was not significant (Muir et al. 2015). However, there may have been a possible localized avoidance response to high sound levels in the area (Muir et al. 2016). The lack of strong avoidance or other strong responses during the 2001 and 2010 programs was presumably in part a result of the comprehensive combination of real-time monitoring and mitigation measures designed to avoid exposing western gray whales to received SPLs above ~163 dB re 1 μPa_{rms} (Johnson et al. 2007; Nowacek et al. 2012, 2013b). In contrast, preliminary data collected during a seismic program in 2015 showed some displacement of animals from the feeding area and responses to lower sound levels than expected (Gailey et al. 2017; Sychenko et al. 2017).

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

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

During seismic surveys in the northwest Atlantic, baleen whales as a group showed localized avoidance of the operating array (Moulton and Holst 2010). Sighting rates were significantly lower during seismic operations compared with non-seismic periods. Baleen whales were seen on average 200 m farther from the vessel during airgun activities vs. non-seismic periods, and these whales more often swam away from the vessel when seismic operations were underway compared with periods when no airguns were operating (Moulton and Holst 2010). Blue whales were seen significantly farther from the vessel during single airgun operations, ramp up, and all other airgun operations compared with non-seismic periods (Moulton and Holst 2010). Similarly, fin whales were seen at significantly farther distances during ramp up than during periods without airgun operations; there was also a trend for fin whales to be sighted farther from the vessel during other airgun operations, but the difference was not significant (Moulton and Holst 2010). Minke whales were seen significantly farther from the vessel during periods with than without seismic operations (Moulton and Holst 2010). Minke whales were also more likely to swim away and less likely to approach during seismic operations compared to periods when airguns were not operating (Moulton and Holst 2010). However, Matos (2015) reported no change in sighting rates of minke whales in Vestfjorden, Norway, during ongoing seismic surveys outside of the fjord. Vilela et al. (2016) cautioned that environmental conditions should be taken into account when comparing sighting rates during seismic surveys, as spatial modeling showed that differences in sighting rates of rorquals (fin and minke whales) during seismic periods and non-seismic periods during a survey in the Gulf of Cadiz could be explained by environmental variables.

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

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

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

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

Preliminary findings of a monitoring study of *narwhals* in Melville Bay, Greenland, (summer and fall 2012) showed no short-term effects of seismic survey activity on narwhal distribution, abundance, migration timing, and feeding habits (Heide-Jørgensen et al. 2013a). In addition, there were no reported effects on narwhal hunting. These findings do not seemingly support a suggestion by Heide-Jørgensen et al. (2013b) that seismic surveys in Baffin Bay may have delayed the migration timing of narwhals, thereby increasing the risk of narwhals to ice entrapment.

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

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

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

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

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

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

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

Hearing Impairment and Other Physical Effects

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

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

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

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

Popov et al. (2016) reported that TTS produced by exposure to a fatiguing noise was larger during the first session (or naïve subject state) with a beluga whale than TTS that resulted from the same sound in subsequent sessions (experienced subject state). Similarly, several other studies have shown that some marine mammals (e.g., bottlenose dolphins, false killer whales) can decrease their hearing sensitivity in order to mitigate the impacts of exposure to loud sounds (e.g., Nachtigall and Supin 2013, 2014, 2015, 2016, 2017).

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

Several studies on TTS in porpoises (e.g., Lucke et al. 2009; Popov et al. 2011; Kastelein et al. 2012a, 2013a,b, 2014, 2015a) indicate that received levels that elicit onset of TTS are lower in porpoises than in other odontocetes. Kastelein et al. (2012a) exposed a harbor porpoise to octave band noise centered at 4 kHz for extended periods. A 6-dB TTS occurred with SELs of 163 dB and 172 dB for low-intensity sound and medium-intensity sound, respectively; high-intensity sound caused a 9-dB TTS at a SEL of 175 dB (Kastelein et al. 2012a). Kastelein et al. (2013b) exposed a harbor porpoise to a long, continuous 1.5-kHz tone, which induced a 14-dB TTS with a total SEL of 190 dB. Popov et al. (2011) examined the effects of fatiguing noise on the hearing threshold of Yangtze finless porpoises when exposed to frequencies of 32–128 kHz at 140–160 dB re 1 μPa for 1–30 min. They found that an exposure of higher level and shorter duration produced a higher TTS than an exposure of equal SEL but of lower level and longer duration. Popov et al. (2011) reported a TTS of 25 dB for a Yangtze finless porpoise that was exposed to high levels of 3-min pulses of half-octave band noise centered at 45 kHz with an SEL of 163 dB.

For the harbor porpoise, Tougaard et al. (2015) have suggested an exposure limit for TTS as an SEL of 100–110 dB above the pure tone hearing threshold at a specific frequency; they also suggested an exposure limit of $L_{\text{eq-fast}}$ (rms average over the duration of the pulse) of 45 dB above the hearing threshold for behavioral responses (i.e., negative phonotaxis). In addition, according to Wensveen et al. (2014) and Tougaard et al. (2015), M-weighting, as used by Southall et al. (2007), might not be appropriate for the harbor porpoise. Thus, Wensveen et al. (2014) developed six auditory weighting functions for the harbor porpoise that could be useful in predicting TTS onset. Mulsow et al. (2015) suggested that basing weighting functions on equal latency/loudness contours may be more appropriate than M-weighting for marine mammals. Simulation modeling to assess the risk of sound exposure to marine mammals (gray seal and harbor porpoise) showed that SEL is most strongly influenced by the weighting function (Donovan et al.

2017). Houser et al. (2017) provide a review of the development and application of auditory weighting functions, as well as recommendations for future work.

Initial evidence from exposures to non-pulses has also suggested that some pinnipeds (harbor seals in particular) incur TTS at somewhat lower received levels than do most small odontocetes exposed for similar durations (Kastak et al. 1999, 2005, 2008; Ketten et al. 2001). Kastelein et al. (2012b) exposed two harbor seals to octave-band white noise centered at 4 kHz at three mean received SPLs of 124, 136, and 148 dB re 1 µPa; TTS >2.5 dB was induced at an SEL of 170 dB (136 dB SPL for 60 min), and the maximum TTS of 10 dB occurred after a 120-min exposure to 148 dB re 1 µPa or an SEL of 187 dB. Kastelein et al. (2013c) reported that a harbor seal unintentionally exposed to the same sound source with a mean received SPL of 163 dB re 1 µPa for 1 h induced a 44 dB TTS. For a harbor seal exposed to octave-band white noise centered at 4 kHz for 60 min with mean SPLs of 124–148 re 1 µPa, the onset of PTS would require a level of at least 22 dB above the TTS onset (Kastelein et al. 2013c). Reichmuth et al. (2016) exposed captive spotted and ringed seals to single airgun pulses with SELs of 165–181 dB and SPLs (peak to peak) of 190–207 re 1 µPa; no low-frequency TTS was observed.

Hermannsen et al. (2015) reported that there is little risk of hearing damage to harbor seals or harbor porpoises when using single airguns in shallow water. Similarly, it is unlikely that a marine mammal would remain close enough to a large airgun array for sufficiently long to incur TTS, let alone PTS. However, Gedamke et al. (2011), based on preliminary simulation modeling that attempted to allow for various uncertainties in assumptions and variability around population means, suggested that some baleen whales whose CPA to a seismic vessel is 1 km or more could experience TTS.

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

The new noise exposure criteria for marine mammals that were recently released by NMFS (2016a) account for the newly-available scientific data on TTS, the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors. For impulsive sounds, such airgun pulses, the thresholds use dual metrics of cumulative SEL (SEL_{cum} over 24 hours) and Peak SPL_{flat}. Onset of PTS is assumed to be 15 dB higher when considering SEL_{cum} and 6 dB higher when considering SPL_{flat}. Different thresholds are provided for the various hearing groups, including LF cetaceans (e.g., baleen whales), MF cetaceans (e.g., most delphinids), HF cetaceans (e.g., porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW).

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

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might (in theory) occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, and other types of organ or tissue damage. Gray and Van Waerebeek (2011) have suggested a cause-effect relationship between a seismic survey off Liberia in 2009 and the erratic movement, postural instability, and akinesia in a pantropical spotted dolphin based on spatially and temporally close association with the airgun array. It is possible that some marine mammal species (i.e., beaked whales) are especially susceptible to injury and/or stranding when exposed to strong transient sounds (e.g., Southall et al. 2007). Ten cases of cetacean strandings in the general area where a seismic survey was ongoing have led to speculation concerning a possible link between seismic surveys and strandings (Castellote and Llorens 2016). An analysis of stranding data found that the number of long-finned pilot whale stranding along Ireland's coast increased with seismic surveys operating offshore (McGeady et al. 2016). However, there is no definitive evidence that any of these effects occur even for marine mammals in close proximity to large arrays of airguns. Morell et al. (2017) examined the inner ears of long-finned pilot whales after a mass stranding in Scotland and reported damage to the cochlea compatible with over-exposure from underwater noise; however, no seismic surveys were occurring in the vicinity in the days leading up to the stranding.

Since 1991, there have been 67 Marine Mammal Unusual Mortality Events (UME) in the U.S. (NMFS 2018b). In a hearing to examine the Bureau of Ocean Energy Management's 2017–2022 OCS Oil and Gas Leasing Program (http://www.energy.senate.gov/public/index.cfm/hearings-and-business-meetings?ID=110E5E8F-3A65-4BEC-9D25-5D843A0284D3), it was Dr. Knapp's (a geologist from the University of South Carolina) interpretation that there was no evidence to suggest a correlation between UMEs and seismic surveys given the similar percentages of UMEs in the Pacific, Atlantic, and Gulf of Mexico, and the greater activity of oil and gas exploration in the Gulf of Mexico.

Non-auditory effects, if they occur at all, would presumably be limited to short distances and to activities that extend over a prolonged period. Marine mammals that show behavioral avoidance of seismic vessels, including most baleen whales, some odontocetes, and some pinnipeds, are especially unlikely to incur non-auditory physical effects. The brief duration of exposure of any given mammal, the deep water in the majority of the survey 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

The Kongsberg EM 122 MBES and Knudsen Chirp 3260 SBP would be operated from the source vessel during the proposed surveys. Information about this equipment was provided in § 2.2.3.1 of the PEIS. A review of the expected potential effects (or lack thereof) of MBESs, SBPs, and pingers on marine mammals appears in § 3.4.4.3, § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS.

There has been some recent attention given to the effects of MBES on marine mammals, as a result of a report issued in September 2013 by an IWC independent scientific review panel linking the operation of an MBES to a mass stranding of melon-headed whales off Madagascar (Southall et al. 2013). During May–June 2008, ~100 melon-headed whales entered and stranded in the Loza Lagoon system in northwest Madagascar at the same time that a 12-kHz MBES survey was being conducted ~65 km away off the coast.

In conducting a retrospective review of available information on the event, an independent scientific review panel concluded that the Kongsberg EM 120 MBES was the most plausible behavioral trigger for the animals initially entering the lagoon system and eventually stranding. The independent scientific review panel, however, identified that an unequivocal conclusion on causality of the event was not possible because of the lack of information about the event and a number of potentially contributing factors. Additionally, the independent review panel report indicated that this incident was likely the result of a complicated confluence of environmental, social, and other factors that have a very low probability of occurring again in the future, but recommended that the potential be considered in environmental planning. It should be noted that this event is the first known marine mammal mass stranding closely associated with the operation of an MBES. Leading scientific experts knowledgeable about MBES expressed concerns about the independent scientific review panel analyses and findings (Bernstein 2013).

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

Lurton (2016) modeled MBES radiation characteristics (pulse design, source level, and radiation directivity pattern) applied to a low-frequency (12-kHz), 240-dB source-level system like that used on the *Langseth*. Using Southall et al. (2007) thresholds, he found that injury impacts were possible only at very short distances, e.g., at 5 m for maximum SPL and 12 m for cumulative SEL for cetaceans; corresponding distances for behavioral response were 9 m and 70 m. For pinnipeds, "all ranges are multiplied by a factor of 4" (Lurton 2016:209).

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

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

Deng et al. (2014) measured the spectral properties of pulses transmitted by three 200-kHz echosounders and found that they generated weaker sounds at frequencies below the center frequency (90–130 kHz). These sounds are within the hearing range of some marine mammals, and the authors suggested that they could be strong enough to elicit behavioral responses within close proximity to the sources, although they would be well below potentially harmful levels. Hastie et al. (2014) reported behavioral responses by gray seals to echosounders with frequencies of 200 and 375 kHz. Short-finned pilot whales increased their heading variance in response to an EK60 echosounder with a resonant frequency of 38 kHz (Quick et al. 2017), and significantly fewer beaked whale vocalizations were detected while an EK60 echosounder was active vs. passive (Cholewiak et al. 2017).

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

Other Possible Effects of Seismic Surveys

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

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

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

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

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

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

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

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

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

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

All takes would be anticipated to be Level B "takes by harassment" as described in § I, involving temporary changes in behavior. As required by NMFS, Level A takes have been requested; given the small

EZ and the proposed mitigation measures to be applied, injurious takes would not be expected. (However, as noted earlier and in the PEIS, there is no specific information demonstrating that injurious Level A "takes" would occur even in the absence of the planned mitigation measures.) In the sections below, we describe the methods used to estimate the number of potential exposures to Level A and Level B threshold and present estimates of the numbers of marine mammals that could be affected during the proposed seismic survey. The estimates are based on consideration of the number of marine mammals that could be disturbed appreciably by the seismic survey in the GOA. The main sources of distributional and numerical data used in deriving the estimates are described in the next subsection.

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

Basis for Estimating "Takes"

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

For the proposed survey, we consulted with NMFS regarding which marine mammal density sources to use for developing take estimates. In response, NMFS recommended the use of habitat-based stratified marine mammal densities developed by the U.S. Navy for assessing potential impacts of training activities in the GOA (DoN 2014). Alternative density estimates available for species in this region are not stratified by water depth and therefore do not reflect the known variability in species distribution relative to habitat features. Consistent with Rone et al. (2014), four strata were defined: Inshore: all waters <1000 m deep; Slope: from 1000 m water depth to the Aleutian trench/subduction zone; Offshore: waters offshore of the Aleutian trench/subduction zone; Seamount: waters within defined seamount areas. Densities corresponding to these strata were based on data from several different sources, including Navy funded line-transect surveys in the GOA as described below and in Appendix B.

To develop densities specific to the GOA, the Navy conducted two comprehensive marine mammal surveys in the Temporary Marine Activities Area (TMAA) in the GOA prior to 2014. The first survey was conducted from 10 to 20 April 2009 and the second was from 23 June to 18 July 2013. Both surveys used systematic line-transect survey protocols including visual and acoustic detection methods (Rone et al. 2010; Rone et al. 2014). The data were collected in four strata that were designed to encompass the four distinct habitats within the TMAA and greater GOA. Rone et al. (2014) provided stratified line-transect density estimates used in this analysis for fin, humpback, blue, sperm, and killer whales, as well as northern fur seals (Table 5). Data from a subsequent survey in 2015 were used to calculate alternative density estimates for several species (Rone et al. 2017) and the density estimates for Dall's porpoise used here were taken from that source.

DoN (2014) derived gray whale densities in two zones, nearshore (0–2.25 n.mi from shore) and offshore (from 2.25–20 n.mi. from shore). In our calculations, the nearshore density was used to represent the inshore zone and the offshore density was used to represent the slope zone.

Harbor porpoise densities in DoN (2014) were derived from Hobbs and Waite (2010) which included additional shallow water depth strata. The density estimate from the 100 m to 200 m depth strata was used to represent the entire inshore zone (<1000 m) in this analysis. Similarly, harbor seals typically remain close to shore so minimal estimates were used for the three deep water zones and a one thousand fold increase of the minimal density was used to represent the entire inshore zone (DoN 2014).

TABLE 5. Densities of marine mammals that could be exposed to Level B and Level A thresholds for NMFS defined hearing groups during the proposed GOA survey. Species in *italics* are listed under the ESA.

	Estimated Density (#/1000 km^2)			
Species	**Inshore** <1000 m	**Slope** (1000 m to Aleutian Trench)	**Offshore** (Offshore of Aleutian Trench)	**Seamount** (In Defined Seamount Areas)
LF Cetaceans				
North Pacific right whale	0.01	0.01	0.01	0.01
Humpback whale	129.00	0.20	1.00	1.00
Blue whale	0.50	0.50	0.50	2.00
Fin whale	71.00	14.00	21.00	5.00
Sei whale	0.10	0.10	0.10	0.10
Minke whale	0.60	0.60	0.60	0.60
Gray whale	48.57	2.43	0.00	0.00
MF Cetaceans				
Sperm whale	0.00	3.30	1.30	0.36
Killer whale	5.00	20.00	2.00	2.00
Pacific white-sided dolphin	20.80	20.80	20.80	20.80
Cuvier's beaked whale	2.20	2.20	2.20	2.20
Baird's beaked whale	0.50	0.50	0.50	0.50
Stejneger's beaked whale	0.01	1.42	1.42	1.42
Risso's dolphin	0.01	0.01	0.01	0.01
HF Cetaceans				
Harbor Porpoise	47.30	0.00	0.00	0.00
Dall's porpoise	218.00	196.00	37.00	24.00
Otariid Seals				
Steller sea lion	9.80	9.80	9.80	9.80
California sea lion	0.01	0.01	0.01	0.01
Northern fur seal	15.00	4.00	17.00	6.00
Phocid Seal				
Northern elephant seal	2.20	2.20	2.20	2.20
Harbor seal	10.00	0.01	0.01	0.01

Densities for Minke whale, Pacific white-sided dolpin, and Cuvier's and Baird's beaked whales were based on Waite (2003 *in* DoN 2009). Although sei whale sightings and Stejneger's beaked whale acoustic detections were recorded during the Navy funded GOA surveys, data were insufficient to calculate densities for these species, so predictions from a global model of marine mammals densities were used (DoN 2014).

Steller sea lion and northern elephant seal densities were calculated using shore-based population estimates divided by the area of the GOA Large Marine Ecosystem (DoN 2014).

The North Pacific right whale, Risso's dolphin, and California sea lion are only rarely observed in or near the survey area, so minimal densities were used to represent their potential presence.

All densities were corrected for perception bias [$f(0)$] but only harbor porpoise densities were corrected for availability bias [$g(0)$], as described by the respective authors. There is some uncertainty related to the estimated density data and the assumptions used in their calculations, as with all density data estimates. However, the approach used here is based on the best available data that are stratified by the water depth (habitat) zones present within the survey area. Alternative density estimates available for species in this region are not stratified by water depth and therefore do not reflect the known variability in species distribution relative to habitat features. The calculated exposures that are based on these densities are best estimates for the proposed survey.

The estimated numbers of individuals potentially exposed are based on the 160-dB re 1 μPa_{rms} criterion for all marine mammals. It is assumed that marine mammals exposed to airgun sounds that strong could change their behavior sufficiently to be considered "taken by harassment". Using the density estimates shown in Table 5, estimates of the number of marine mammals that potentially could be exposed to ≥160 dB re 1 μPa_{rms} during the proposed seismic survey in GOA if no animals moved away from the survey vessel are shown in Table 6. The *Requested Take Authorization* is given in the right-most column of Table 6. The North Pacific right whale and Risso's dolphin were the only species for which the *Requested Take Authorization* was increased from the density-based calculations to mean group size based on Shelden et al. (2005), Waite et al. (2003) and Wade et al. (2011a) for North Pacific right whale and Bradford et al. (2017) for Risso's dolphin.

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

Consideration should be given to the hypothesis that delphinids are less responsive to airgun sounds than are mysticetes, as referenced in the NSF/USGS PEIS. The 160-dB (rms) criterion currently applied by NMFS, on which the Level B estimates are based, was developed primarily using data from gray and bowhead whales. The estimates of "takes by harassment" of delphinids are thus considered precautionary. Available data suggest that the current use of a 160-dB criterion could be improved upon, as behavioral response might not occur for some percentage of marine mammals exposed to received levels >160 dB, whereas other individuals or groups might respond in a manner considered as "taken" to sound levels <160 dB (NMFS 2013b). It has become evident that the context of an exposure of a marine mammal to sound can affect the animal's initial response to the sound (NMFS 2013b).

The number of marine mammals that could be exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} (Level B) for marine mammals on one or more occasions have been estimated using a method required by NMFS for calculating the marine area that would be within the Level B threshold around the operating seismic source, along with the expected density of animals in the area. This method was developed to account in some way for the number of exposures as well as the number of individuals exposed. It involves selecting a seismic trackline(s) that could be surveyed on one day (~222 km) with a proportion occurring in the marine mammal density zones (inshore, slope, offshore, and seamount) that is roughly similar to that of the entire survey. The area expected to be ensonified on that day was determined by entering the planned survey lines into a MapInfo GIS, using GIS to identify the relevant areas by "drawing" the applicable 160-dB (Table 1) and PTS threshold buffers (Table 2) around each line. The ensonified areas, increased by 25%, were then multiplied by the number of survey days (18 days). This is equivalent to adding an additional 25% to the proposed line km (Appendix D). The approach assumes that no marine mammals would move away or toward the trackline in response to increasing sound levels before the levels reach the specific thresholds as the *Langseth* approaches.

TABLE 6. Densities and estimates of the possible numbers of marine mammals that could be exposed to Level B and Level A thresholds for various hearing groups during the proposed GOA survey.

Species	Calculated Take NMFS Daily Method[1]		Regional Population Size	Level B + Level A as % of Pop.[4]	Requested Take Authorization[5]
	Level B[2]	Level A[3]			
LF Cetaceans					
North Pacific right whale [6]	1	1	400	1.0	4
Humpback whale	5,730	1	21,063	27.2	5,731
Blue whale	49	1	1,647	3.0	50
Fin whale	3,913	1	18,680	21.0	3,914
Sei whale	9	1	27,197	0.0	10
Minke whale	54	1	25,000	0.2	55
Gray whale	2,183	1	20,990	10.4	2,184
MF Cetaceans					
Sperm whale	86	1	26,300	0.3	87
Killer whale	587	1	8,500	6.9	588
Pacific white-sided dolphin	1,838	1	988,333	0.2	1,839
Cuvier's beaked whale	195	1	20,000	1.0	196
Baird's beaked whale	45	1	25,300	0.2	46
Stejneger's beaked whale[7]	64	1	25,300	0.3	65
Risso's dolphin[8]	1	1	838,000	0.0	17
HF Cetaceans					
Harbor Porpoise	2,090	3	79,261	2.6	2,093
Dall's porpoise	13,677	21	1,186,000	1.2	13,698
Otariid Seals					
Steller sea lion	866	1	53,303	1.6	867
California sea lion	1	1	296,750	0.0	2
Northern fur seal	1,184	1	1,100,000	0.1	1,185
Phocid Seal					
Northern elephant seal	195	1	239,000	0.1	196
Harbor seal	443	1	129,000	0.3	444

[1]Take using NMFS daily method for calculating ensonified area: estimated density multiplied by the daily ensonified area to levels ≥160 dB re 1 µPa$_{rms}$ on one selected day (222 km) multiplied by the number of survey days (18 days), times 1.25; daily ensonified area = full 160-dB area minus ensonified area for the appropriate PTS thresholds. See text for more details.
[2] Level A takes if there were no mitigation measures.
[3] Level B takes, based on the 160-dB criterion, excluding exposures to sound levels equivalent to PTS thresholds.
[4] Requested Level A and B takes (used by NMFS as proxy for number of individuals exposed) expressed as % of population in the North Pacific (see Table 4).
[5] Requested take authorization is Level A plus Level B calculated takes, unless otherwise indicated.
[6] To avoid incidental take, a shutdown of operating airguns would occur upon sighting of a North Pacific right whale at any distance (see Mitigation), so no incidental take is expected; however, as a cautionary approach, two Level A and two Level B takes are requested. Two individuals is a conservative estimate of the group size of this species sighted in the Gulf of Alaska (Shelden et al. 2005; Waite et al. 2003; Wade et al. 2011a).
[7] Abundance estimate not available, but acoustic monitoring suggests Stejneger's beaked whales are at least as abundant as Baird's beaked whale in the GOA (Baumann-Pickering et al. 2014), so use of Baird's beaked whale abundance estimate should result in a cautionary estimate of the percent of the population potentially taken.
[8] Requested take authorization (Level B only) increased to mean group size.
[9] Calculated using area ensonified to ≥160 dB re 1 µPa$_{rms}$ in waters <40 m deep.

Per NMFS requirement, estimates of the numbers of cetaceans and pinnipeds that could be exposed to seismic sounds with received levels equal to Level A thresholds for various hearing groups (see Table 2), if there were no mitigation measures (power downs or shut downs when PSOs observed animals approaching or inside the EZs), are also given in Table 6. Those numbers likely overestimate actual Level

A takes because the predicted Level A EZs are small and mitigation measures would further reduce the chances of, if not eliminate, any such takes. In addition, most marine mammals would move away from a sound source before they are exposed to sound levels that could result in a Level A take. Dall's porpoise could be more susceptible to exposure to sound levels that exceed the PTS threshold than other marine mammals, as this species is known to approach vessels to bowride. However, Level A takes are considered highly unlikely for most marine mammal species that could be encountered in the proposed survey area.

The estimate of the number of marine mammals that could be exposed to seismic sounds with received levels ≥160 dB re 1 μPa_{rms} in the GOA survey area is 27,099 cetaceans and 2,037 pinnipeds (Table 6). That total includes 3,613 cetaceans listed as ***endangered*** under the ESA: 80 sperm whales, 9 sei whales, 3,480 fin whales, 44 blue whales, representing 0.3%, 0.03%, 18.6%, 2.7% of their regional populations, respectively. The total also includes 781 pinnipeds listed as endangered under the ESA, all of which are Stellar sea lions which represents 1.5% of the population. In addition, 277 beaked whales could be exposed. Most (52%) of the cetaceans potentially exposed would be porpoise; the Dalls' porpoise is expected to be the most common marine mammal species in the area, with up to 12,172 exposed to ≥160 dB re 1 μPa_{rms}, (1% of their regional populations).

Conclusions

In § 3.6.7, § 3.7.7, § 3.8.7, and § 3.9.7, the PEIS concluded that airgun operations with implementation of the proposed monitoring and mitigation measures could result in a small number of Level B behavioral effects in some mysticete, odontocete, pinniped, and fissiped species and that Level A effects were highly unlikely. NMFS required the calculation of and request for potential Level A takes for the Proposed Action (following a different methodology than used in the PEIS and most previous analyses for NSF-funded seismic surveys). For recent NSF-funded seismic surveys, NMFS issued small numbers of Level A take for some marine mammal species for the remote possibility of low-level physiological effects; however, NMFS expected neither mortality nor serious injury of marine mammals to result from the surveys (NMFS 2015, 2016e,f, 2017a).

In this analysis, estimates of the numbers of marine mammals that could be exposed to airgun sounds during the proposed program have been presented, together with the requested "take authorization". The estimated numbers of animals potentially exposed to sound levels sufficient to cause Level A and/or B harassment are low percentages of the regional population sizes (Table 9). However, the relatively short-term exposures are unlikely to result in any long-term negative consequences for the individuals or their populations. Therefore, no significant impacts on marine mammals would be anticipated from the proposed activity, and it is not likely to adversely affect ESA-listed species.

In decades of seismic surveys carried out by the *Langseth* and its predecessor, the R/V *Ewing*, PSOs and other crew members have seen no seismic sound-related marine mammal injuries or mortality. Also, the actual numbers of animals potentially exposed to sound levels sufficient to cause disturbance (i.e., what would be considered takes) have almost always been much lower than the predicted and authorized takes. For example, during an NSF-funded, ~5000-km, 2-D seismic survey conducted by the *Langseth* off the coast of North Carolina in September–October 2014, only 296 cetaceans were observed within the predicted 160-dB zone and potentially taken, representing <2% of the 15,498 takes authorized by NMFS (RPS 2015). During a USGS-funded, ~2700 km, 2-D seismic survey conducted by the *Langseth* along the U.S. east coast in August–September 2014, only 3 unidentified dolphins were observed within the predicted 160-dB zone and potentially taken, representing <0.03% of the 11,367 authorized takes (RPS 2014). During an NSF-funded ~3455 km, 2-D seismic survey conducted by the *Langseth* off the coast of Hawaii in 2018, no marine mammals were observed within the predicted 160-dB zone and potentially taken, representing 0% of the 11,068 takes authorized by NMFS (RPS in prep.). Furthermore, as defined, all animals exposed to sound levels >160 dB are Level B 'takes' whether or not a behavioral response occurred. The Level B estimates are thought to be conservative; thus, not all animals detected within this threshold distance would be expected to have been exposed to actual sound levels >160 dB.

VIII. ANTICIPATED IMPACT ON SUBSISTENCE

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

Subsistence hunting continues to feature prominently in the household economies and social welfare of some Alaskan residents, particularly among those living in small, rural villages (Wolfe and Walker 1987). Subsistence remains the basis for Alaska Native culture and community. In rural Alaska, subsistence activities are often central to many aspects of human existence from patterns of family life to artistic expression and community religious and celebratory activities.

Marine mammals are hunted legally in Alaskan waters by coastal Alaska Natives. In the GOA, the marine mammals that are hunted are Steller sea lions and harbor seals. In 2011–2012, 37 harbor seals were taken from the North Kodiak Stock and 126 harbor seals were taken from the South Kodiak Stock by communities on Kodiak Island (Muto et al. 2016). The number taken from the Cook Inlet/Shelikof Strait Stock for 2011–2012 is unknown, but an average of 233 were taken from this stock annually during 2004-2008 (Muto et al. 2016). The seasonal distribution of harbor seal takes by Alaska Natives typically shows two distinct hunting peaks — one during spring and one during fall and early winter; however, seals are taken in all months (Wolfe et al. 2012). In general, the months of highest harvest are September through December, with a smaller peak in February/March (Wolfe et al. 2012). Harvests are traditionally low from May through August, when harbor seals are raising pups and molting.

In 2008, 19 steller sea lions were taken in the Kodiak Island region and 9 were taken along the South Alaska Peninsula (Wolfe et al. 2009). As of 2009, data on community subsistence harvests are no longer being collected consistently so few data are available. Wolfe et al. (2012) reported an estimated 20 sea lions taken by hunters on Kodiak Island in 2011. The most recent 5-year period with data available (2004–2008) shows an annual average catch of 172 steller sea lions for all areas in Alaska combined except the Pribilof Islands in the Bering Sea (Muto et al. 2018). Sea lions are taken from Kodiak Island in low numbers year round (Wolfe et al. 2012).

An endangered DPS of beluga whales occurs in Cook Inlet. Although these belugas have been hunted in the past, harvesting of this population is currently not permitted, because of the small population size (see § III). Gray whales are not hunted within the project area. Some of the gray whales that migrate through the GOA in spring and late autumn are hunted in Russian waters, and a very limited subsistence hunt has occurred in recent years off Washington. Any small-scale disturbance effects that might occur in the GOA as a result of the proposed activity would have no effect on the hunts for gray whales in those distant locations.

The proposed project could potentially impact the availability of marine mammals for harvest in a small area immediately around the *Langseth*, and for a very short time period during seismic operations. Considering the limited time that the planned seismic surveys would take place close to shore, where most subsistence harvest of marine mammals occurs, the proposed project is not expected to have any significant impacts to the availability of Steller sea lions or harbor seals for subsistence harvest.

IX. ANTICIPATED IMPACT ON HABITAT

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

The proposed seismic surveys would not result in any permanent impact on habitats used by marine mammals or to the food sources they use. The main impact issue associated with the proposed activity would be temporarily elevated noise levels and the associated direct effects on marine mammals, as discussed in § VII, above.

Effects of seismic sound on marine invertebrates (crustaceans and cephalopods), marine fish, and their fisheries are discussed in § 3.2.4 and § 3.3.4 and Appendix D of the PEIS. The PEIS concluded that there could be changes in behavior and other non-lethal, short-term, temporary impacts, and injurious or mortal impacts on a small number of individuals within a few meters of a high-energy acoustic source, but that there would be no significant impacts of NSF-funded marine seismic research on populations. The potential to negatively impact subsistence hunting would be minimized through outreach and avoidance.

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

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

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

XI. MITIGATION MEASURES

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

Marine mammals and sea turtles are known to occur in the proposed survey areas. To minimize the likelihood that impacts would occur to the species and stocks, airgun operations would be conducted in accordance with the MMPA and the ESA, including obtaining permission for incidental harassment or incidental 'take' of marine mammals and other endangered species and following requirements issued in the IHA and associated Incidental Take Statement (ITS). The proposed activities would take place within the EEZ in the Gulf of Alaska in the northeastern Pacific Ocean.

Standard monitoring and mitigation measures for seismic surveys are described in § 2.4.1.1 and 2.4.2 of the PEIS and would occur in two phases: pre-cruise planning and operations. The following sections describe the efforts during both stages for the proposed activities. Numerous papers have been published recently with recommendations on how to reduce anthropogenic sound in the ocean (e.g., Simmonds et al. 2014; Wright 2014; Dolman and Jasny 2015). Some of those recommendations have been taken into account here.

Planning Phase

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

1. *Energy Source*—Part of the considerations for the proposed marine seismic survey was to evaluate whether the research objectives could be met with a smaller energy source. The scientific objectives for the proposed survey could not be met using smaller sources, as the primary aim of the project is deep imaging of the megathrust from 0–40 km depth, the crust-mantle boundary (Moho) of the overriding continental plate (~35 km depth), and downgoing oceanic plate (~12 km depth, including water column), and to explore the upper-most mantle anisotropy of the oceanic plate, for which a large, low-frequency airgun array is required.
2. *Survey Location and Timing*—The survey needs to be conducted while the AACSE OBSs are on the sea floor (before 6 August 2019). The most value-added time window is mid-May through mid-June, when an on-shore, 400–450 element nodal seismic array will also be deployed on Kodiak Island and which could record an unprecedented ship-to-shore dataset.

   When considering potential times to carry out the proposed survey, key factors taken into consideration included environmental conditions (i.e., the seasonal presence of marine mammals, sea turtles, and seabirds), weather conditions, equipment, and optimal timing for other proposed seismic surveys using the *Langseth*. Many marine mammal species occur in the area year-round. However, baleen whale presence in the area is highest on a seasonal basis (summer and fall, beginning in June). Thus, the likely timing (i.e., late spring) for the proposed survey in late May or early June is advantageous for reducing potential impacts on baleen whales. In addition, subsistence hunting of marine mammals off Kodiak Island is generally low during June and July, thus minimizing the impact of the survey on subsistence hunting.
3. *Mitigation Zones*—During the planning phase, mitigation zones for the proposed marine seismic survey were not derived from the farfield signature but calculated based on modeling by L-DEO for both the exclusion zones (EZ) for Level A takes and safety zones (160 dB re $1\mu Pa_{rms}$) for Level B takes. The background information and methodology for this are provided in Appendix A.

   The proposed survey would acquire data with the 36-airgun array at a maximum tow depth of 12 m. L-DEO model results are used to determine the 160-dB_{rms} radius for the 36-airgun array and 40-in^3 airgun at a 12-m tow depth in deep water (>1000 m) down to a maximum depth of 2000 m. The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor of 1.5. For shallow water (<100 m), radii are based on empirically derived measurements in the Gulf of Mexico (GoM) with scaling applied to account for differences in tow depth (see Appendix A). Table 1 shows the distances at which the 160-dB re $1\mu Pa_{rms}$ sound levels are expected to be received for the 36-airgun array and the single (mitigation) airgun. The 160-dB level is the behavioral disturbance criterion (Level B) that is used by NMFS to estimate anticipated takes for marine mammals.

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

Mitigation During Operations

Mitigation measures that would be adopted during the proposed surveys include (1) power-down procedures, (2) shut-down procedures, and (3) ramp-up procedures. Although these measures are proposed by L-DEO based on past experience and for consistency with the PEIS, L-DEO would ultimately follow monitoring and mitigation measures required by the IHA and ITS.

Power-down Procedures

A power down involves decreasing the number of airguns in use such that the radius of the threshold zone is decreased to the extent that marine mammals or turtles are no longer in or about to enter the EZ. The acoustic source would also be powered down in the event an ESA-listed seabird were observed diving or foraging within the designated EZ. During a power down, one airgun would be operated. The continued operation of one airgun is intended to alert marine mammals and turtles to the presence of the seismic vessel in the area. In contrast, a shut down occurs when all airgun activity is suspended.

If a marine mammal or turtle is detected outside the EZ but is likely to enter the EZ, the airguns would be powered down before the animal is within the EZ. Likewise, if a mammal or turtle is already within the EZ when first detected, the airguns would be powered down immediately. During a power down of the airgun array, the 40-in^3 airgun would be operated. If a marine mammal or turtle is detected within or near the smaller EZ around that single airgun, it would be shut down (see next subsection). In recent IHAs, NMFS has required implementation of shutdowns/powerdowns from a buffer zone distance determined by NMFS. As noted previously, L-DEO would ultimately follow the mitigation measures required by the IHA and ITS.

Following a power down, airgun activity would not resume until the marine mammal or turtle has cleared the EZ. The animal would be considered to have cleared the EZ if

- it is visually observed to have left the EZ, or
- it has not been seen within the zone for 15 min in the case of small odontocetes, or
- it has not been seen within the zone for 30 min in the case of mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, and beaked whales, or
- the vessel has moved outside the EZ for turtles, e.g., if a turtle is sighted close to the vessel and the ship speed is 7.6 km/h, it would take the vessel ~15 min to leave the turtle behind in deep water.

The airgun array would be ramped up gradually after a power down or shut down for a marine mammal or sea turtle. Ramp-up procedures are described below. Under a power-down scenario, a single mitigation airgun still would be operating to alert and warn animals of the on-going activity.

Shut-down Procedures

The operating airgun(s) would be shut down if a marine mammal or turtle is seen within or approaching the EZ for the single airgun. The operating airgun(s) would also be shut down in the event an ESA-listed seabird were observed diving or foraging within the designated EZ.

Shut downs would be implemented (1) if an animal enters the EZ of the single airgun after a power down has been initiated, or (2) if an animal is initially seen within the EZ of a single airgun when more than one airgun (typically the full array) is operating, or (3) if a power-down has exceeded 30 min. Airgun activity would not resume until the marine mammal or turtle has cleared the EZ, or until the PSO is confident that the animal has left the vicinity of the vessel. Criteria for judging that the animal has cleared the EZ would be as described in the preceding subsection.

Ramp-up Procedures

A ramp-up procedure would be followed when the airgun array begins operating after a specified period without airgun operations. It is proposed that, for the present survey, this period would be 30 min, as long as PSOs have maintained constant visual and acoustic observations and no detections within the EZ have occurred. Ramp up would not occur if a marine mammal or sea turtle has not cleared the EZ as described earlier.

Ramp up would begin with the smallest airgun in the array (40 in^3). Ramp-up would begin by activating a single airgun of the smallest volume in the array and shall continue in stages by doubling the number of active elements at the commencement of each stage, with each stage of approximately the same duration. Airguns would be added in a sequence such that the source level of the array would increase in steps not exceeding 6 dB per 5-min period. During ramp up, the PSOs would monitor the EZ, and if marine mammals or turtles are sighted, a power down or shut down would be implemented as though the full array were operational. Ramp up would not commence at night or during poor visibility unless the EZ has been monitored visually and PAM has occurred for 30 min prior to the start of operations and no marine mammal or sea turtle detections occurred during that period.

XII. PLAN OF COOPERATION

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

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

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

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

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

Not applicable. The proposed activity will take place in the western GOA, and no activities will take place in or near a traditional Arctic subsistence hunting area.

XIII. MONITORING AND REPORTING PLAN

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

L-DEO proposes to sponsor marine mammal monitoring during the present project, in order to implement the proposed mitigation measures that require real-time monitoring and to satisfy the expected monitoring requirements of the IHA. L-DEO's proposed Monitoring Plan is described below. L-DEO understands that this Monitoring Plan would be subject to review by NMFS and that refinements may be required.

The monitoring work described here has been planned as a self-contained project independent of any other related monitoring projects that may be occurring simultaneously in the same regions. L-DEO is prepared to discuss coordination of its monitoring program with any related work that might be done by other groups insofar as this is practical and desirable.

Vessel-based Visual Monitoring

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

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

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

Passive Acoustic Monitoring

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

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

The towed hydrophones would ideally be monitored 24 h per day while at the seismic survey areas during airgun operations, and during most periods when the *Langseth* is underway while the airguns are not operating. However, PAM may not be possible if damage occurs to the array or back-up systems during operations. One PSO would monitor the acoustic detection system at any one time, by listening to the signals from two channels via headphones and/or speakers and watching the real-time spectrographic display for frequency ranges produced by cetaceans. The PSO monitoring the acoustical data referred to as the PSAO, would be on shift for 1–6 h at a time. All observers would be expected to rotate through the PAM position, although the most experienced with acoustics would be on PAM duty more frequently.

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

PSO Data and Documentation

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

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

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

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

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

Results from the vessel-based observations would provide

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

2. information needed to estimate the number of marine mammals potentially taken by harassment, which must be reported to NMFS;
3. data on the occurrence, distribution, and activities of marine mammals, turtles, and diving ESA-listed seabirds in the area where the seismic study is conducted;
4. information to compare the distance and distribution of marine mammals, turtles, and diving ESA-listed seabirds relative to the source vessel at times with and without seismic activity;
5. data on the behavior and movement patterns of marine mammals and turtles seen at times with and without seismic activity; and
6. any observations of fish potentially affected by the sound sources.

A report would be submitted to NMFS and NSF within 90 days after the end of the cruise. The report would describe the operations that were conducted and sightings of marine mammals, turtles, and diving ESA-listed seabirds near the operations. The report would provide full documentation of methods, results, and interpretation pertaining to all monitoring. The 90-day report would summarize the dates and locations of seismic operations, all marine mammal, turtle, and diving ESA-listed seabird sightings (dates, times, locations, activities, associated seismic survey activities), and any observations of fish potentially affected by the sound sources. The report would also include estimates of the number and nature of exposures that could result in "takes" of marine mammals by harassment or in other ways.

XIV. Coordinating Research to Reduce and Evaluate Incidental Take

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

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

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APPENDIX A: DETERMINATION OF MITIGATION ZONES

APPENDIX A: DETERMINATION OF MITIGATION ZONES

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

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 the 36-airgun array at a maximum tow depth of 12 m. For deep water (>1000 m), we use the deep-water radii obtained from L-DEO model results down to a maximum water depth of 2000 m. 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 tow depth between the calibration survey (6 m) and the proposed survey (12 m); whereas the shallow water in the GoM may not exactly replicate the shallow water environment at the proposed survey site, 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 determined by the deep-water L-DEO model, which are essentially a measure of the energy radiated by the source array.

For the 36-airgun array, the 150-dB Sound Exposure Level (SEL)[1] corresponds to deep-water maximum radii of 10,553 m for 12-m tow depth (Fig. A-1) and 7244 m for a 6-m tow depth (Fig. A-2), yielding a scaling factor of 1.4568 to be applied to the shallow-water 6-m tow depth results. Similarly, the 165 dB SEL corresponds to deep-water maximum radii of 1864 m for 12-m tow depth (Fig. A-1) and 1284 m for for 6-m tow depth (Fig. A-2), yielding a scaling factor of 1.4517. The 185 SEL corresponds to deep-water maximum radii of 181 m for 12-m tow depth (Fig. A-1) and 126 m for 6-m tow depth (Fig. A-2), yielding a scaling factor of 1.4331. Measured 160-, 175-, 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, and 0.24 km, respectively, based on a 95th percentile fit (Tolstoy et al. 2009). Multiplying by the scaling factors to account for the tow depth difference between 6 and 12 m yields distances of 25,494 m, 4123 m, and 344 m for the 160-, 175-, and 195-dB sound levels, respectively.

Measurements have not been reported for the single 40-in^3 airgun. L-DEO model results are used to determine the 160-dB_{rms} radius for the 40-in^3 airgun at a 12-m tow depth in deep water (Fig. A-3). For intermediate-water depths, a correction factor of 1.5 was applied to the deep-water model results. For shallow water, a scaling of the field measurements obtained for the 36-airgun array was used. The 150-dB SEL level corresponds to a deep-water radius of 431 m for the 40-in^3 airgun at 12-m tow depth (Fig. A-3) and 7244 for the 36-airgun array at 6-m tow depth (Fig. A-2), yielding a scaling factor of 0.0595. Similarly, the 165-dB SEL level corresponds to a deep-water radius of 77 m for the 40-in^3 airgun at 12-m tow depth (Fig. A-3) and 1284 m for the 36-airgun array at 6-m tow depth (Fig. A-2), yielding a scaling factor of 0.060. The 185-dB SEL level corresponds to a deep-water radius of 7.5 m for the 40-in^3 airgun at 12-m tow depth (Fig. A-3) and 126.3 m for the 36-airgun array at 6-m tow depth (Fig. A-2), yielding a scaling factor of 0.0594. Measured 160-, 175-, and 195-dB re 1µPa_{rms} distances in shallow water for the 36-airgun array towed at 6-m depth were 17.5 km, 2.8 km, and 240 m, respectively, based on a 95th percentile fit (Tolstoy et al. 2009). Multiplying by the scaling factors to account for the difference in array sizes and tow depths yields distances of 1041 m, 170 m, and 14 m, respectively.

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[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.

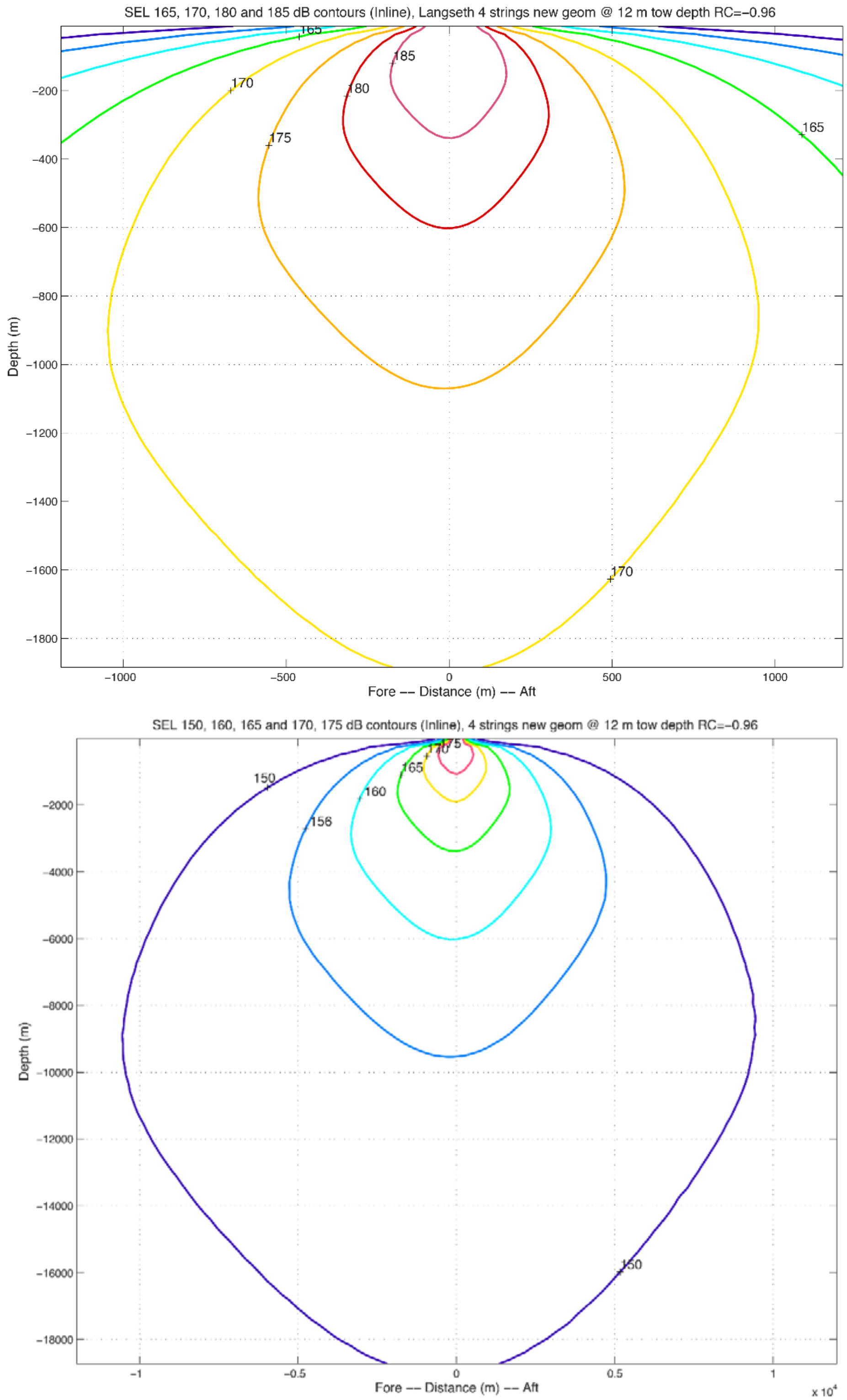
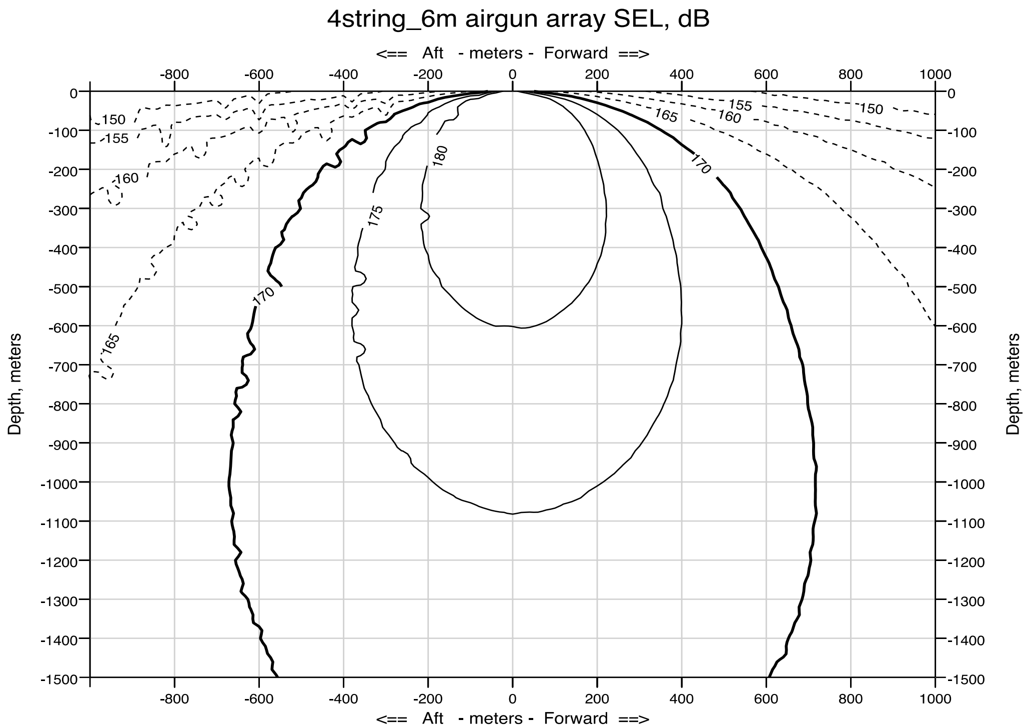


FIGURE A-1. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array at a 12-m tow depth planned for use during the proposed survey in the Gulf of Alaska. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.



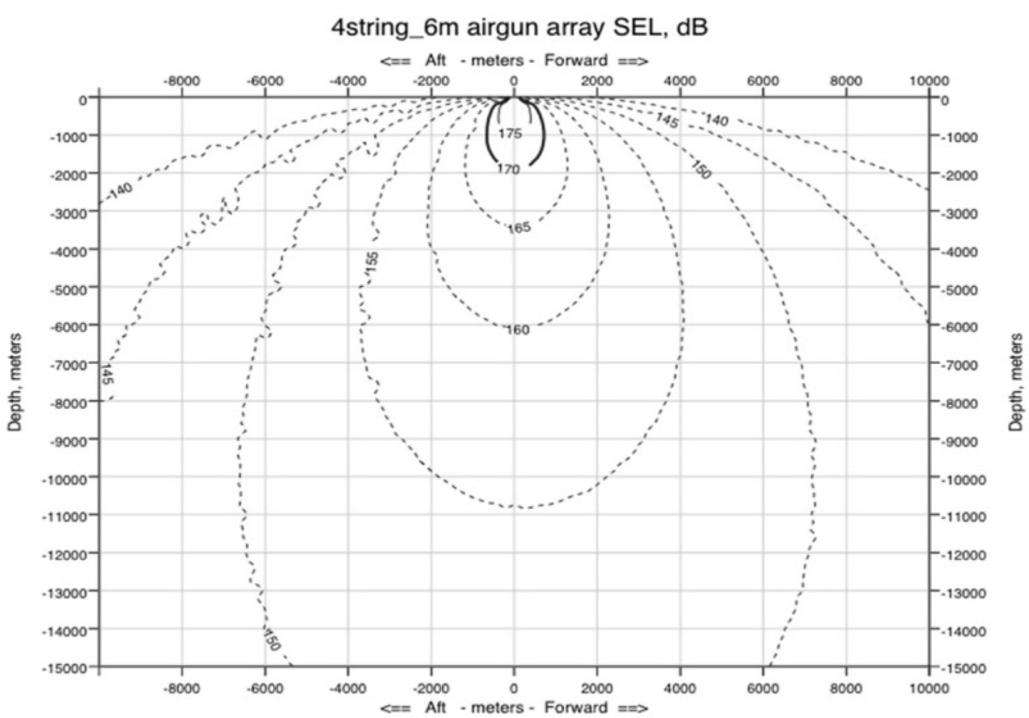


Figure A-2. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array at a 6-m tow depth used during the GoM calibration survey. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150 dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.

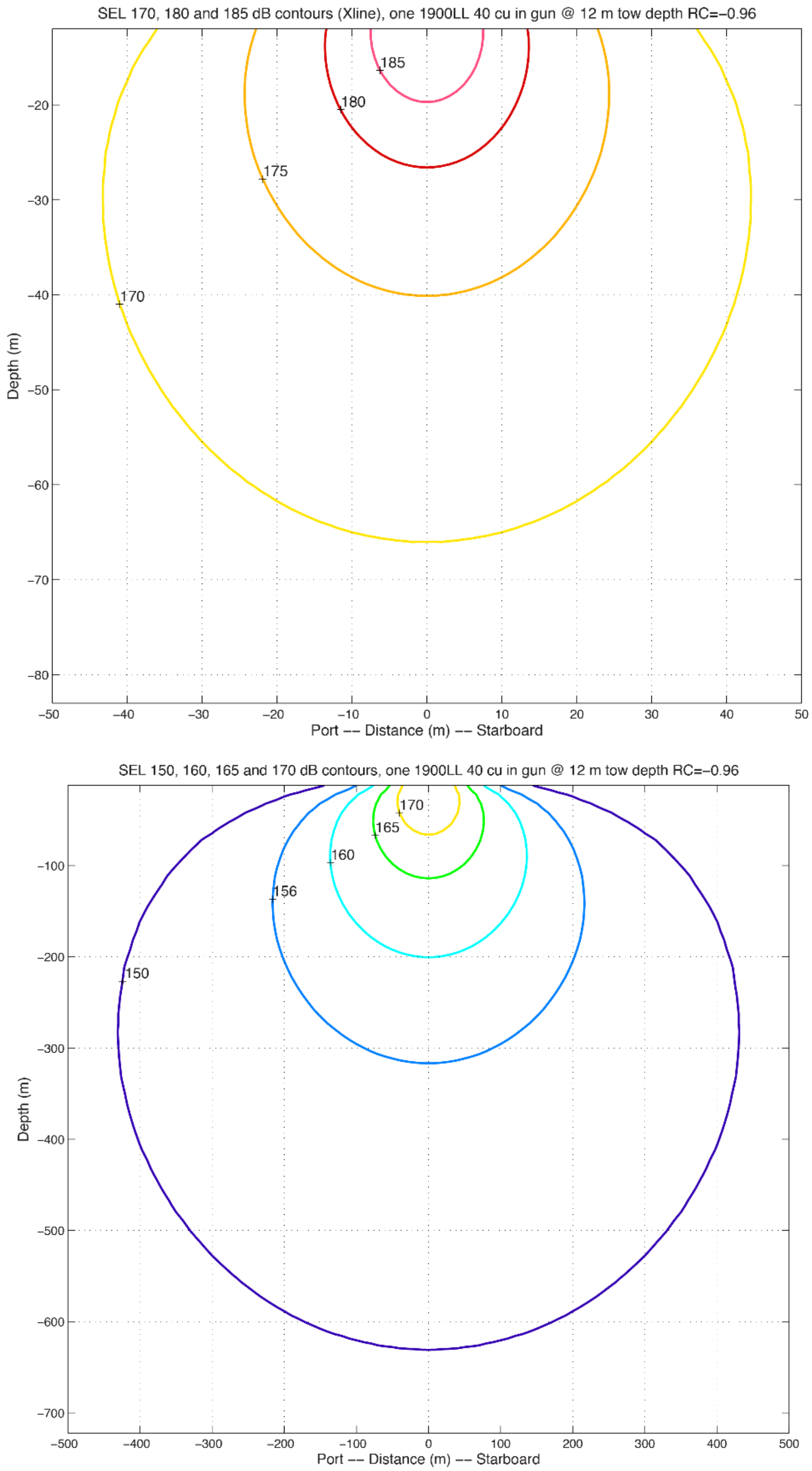


FIGURE A-3. Modeled deep-water received SELs from a single 40-in^3 airgun towed at a 12-m depth, which is planned for use as a mitigation airgun during the proposed survey in the Gulf of Alaska. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.

Table A-1 shows the distances at which the 160-dB re 1µPa$_{rms}$ sound levels are expected to be received for the 36-airgun array and the single (mitigation) airgun. The 160-dB level is the behavioral disturbance criterion (Level B) that is used by NMFS to estimate anticipated takes for marine mammals. 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, data collected by Crone et al. (2017) during a survey off New Jersey in 2014 and 2015 confirmed that *in situ* measurements and estimates of the 160- and 180-dB distances collected by the *Langseth* hydrophone streamer were 2–3 times smaller than the predicted operational mitigation radii. In fact, five separate comparisons conducted of the L-DEO model with *in situ* received levels[2] have confirmed that the L-DEO model generated conservative EZs, resulting in significantly larger EZs than required by National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS).

In July 2016, NMFS released new technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (NMFS 2016). The new guidance established new thresholds for permanent threshold shift (PTS) onset or Level A Harassment (injury), for marine mammal species. The new noise exposure criteria for marine mammals account for the newly-available scientific data on temporary threshold shifts (TTS), the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors, as summarized by Finneran (2016). For impulsive sources, onset of PTS was assumed to be 15 dB or 6 dB higher when considering SEL$_{cum}$ and SPL$_{flat}$, respectively. The new guidance incorporates marine mammal auditory weighting functions (Fig. A-4) and dual metrics of cumulative sound exposure level (SEL$_{cum}$ over 24 hours) and peak sound pressure levels (SPL$_{flat}$). Different thresholds are provided for the various hearing groups, including low-frequency (LF) cetaceans (e.g., baleen whales), mid-frequency (MF) cetaceans (e.g., most delphinids), high-frequency (HF) cetaceans (e.g., porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW). As required by NMFS (2016), the largest distance of the dual criteria (SEL$_{cum}$ or Peak SPL$_{flat}$) was used to calculate takes and Level A threshold distances. The new guidance did not alter the current threshold, 160 dB re 1µPa$_{rms}$, for Level B harassment (behavior).

The SEL$_{cum}$ for the *Langseth* array is derived from calculating the modified farfield signature. The farfield signature is often used as a theoretical representation of the source level. To compute the farfield signature, the source level is estimated at a large distance directly below the array (e.g., 9 km), and this level is back projected mathematically to a notional distance of 1 m from the array's geometrical center. However, it has been recognized that the source level from the theoretical farfield signature is never physically achieved at the source when the source is an array of multiple airguns separated in space (Tolstoy et al. 2009). Near the source (at short ranges, distances <1 km), the pulses of sound pressure from each individual airgun in the source array do not stack constructively as they do for the theoretical farfield signature. The pulses from the different airguns spread out in time such that the source levels observed or modeled are the result of the summation of pulses from a few airguns, not the full array

[2] L-DEO surveys off the Yucatán Peninsula in 2004 (Barton et al. 2006; Diebold et al. 2006), in the Gulf of Mexico in 2008 (Tolstoy et al. 2009; Diebold et al. 2010), off Washington and Oregon in 2012 (Crone et al. 2014), and off New Jersey in 2014 and 2015 (Crone et al. 2017).

TABLE A-1. Level B. Predicted distances to which sound levels ≥160-dB re 1 μPa$_{rms}$ could be received during the proposed survey in the GOA. The 160-dB criterion applies to all hearing groups of marine mammals.

Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted distances (in m) to the 160-dB Received Sound Level
Single Bolt airgun, 40 in^3	12	>1000 m	431[1]
		100–1000 m	647[2]
		<100 m	1,041[3]
4 strings, 36 airguns, 6600 in^3	12	>1000 m	6,733[1]
		100–1000 m	10,100[2]
		<100 m	25,494[3]

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

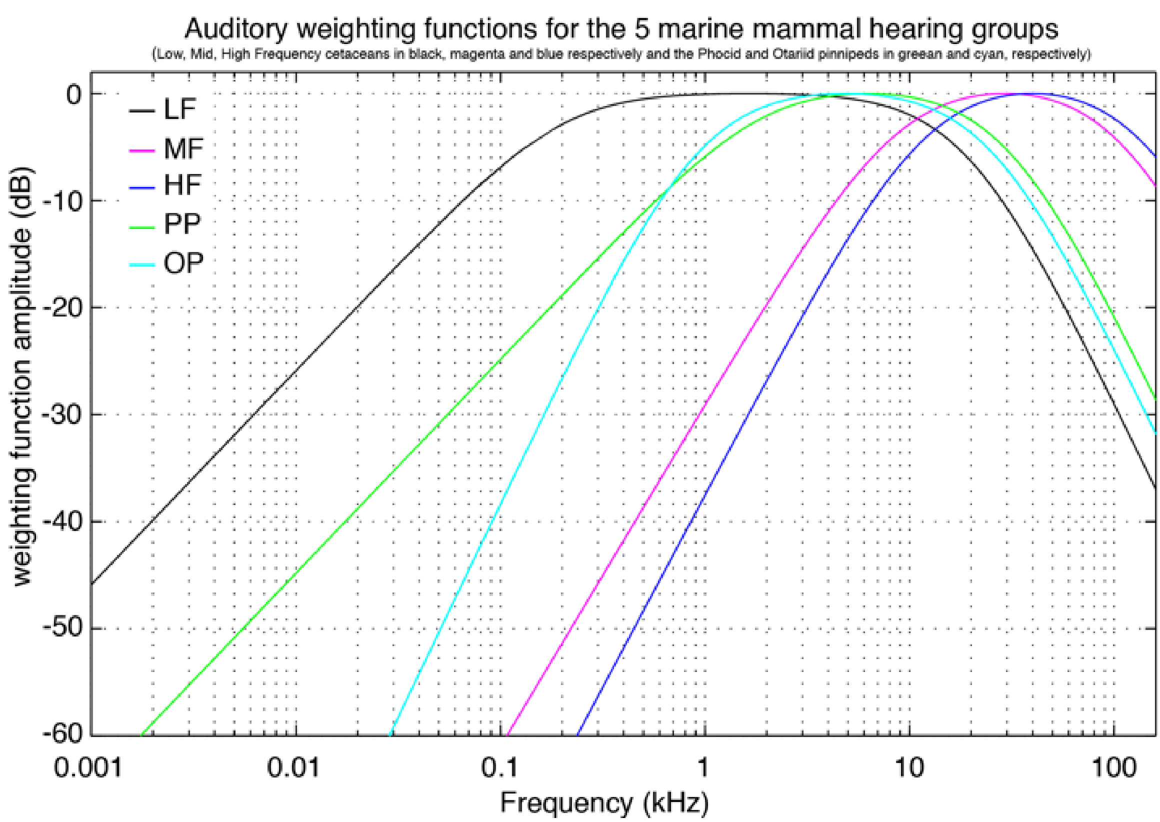


FIGURE A-4. Auditory weighting functions for five marine mammal hearing groups from the NMFS Technical Guidance Spreadsheet.

(Tolstoy et al. 2009). At larger distances, away from the source array center, sound pressure of all the airguns in the array stack coherently, but not within one time sample, resulting in smaller source levels (a few dB) than the source level derived from the farfield signature. Because the farfield signature does not take into account the large array effect near the source and is calculated as a point source, the farfield signature is not an appropriate measure of the sound source level for large arrays.

To estimate SEL_{cum} and Peak SPL, we used the acoustic modeling developed at L-DEO (same as used for Level B takes) with a small grid step in both the inline and depth directions. The propagation modeling takes into account all airgun interactions at short distances from the source including interactions between subarrays which we do using the NUCLEUS software to estimate the notional signature and the MATLAB software to calculate the pressure signal at each mesh point of a grid.

PTS onset acoustic thresholds estimated in the NMFS User Spreadsheet rely on overriding the default values and calculating individual adjustment factors (dB) based on the modified farfield and by using the difference between levels with and without weighting functions for each of the five categories of hearing groups. The new adjustment factors in the spreadsheet allow for the calculation of SEL_{cum} isopleths in the spreadsheet and account for the accumulation (Safe Distance Methodology) using the source characteristics (source velocity and duty) after Sivle et al. (2014). A source velocity of 2.57222 m/s and a 1/Repetition rate of 155.2355 s were used as inputs to the NMFS User Spreadsheet for calculating the distances to the SEL_{cum} PTS thresholds (Level A) for the 36-airgun array and the single 40-in^3 mitigation airgun.

For the LF cetaceans during operations with the 36-airgun array, we estimated a new adjustment value by computing the distance from the geometrical center of the source to where the 183 dB SEL_{cum} isopleth is the largest. We first ran the modeling for a single shot without applying any weighting function; we then ran the modeling for a single shot with the LF cetacean weighting function applied to the full spectrum. The difference between these values provides an adjustment factor of -12.91 dB assuming a propagation of $20\log_{10}$(Radial distance) (Table A-2).

However, for MF and HF cetaceans, and OW and PW pinnipeds, the modeling for a single shot with the weighted function applied leads to 0-m isopleths; the adjustment factors thus cannot be derived the same way as for LF cetaceans. Hence, for MF and HF cetaceans, and OW and PW pinnipeds, the difference between weighted and unweighted spectral source levels at each frequency up to 3 kHz was integrated to actually calculate these adjustment factors in dB. These calculations also account for the accumulation (Safe Distance Methodology) using the source characteristics (duty cycle and speed) after Sivle et al. (2014).

For the 36-airgun array, the results for single shot SEL source level modeling are shown in Table A-2. The weighting function calculations, thresholds for SEL_{cum}, and the distances to the PTS thresholds for the 36-airgun array are shown in Table A-3. Figure A-5 shows the impact of weighting functions by hearing group. Figures A-5–A-7 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure A-8 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans.

The thresholds for Peak SPL_{flat} for the 36-airgun array, as well as the distances to the PTS thresholds, are shown in Table A-4. Figures A-10–A-12 show the modeled received sound levels to the Peak SPL_{flat} thresholds, for a single shot. A summary of the Level A threshold distances are shown in Table A-5.

TABLE A-2. Results for single SEL source level modeling for the 36-airgun array with and without applying weighting functions to the five hearing groups. The modified farfield signature is estimated using the distance from the source array geometrical center to where the SEL_{cum} threshold is the largest. A propagation of 20 $\log_{10}$ (Radial distance) is used to estimate the modified farfield SEL.

SEL_{cum} Threshold	**183**	**185**	**155**	**185**	**203**
Radial Distance (m) (no weighting function)	315.5691	246.4678	8033.2	246.4678	28.4413
Modified Farfield SEL	232.9819	232.8352	233.0978	232.8352	232.0790
Radial Distance (m) (with weighting function)	71.3752	N.A.	N.A.	N.A.	N.A.
Adjustment (dB)	-12.91	N.A.	N.A.	N.A.	N.A.

* Propagation of 20 log R. N.A. means not applicable or not available.

For the single 40 in^3 mitigation airgun, the results for single shot SEL source level modeling are shown in Table A-6. The weighting function calculations, thresholds for SEL_{cum}, and the distances to the PTS thresholds for the 40 in^3 airgun are shown in Table A-7. Figure A-13 shows the impact of weighting functions by hearing group for the single mitigation airgun. Figures A-14–A-15 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure A-16 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans. The thresholds for Peak SPL_{flat} for the 40 in^3 airgun, as well as the distances to the PTS thresholds, are shown in Table A-8. Figures A-17–A-18 show the modeled received sound levels to the Peak SPL_{flat} thresholds, for a single shot.

Table A-9 shows the distances at which the 175- and 195-dB re 1µPa_{rms} sound levels are expected to be received for the 36-airgun array, and a single airgun, based on L-DEO modeling. The 195-dB distance would be used as the EZ for sea turtles, as required by NMFS. The 175-dB level is used by NMFS, based on data from the USN (2017), to determine behavioral disturbance for turtles.

TABLE A-3. Results for single shot SEL source level modeling for the 36-airgun array with weighting function calculations for the SEL_{cum} criteria, as well as resulting isopleths to thresholds for various hearing groups.

STEP 1: GENERAL PROJECT INFORMATION	
PROJECT TITLE	R/V Langseth (Airgun shooting Supplement to Alaska Amphibious Community Seismic Experiment (AACSE))
PROJECT/SOURCE INFORMATION	source : 4 string 36 element 6600 cu.in of the R/V Langseth at a 12m towed depth. Shot inteval of 399.3 m. Source velocity of 5 knots
Please include any assumptions	
PROJECT CONTACT	

STEP 2: WEIGHTING FACTOR ADJUSTMENT		Specify if relying on source-specific WFA, alternative weighting/dB adjustment, or if using default value
Weighting Factor Adjustment (kHz)[¥]	NA	Override WFA: Using LDEO modeling
[¥] Broadband: 95% frequency contour percentile (kHz) OR Narrowband: frequency (kHz); For appropriate default WFA: See INTRODUCTION tab		
		† If a user relies on alternative weighting/dB adjustment rather than relying upon the WFA (source-specific or default), they may override the Adjustment (dB) (row 62), and enter the new value directly. However, they must provide additional support and documentation supporting this modification.

STEP 3: SOURCE-SPECIFIC INFORMATION

NOTE: Choose either F1 OR F2 method to calculate isopleths (not required to fill in sage boxes for both) — NOTE: LDEO modeling relies on Method F2

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

SEL_{cum}

Source Velocity (meters/second)	2.57222
1/Repetition rate^ (seconds)	155.2355

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

^Time between onset of successive pulses.

	Modified farfield SEL	232.9819	232.8352	233.0978	232.8352	232.079
	Source Factor	1.27997E+21	1.23745E+21	1.31459E+21	1.23745E+21	1.0397E+21
RESULTANT ISOPLETHS*	*Impulsive sounds have dual metric thresholds (SELcum & PK). Metric producing largest isopleth should be used.					
	Hearing Group	**Low-Frequency Cetaceans**	**Mid-Frequency Cetaceans**	**High-Frequency Cetaceans**	**Phocid Pinnipeds**	**Otariid Pinnipeds**
	SEL_{cum} Threshold	183	185	155	185	203
	PTS SEL_{cum} Isopleth to threshold (meters)	**40.1**	**0.0**	**0.1**	**1.3**	**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)†	**-12.91**	**-56.70**	**-66.07**	**-25.65**	**-32.62**	**OVERIDE Using LDEO Modeling**

†For LF cetaceans, the adjustment factor (dB) is derived by estimating the radial distance of the 183-dB isopleth without applying the weighting function and a second time with applying the weighting function. Adjustment was derived using a propagation of $20*\log_{10}$ (Radial distance) and the modified farfield signature. For MF and HF cetaceans and pinnipeds, the difference between weighted–unweighted spectral source levels at each frequency was integrated to calculate adjustment factors (see spectrum levels in Figure A-5).

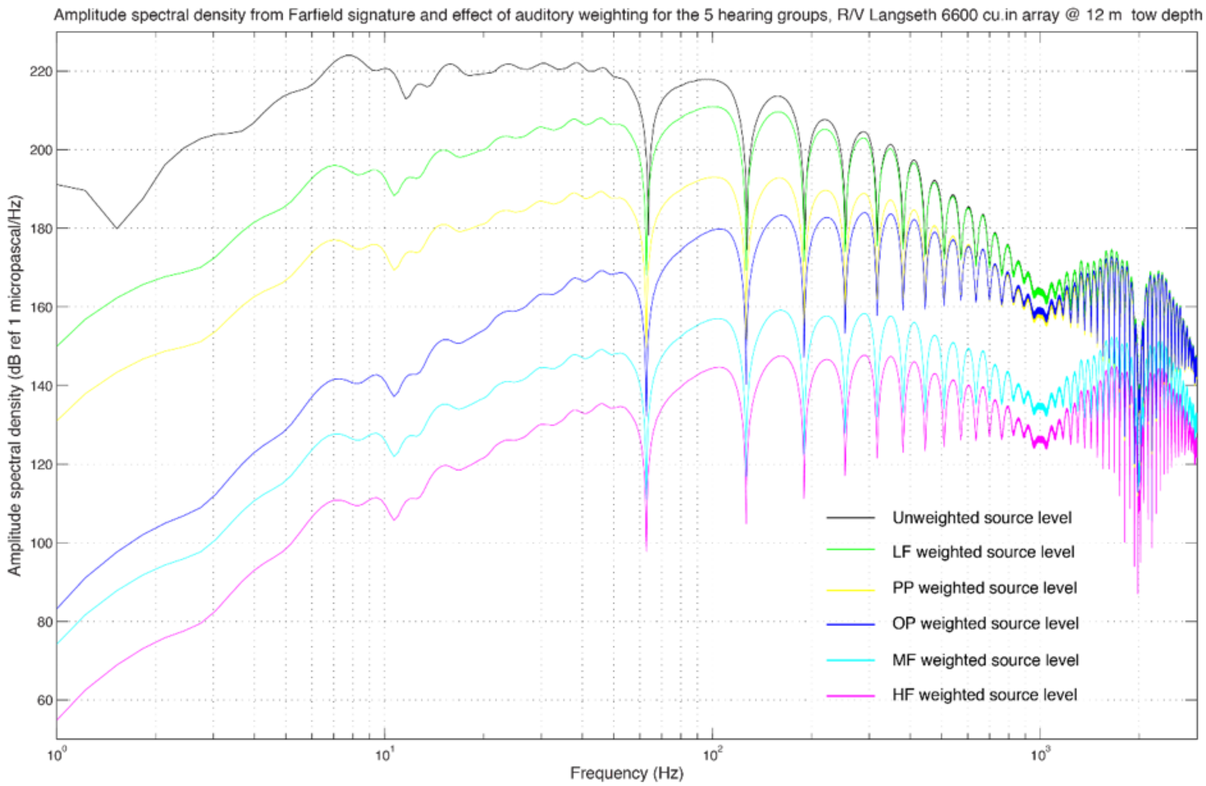


FIGURE A-5. Modeled amplitude spectral density of the 36-airgun array farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral levels are used to calculate the difference between the unweighted and weighted source level at each frequency and to derive the adjustment factors for the hearing groups as inputs into the NMFS User Spreadsheet.

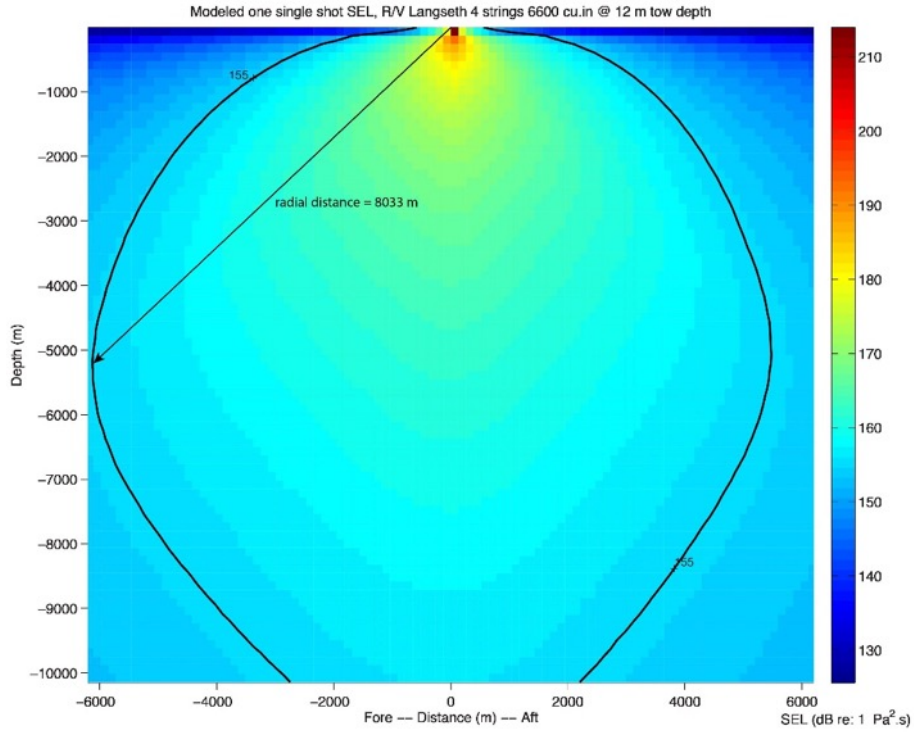


FIGURE A-6. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 155-dB SEL isopleth (8033 m). Radial distance allows us to determine the modified farfield SEL using a propagation of 20log$_{10}$(radial distance).

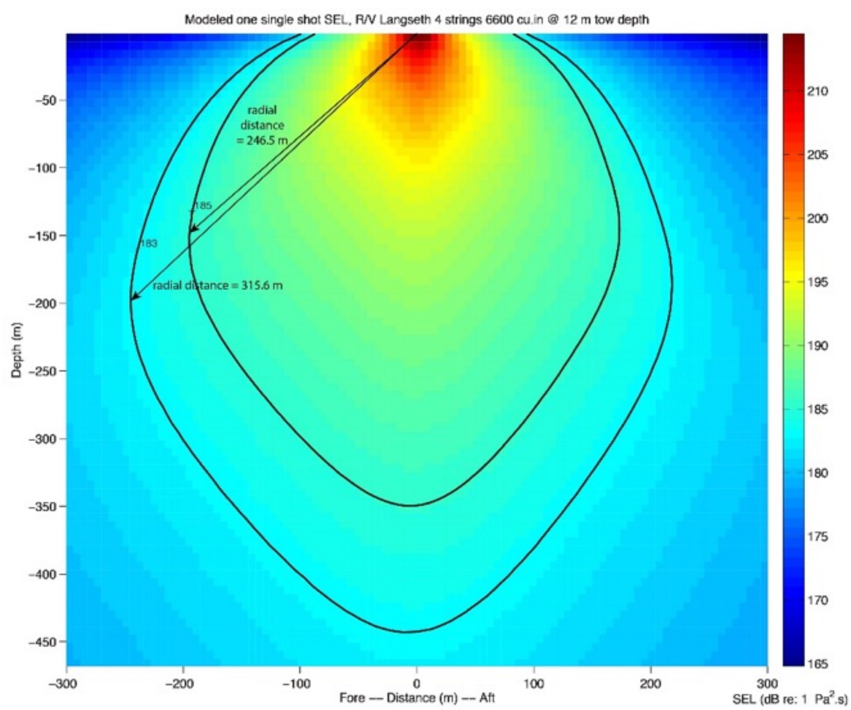


FIGURE A-7. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 183–185-dB SEL isopleths (315.6 and 246.5 m, respectively).

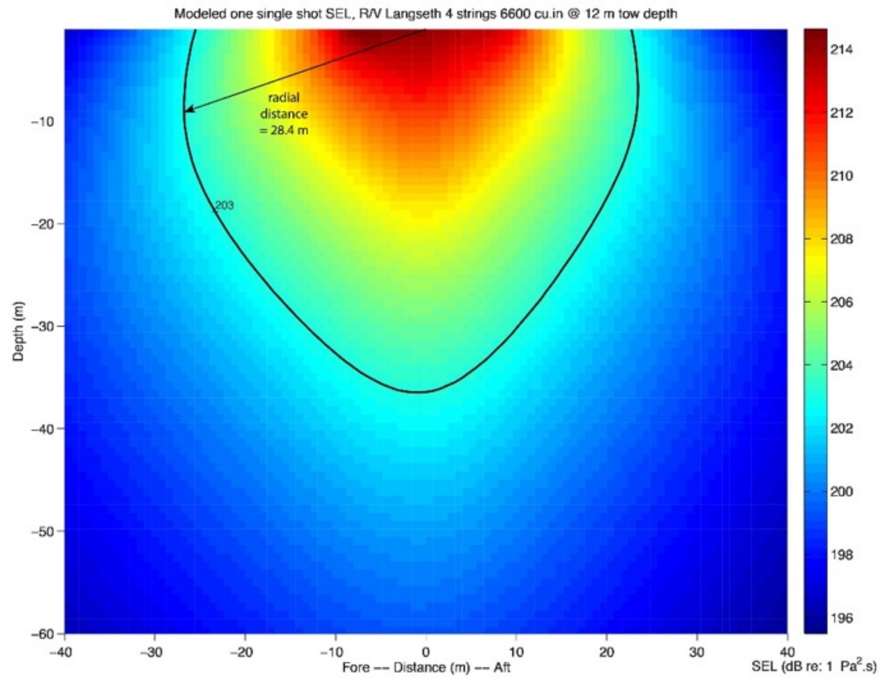


FIGURE A-8. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 203-dB SEL isopleth (28.4 m).

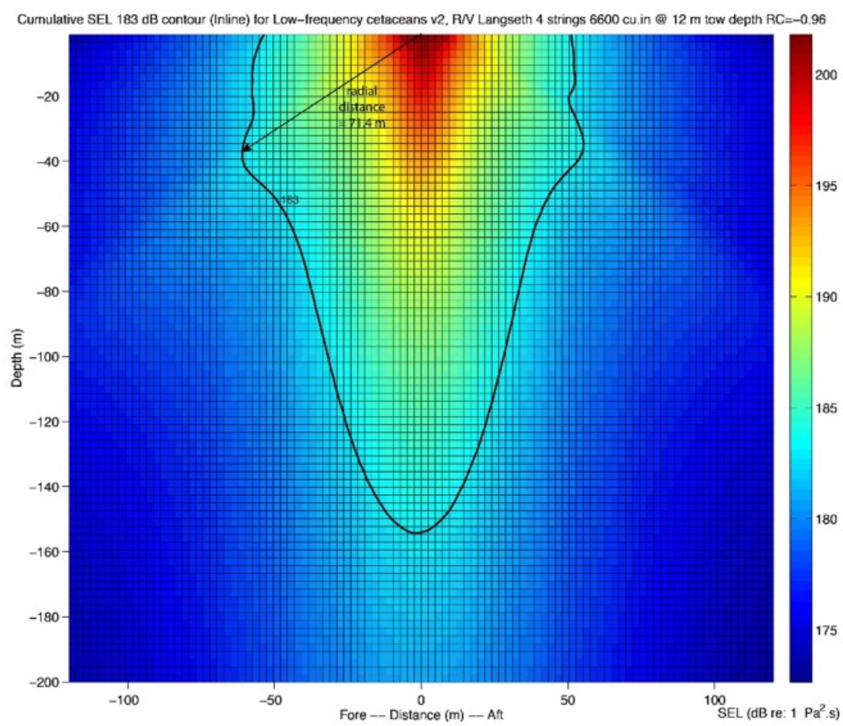


FIGURE A-9. Modeled received sound exposure levels (SELs) from the 36-airgun array at a 12-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one shot. The difference in radial distances between Fig. A-7 and this figure (71.4 m) allows us to estimate the adjustment in dB.

TABLE A-4. NMFS Level A acoustic thresholds (Peak SPL_{flat}) for impulsive sources for marine mammals and predicted distances to Level A thresholds for various marine mammal hearing groups that could be received from the 36-airgun array during the proposed survey in the GOA.

Hearing Group	**Low-Frequency Cetaceans**	**Mid-Frequency Cetaceans**	**High-Frequency Cetaceans**	**Phocid Pinnipeds**	**Otariid Pinnipeds**
Peak Threshold	**219**	**230**	**202**	**218**	**232**
Radial Distance to Threshold (m)	45.00	13.57	364.67	51.59	10.62
Modified Farfield Peak SPL	252.06	252.65	253.24	252.25	252.52
PTS Peak Isopleth (Radius) to Threshold (m)	38.9	13.6	268.3	43.7	10.6

N.A. means not applicable or not available.

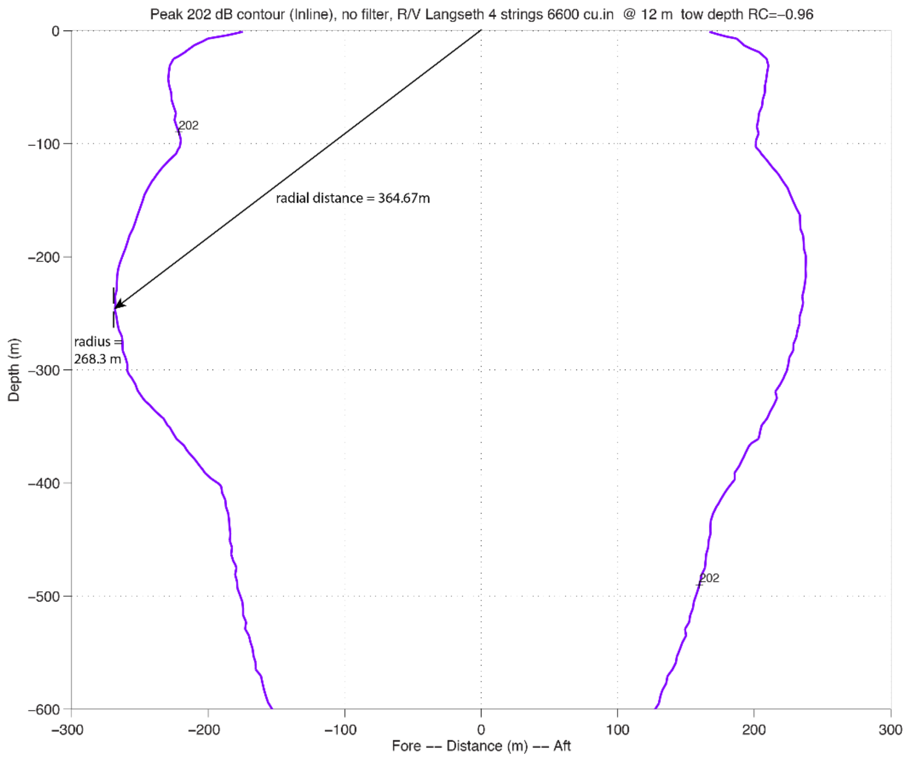


FIGURE A-10. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distance to the 202-dB Peak isopleth.

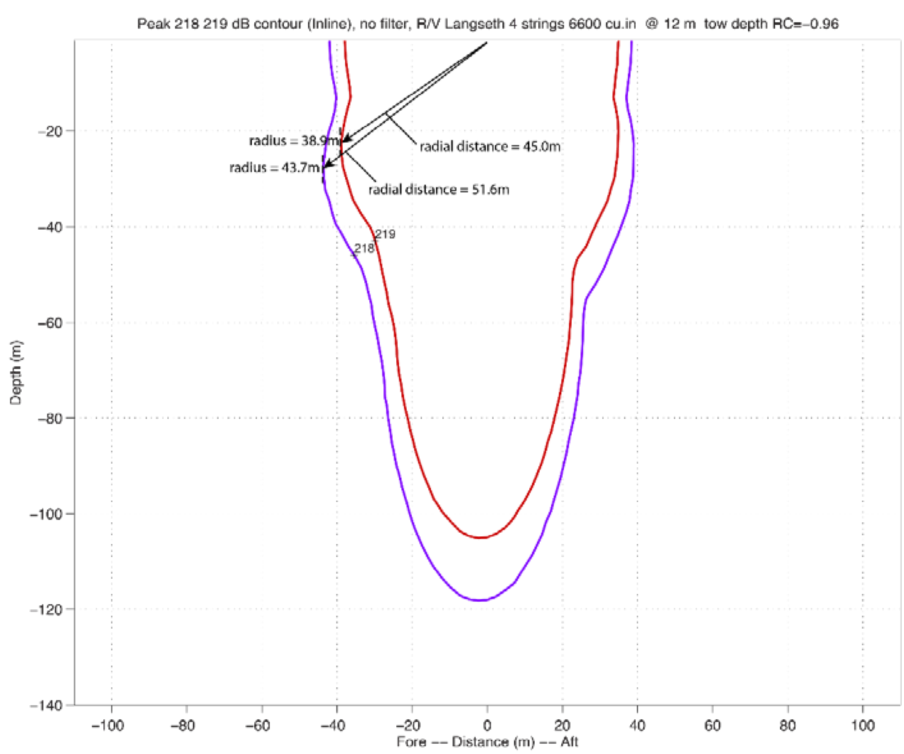


FIGURE A-11. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distances to the 218- and 219-dB Peak isopleths.

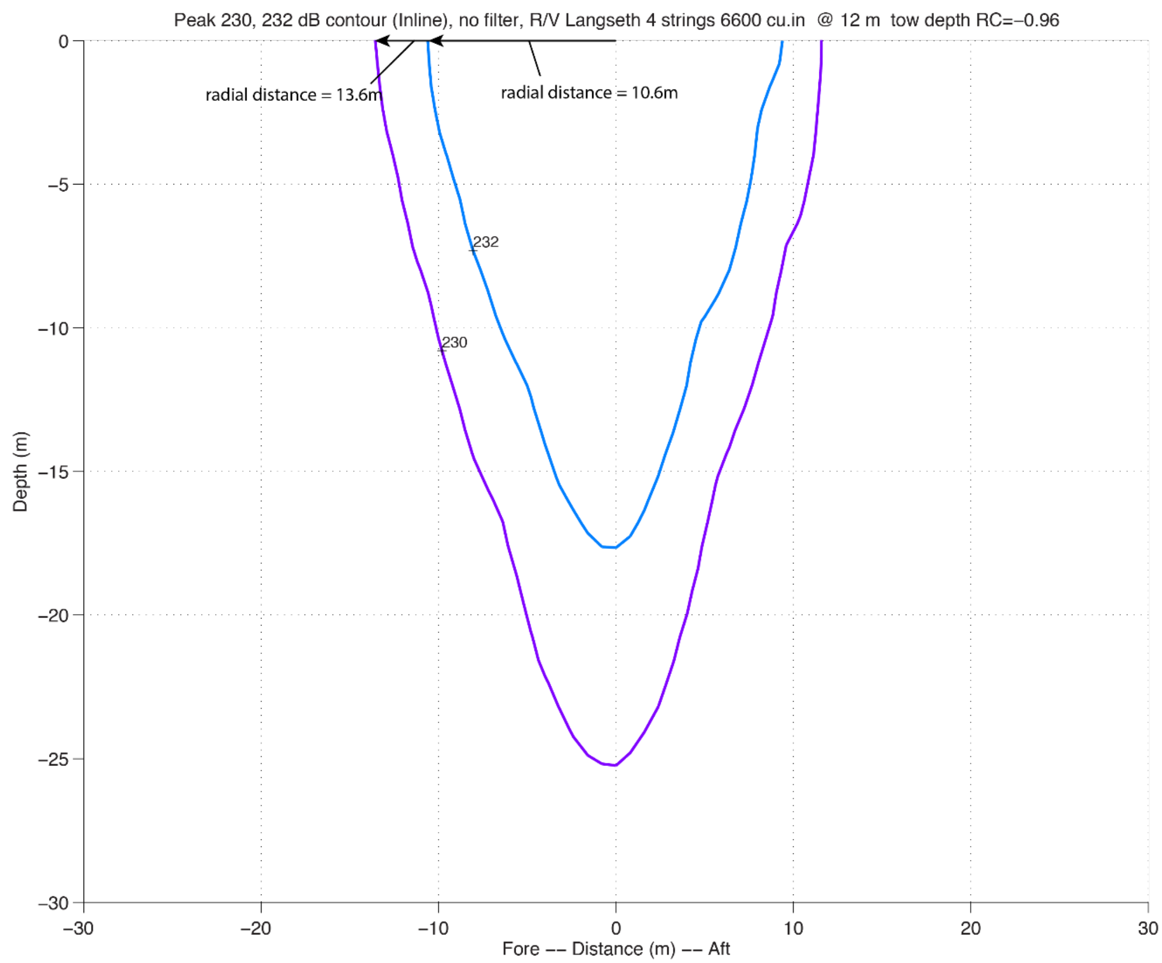


FIGURE A-12. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distances to the 230- and 232-dB Peak isopleths.

TABLE A-5. Level A threshold distances for different marine mammal hearing groups. As required by NMFS (2016), the largest distance (in bold) of the dual criteria (SEL_{cum} or Peak SPL_{flat}) was used to calculate takes and Level A threshold distances.

	Level A Threshold Distances (m) for Various Hearing Groups				
36-airgun array; 6600 in^3	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
PTS SEL_{cum}	**40.1**	0	0.1	1.3	0
PTS Peak	38.9	**13.6**	**268.3**	**43.7**	**10.6**

TABLE A-6. Results for single shot SEL source level modeling for the 40 in^3 airgun with and without applying weighting function to the various hearing groups. The modified farfield signature is estimated using the distance from the source array geometrical center to where the SEL_{cum} threshold is the largest. A propagation of 20 $\log_{10}$ (Radial distance) is used to estimate the modified farfield SEL.

SEL_{cum} Threshold	**183**	**185**	**155**	**185**	**203**
Distance (m) (no weighting function)	9.9893	7.8477	294.0371	7.8477	0.9278
Modified Farfield SEL*	202.9907	202.8948	204.3680	202.8948	202.3491
Distance (m) (with weighting function)	2.3852	N.A.	N.A.	N.A.	N.A.
Adjustment (dB)	-12.44	N.A.	N.A.	N.A.	N.A.

*Propagation of 20 log R. N.A. means not applicable or not available.

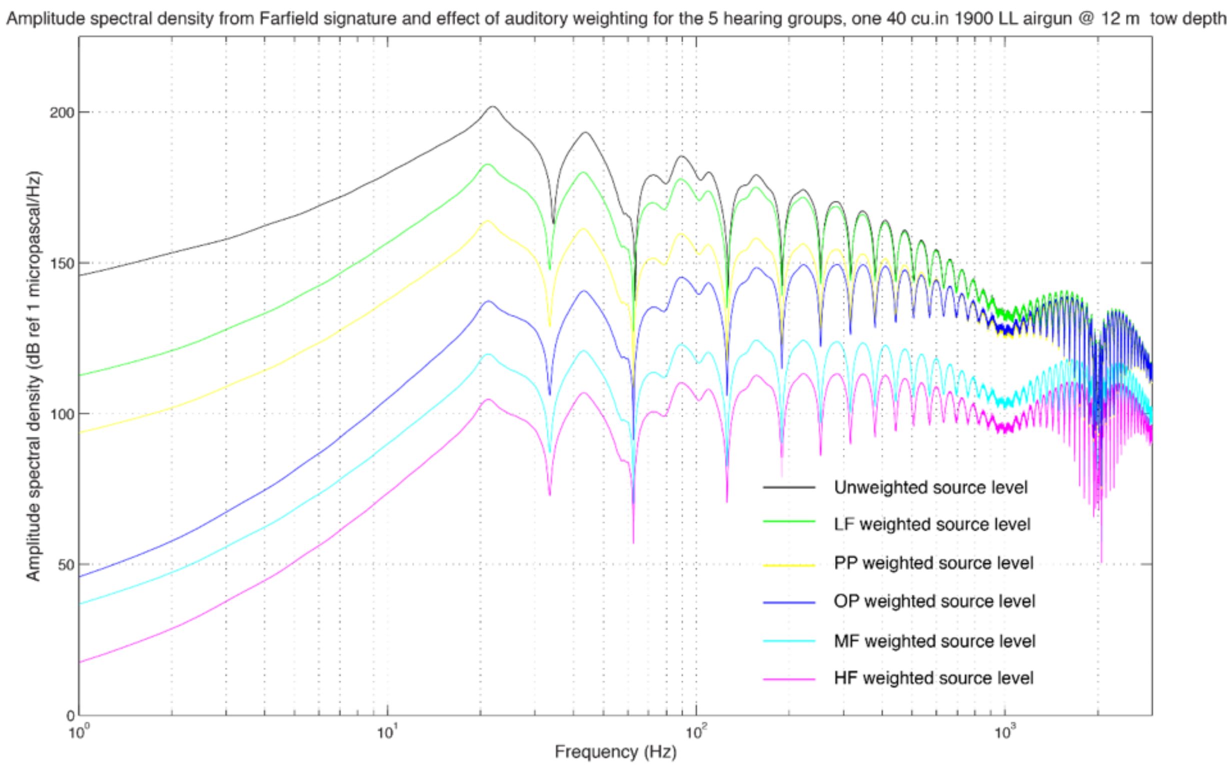


FIGURE A-13. Modeled amplitude spectral density of the 40-in^3 airgun farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral levels are used to calculate the difference between the unweighted and weighted source level at each frequency and to derive the adjustment factors for the hearing groups as inputs into the NMFS User Spreadsheet.

TABLE A-7. Results for single shot SEL source level modeling for the single 40-in³ mitigation airgun with weighting function calculations for the SEL_{cum} criteria, as well as resulting isopleths to thresholds for various hearing groups.

STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	R/V Langseth mitigation gun
PROJECT/SOURCE INFORMATION Please include any assumptions	one 40 cu.in 1900LL airgun @ a 12 m tow depth
PROJECT CONTACT	

STEP 2: WEIGHTING FACTOR ADJUSTMENT

Specify if relying on source-specific WFA, alternative weighting/dB adjustment, or if using default value

Weighting Factor Adjustment (kHz)[¥]	NA	Override WFA: Using LDEO modeling

[¥] Broadband: 95% frequency contour percentile (kHz) OR Narrowband: frequency (kHz); For appropriate default WFA: See INTRODUCTION tab

† If a user relies on alternative weighting/dB adjustment rather than relying upon the WFA (source-specific or default), they may override the Adjustment (dB) (row 62), and enter the new value directly. However, they must provide additional support and documentation supporting this modification.

STEP 3: SOURCE-SPECIFIC INFORMATION

NOTE: Choose either F1 OR F2 method to calculate isopleths (not required to fill in sage boxes for both)

NOTE: LDEO modeling relies on Method F2

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

SEL_{cum}

Source Velocity (meters/second)	2.57222	5 knots
1/Repetition rate^ (seconds)	155.2355	

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

^Time between onset of successive pulses.

Modified farfield SEL	202.9907	202.8948	204.368	202.8948	202.3491
Source Factor	1.28256E+18	1.25455E+18	1.7612E+18	1.25455E+18	1.10642E+18

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)	0.0	0.0	0.0	0.0	0.0

WEIGHTING FUNCTION CALCULATIONS

Weighting Function Parameters	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	
a	1	1.6	1.8	1	2	
b	2	2	2	2	2	
f_1	0.2	8.8	12	1.9	0.94	
f_2	19	110	140	30	25	
C	0.13	1.2	1.36	0.75	0.64	
Adjustment (dB)†	-12.44	-60.85	-70.00	-30.09	-36.69	OVERIDE Using LDEO Modeling

†For LF cetaceans, the adjustment factor (dB) is derived by estimating the radial distance of the 183-dB isopleth without applying the weighting function and a second time with applying the weighting function. Adjustment was derived using a propagation of 20*log₁₀ (Radial distance) and the modified farfield signature. For MF and HF cetaceans and pinnipeds, the difference between weighted–unweighted spectral source levels at each frequency was integrated to calculate adjustment factors (see spectrum levels in Figure A-13).

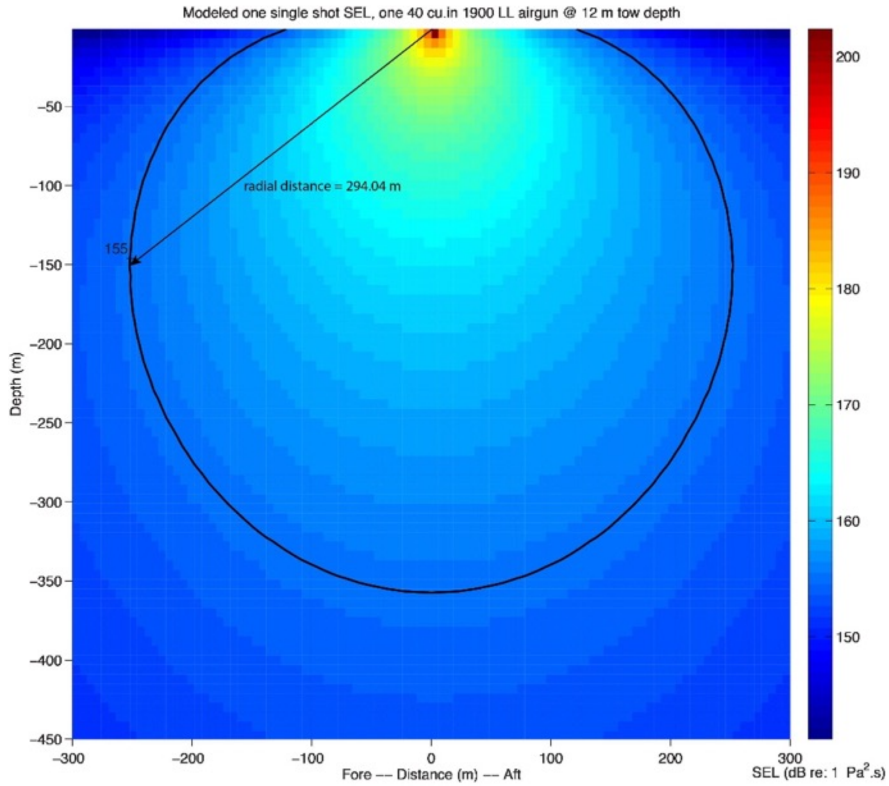


FIGURE A-14. Modeled received sound levels (SELs) in deep water from one 40-in³ airgun at a 12-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (294.04 m).

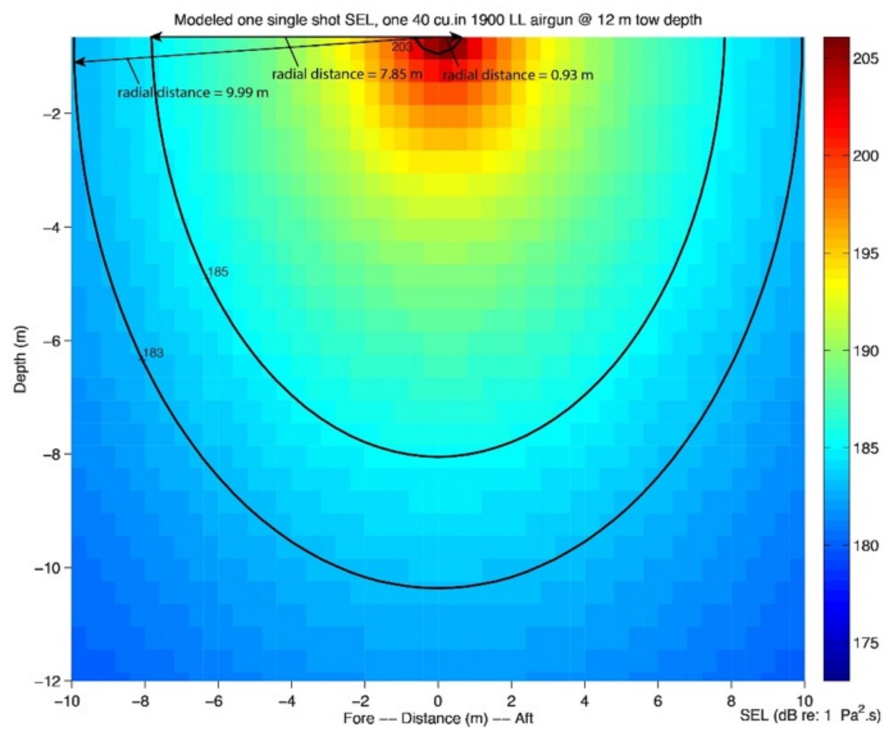


FIGURE A-15. Modeled received sound levels (SELs) in deep water from one 40-in³ airgun at a 12-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183–185 dB and 203 dB SEL isopleths.

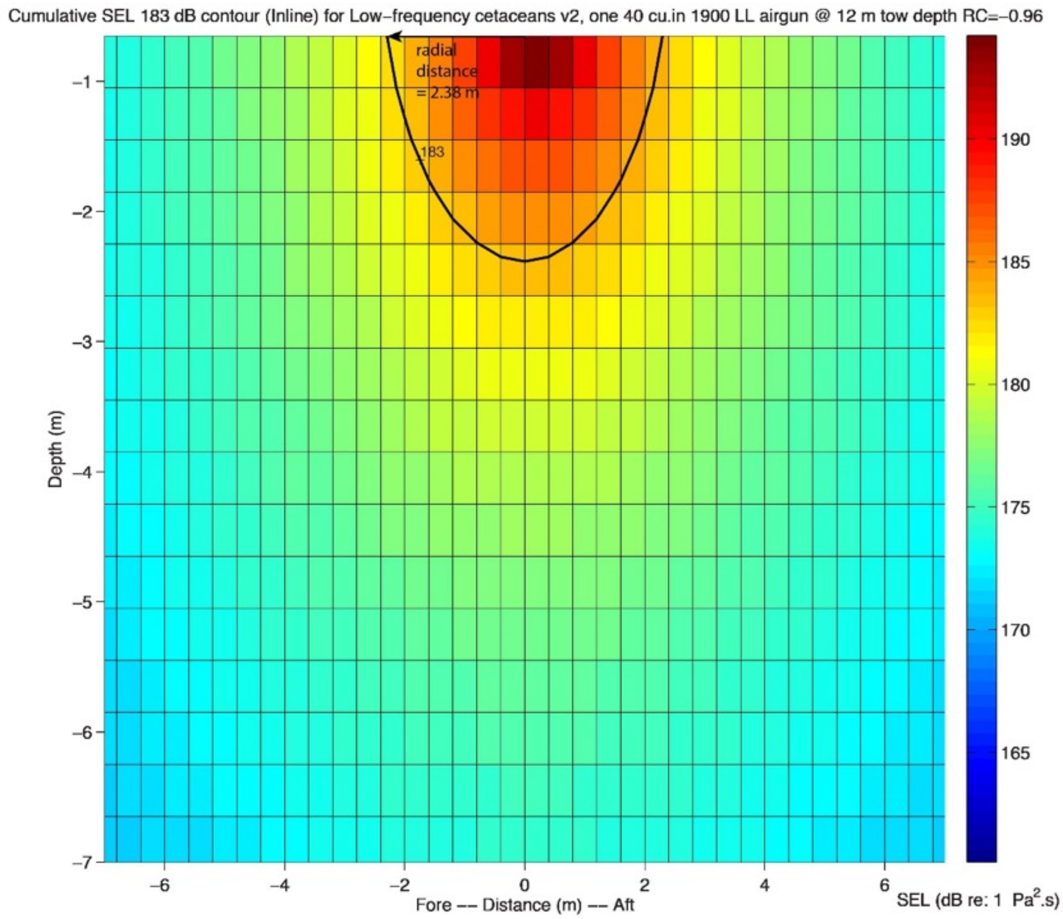


FIGURE A-16. Modeled received sound exposure levels (SELs) from one 40-in³ mitigation at a 12-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one shot. The difference in radial distances between Fig. A-15 and this figure allows us to estimate the adjustment in dB.

TABLE A-8. NMFS Level A acoustic thresholds (Peak SPL_{flat}) for impulsive sources for marine mammals and predicted distances to Level A thresholds for various marine mammal hearing groups that could be received from the 40-in³ airgun during the proposed seismic survey in the GOA.

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
Peak Threshold	**219**	**230**	**202**	**218**	**232**
Radial Distance to Threshold (m)	1.76	N.A.	12.47	1.98	N.A.
Modified Farfield Peak	223.93	N.A.	223.92	223.95	N.A.
PTS Peak Isopleth (Radius) to Threshold (m)	1.76	N.A.	12.5	1.98	N.A.

N.A. means not applicable or not available.

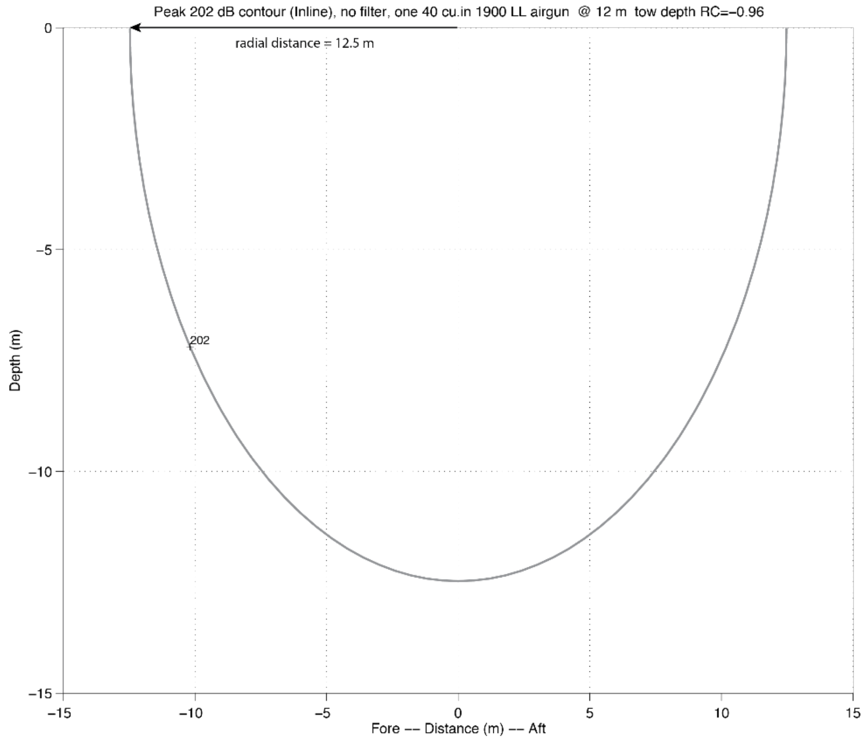


FIGURE A-17. Modeled deep-water received Peak SPL from one 40 in^3 airgun at a 12-m tow depth. The plot provides the radial distance from the source geometrical center to the 202-dB Peak isopleth.

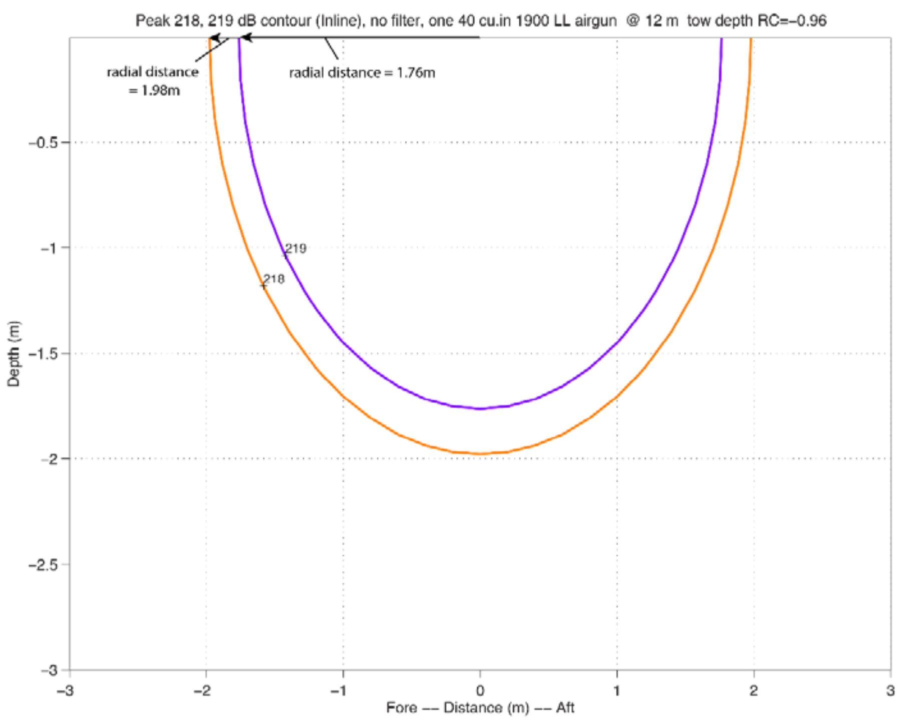


FIGURE A-18. Modeled deep-water received Peak SPL from one 40 in^3 airgun at a 12-m tow depth. The plot provides the radial distances from the source geometrical center to the 218 and 219-dB Peak isopleths.

TABLE A-9. Sea turtle thresholds recommended by NMFS. Predicted distances to which sound levels ≥195- and 175-dB re 1 μPa$_{rms}$ could be received during the proposed survey in the GOA.

Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted distances (in m) to Received Sound Levels	
			195 dB	**175 dB**
Single Bolt airgun, 40 in^3	12	>1000 m	8[1] (100[3])	77[1]
		100–1000 m	11[2] (100[3])	116[2]
		<100 m	14[4](100[3])	170[4]
4 strings, 36 airguns, 6600 in^3	12	>1000 m	181[1]	1,864[1]
		100–1000 m	272[1]	2,796[2]
		<100 m	344[4]	4,123[4]

[1] Distance is based on L-DEO model results.
[2] Distance is based on L-DEO model results with a 1.5 × correction factor between deep and intermediate water depths.
[3] An EZ of 100 m would be used as the shut-down distance for sea turtles, as specified for low-energy sources in the PEIS.
[4] Distance is based on empirically derived measurements in the GoM with scaling applied to account for differences in tow depth.

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APPENDIX B: MARINE MAMMAL DENSITIES

Sources of Marine Mammal Densities

For the proposed survey, we consulted with NMFS regarding which marine mammal density sources to use for developing take estimates. In response, NMFS recommended the use of habitat-based stratified marine mammal densities developed by the U.S. Navy for assessing potential impacts of training activities in the GOA (DoN 2014). To develop densities specific to the GOA, the Navy conducted two comprehensive marine mammal surveys in the Temporary Marine Activities Area (TMAA) in the GOA prior to 2014. The first survey was conducted from 10 to 20 April 2009 and the second was from 23 June to 18 July 2013. Both surveys used systematic line-transect survey protocols including visual and acoustic detection methods (Rone et al. 2010; Rone et al. 2014). The data were collected in four strata that were designed to encompass the four distinct habitats within the TMAA and greater GOA: Inshore – all waters <1000 m deep; Slope – from 1000 m water depth to the Aleutian trench/subduction zone; Offshore – waters offshore of the Aleutian trench/subduction zone; Seamount – waters within defined seamount areas (Rone et al. 2014).

Rone et al. (2014) provided stratified line-transect density estimates used in this analysis for fin, humpback, blue, sperm, and killer whales, as well as northern fur seals (Table B-1). Abundance estimates for unidentified large whales were prorated among blue, fin, and humpback whales within each stratum and proportionately incorporated into each species density estimate. Data from a subsequent survey in 2015 were used to calculate alternative density estimates for several species (Rone et al. 2017); however, the reported densities for blue, fin and humpback whales were not prorated for unidentified large whale sightings so the densities from Rone et al. (2014) were maintained. The density estimates for Dall's porpoise in Rone et al. (2017) were somewhat larger than those in Rone et al. (2014), so the larger densities were used as a cautionary approach.

There were insufficient sightings data from the 2009, 2013 and 2015 line-transect surveys to calculate reliable density estimates for other marine mammal species in the GOA. DoN (2014) derived gray whale densities in two zones, nearshore (0–2.25 n.mi from shore) and offshore (from 2.25–20 n.mi. from shore). In our calculations, the nearshore density was used to represent the Inshore zone and the offshore density was used to represent the Slope zone. This approach assumes a higher density of gray whales across a larger area and should yield a conservative estimate of potential exposures.

Harbor porpoise densities in DoN (2014) were derived from Hobbs and Waite (2010) which included additional shallow water depth strata. The density estimate from the 100 m to 200 m depth strata was used to represent the entire Inshore zone (<1000 m) in this analysis. Similarly, harbor seals typically remain close to shore so minimal estimates were used for the three deep water zones and a one thousand fold increase of the minimal density was used to represent the entire inshore zone (DoN 2014).

Densities for Minke whale, Pacific white-sided dolphin, and Cuvier's and Baird's beaked whales were based on Waite (2003; *in* DoN 2009). Although sei whale sightings and Stejneger's beaked whale acoustic detections were recorded during the Navy funded GOA surveys, data were insufficient to calculate densities for these species, so predictions from a global model of marine mammals densities were used (DoN 2014). Steller sea lion and northern elephant seal densities were calculated using shore-based population estimates divided by the area of the GOA Large Marine Ecosystem (DoN 2014). The North Pacific right whale, Risso's dolphin, and California sea lion are only rarely observed in or near the survey area, so minimal densities were used to represent their potential presence.

All densities were corrected for perception bias [*f*(0)] but only harbor porpoise densities were corrected for availability bias [*g*(0)], as described by the respective authors.

TABLE B-1. Densities of marine mammals in the Gulf of Alaska survey area. Species listed as "Endangered" under the ESA are in italics.

Species	Estimated Density (#/1000 km²)				Source
	Inshore <1000 m	**Slope** (1000 m to Aleutian Trench)	**Offshore** (Offshore of Aleutian Trench)	**Seamount** (In Defined Seamount Areas)	
LF Cetaceans					
North Pacific right whale	0.01	0.01	0.01	0.01	DoN (2014)
Humpback whale	129.00	0.20	1.00	1.00	Rone et al. (2014)
Blue whale	0.50	0.50	0.50	2.00	Rone et al. (2014)
Fin whale	71.00	14.00	21.00	5.00	Rone et al. (2014)
Sei whale	0.10	0.10	0.10	0.10	Kaschner et al. (2012) *in* DoN (2014)
Minke whale	0.60	0.60	0.60	0.60	Waite (2003) *in* DoN (2009)
Gray whale	48.57	2.43	0.00	0.00	DoN (2014)
MF Cetaceans					
Sperm whale	0.00	3.30	1.30	0.36	Rone et al. (2014)
Killer whale	5.00	20.00	2.00	2.00	Rone et al. (2014)
Pacific white-sided dolphin	20.80	20.80	20.80	20.80	Waite (2003) *in* DoN (2009)
Cuvier's beaked whale	2.20	2.20	2.20	2.20	Waite (2003) *in* DoN (2009)
Baird's beaked whale	0.50	0.50	0.50	0.50	Waite (2003) *in* DoN (2009)
Stejneger's beaked whale	0.01	1.42	1.42	1.42	Kaschner et al. (2012) *in* DoN (2014)
Risso's dolphin	0.01	0.01	0.01	0.01	DoN (2014)
HF Cetaceans					
Harbor Porpoise	47.30	0.00	0.00	0.00	Hobbs and Waite (2010) *in* DoN (2014)
Dall's porpoise	218.00	196.00	37.00	24.00	Rone et al. (2017)
Otariid Seals					
Steller sea lion	9.80	9.80	9.80	9.80	DoN (2014)
California sea lion	0.01	0.01	0.01	0.01	DoN (2014)
Northern fur seal	15.00	4.00	17.00	6.00	Rone et al. (2014)
Phocid Seal					
Northern elephant seal	2.20	2.20	2.20	2.20	DoN (2014)
Harbor seal	10.00	0.01	0.01	0.01	DoN (2014)

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APPENDIX C: MARINE MAMMAL TAKE CALCULATIONS

TABLE C-1. Densities of marine mammals and areas ensonified above threshold levels used to calculate potential takes from the proposed Gulf of Alaska survey. Species listed as "Endangered" under the ESA are in italics.

	Estimated Density (#/1000 km²)					NMFS Level B 160 dB Daily Ensonified Area				Level A Ensonified Area (km²)							
Species	Inshore <1000 m	Slope 1000 m to Aleutian Trench	Offshore Offshore of Aleutian Trench	Seamount Within Defined Seamount Areas	Regional Population Size	Inshore <1000 m	Slope 1000 m to Aleutian Trench	Offshore Offshore of Aleutian Trench	Seamount Within Defined Seamount Areas	Inshore <1000 m	Slope 1000 m to Aleutian Trench	Offshore Offshore of Aleutian Trench	Seamount Within Defined Seamount Areas	Total Level B Takes	Total Level A Takes	Total Takes	% of Pop. (Total Takes)
LF Cetaceans																	
North Pacific right whale	0.01	0.01	0.01	0.01	400	2,454	855	1,449	150	7	7	1	4	1	1	4	1.00
Humpback whale	129.00	0.20	1.00	1.00	21,063	2,454	855	1,449	150	7	7	1	4	5,730	1	5,731	27.21
Blue whale	0.50	0.50	0.50	2.00	1,647	2,454	855	1,449	150	7	7	1	4	49	1	50	3.04
Fin whale	71.00	14.00	21.00	5.00	18,680	2,454	855	1,449	150	7	7	1	4	3,913	1	3,914	20.95
Sei whale	0.10	0.10	0.10	0.10	27,197	2,454	855	1,449	150	7	7	1	4	9	1	10	0.04
Minke whale	0.60	0.60	0.60	0.60	25,000	2,454	855	1,449	150	7	7	1	4	54	1	55	0.22
Gray whale	48.57	2.43	0.00	0.00	20990	2,454	855	1,449	150	7	7	1	4	2,183	1	2,184	10.40
MF Cetaceans																	
Sperm whale	0.00	3.30	1.30	0.36	26,300	2,454	855	1,449	150	2	2	0	1	86	1	87	0.33
Killer whale	5.00	20.00	2.00	2.00	8,500	2,454	855	1,449	150	2	2	0	1	587	1	588	6.92
Pacific white-sided dolphin	20.80	20.80	20.80	20.80	988,333	2,454	855	1,449	150	2	2	0	1	1,838	1	1,839	0.19
Cuvier's beaked whale	2.20	2.20	2.20	2.20	20,000	2,454	855	1,449	150	2	2	0	1	195	1	196	0.98
Baird's beaked whale	0.50	0.50	0.50	0.50	25,300	2,454	855	1,449	150	2	2	0	1	45	1	46	0.18
Stejneger's beaked whale[1]	0.01	1.42	1.42	1.42	25,300	2,454	855	1,449	150	2	2	0	1	64	1	65	0.26
Risso's dolphin	0.01	0.01	0.01	0.01	838,000	2,454	855	1,449	150	2	2	0	1	1	1	17	0.00
HF Cetaceans																	
Harbor Porpoise	47.30	0.00	0.00	0.00	79,261	2,454	855	1,449	150	49	43	5	25	2,090	3	2,093	2.64
Dall's porpoise	218.00	196.00	37.00	24.00	1,186,000	2,454	855	1,449	150	49	43	5	25	13,677	21	13,698	1.15
Otariid Seals																	
Steller sea lion	9.80	9.80	9.80	9.80	53,303	2,454	855	1,449	150	2	2	0	1	866	1	867	1.63
California sea lion	0.01	0.01	0.01	0.01	296,750	2,454	855	1,449	150	2	2	0	1	1	1	2	0.00
Northern fur seal	15.00	4.00	17.00	6.00	1,100,000	2,454	855	1,449	150	2	2	0	1	1,184	1	1,185	0.11
Phocid Seal																	
Northern elephant seal	2.20	2.20	2.20	2.20	239,000	2,454	855	1,449	150	8	7	1	4	195	1	196	0.08
Harbor seal	10.00	0.01	0.01	0.01	129,000	2,454	855	1,449	150	8	7	1	4	443	1	444	0.34

[1] Abundance estimate not available, but acoustic monitoring suggests Stejneger's beaked whales are at least as abundant as Baird's beaked whale in the GOA (Baumann-Pickering et al. 2014), so use of Baird's beaked whale abundance estimate should result in a cautionary estimate of the percent of the population potentially taken.

APPENDIX D: ENSONIFIED AREAS FOR MARINE MAMMAL TAKE CALCULATIONS

TABLE D-1. Areas ensonified above threshold levels used to calculate potential takes from the proposed Gulf of Alaska survey.

Survey Zone	Criteria	Daily Ensonified Area (km^2)	Total Survey Days	25% Increase	Total Ensonified Area (km^2)	Relevant Isopleth (m)
Shallow (<40 m)	160 dB	474.8	18	1.25	10,683.7	25,493
Inshore (<1000 m)1	160 dB	1963.1	18	1.25	44,170.3	10,100
Slope (1000 m to Aleutian Trench)	160 dB	684.1	18	1.25	15,392.8	6,733
Offshore (Offshore of Aleutian Trench)	160 dB	1159.5	18	1.25	26,087.8	6,733
Seamount (Within Defined Seamount Areas)	160 dB	119.8	18	1.25	2,695.2	6,733
All zones	LF Cetacean	19.6	18	1.25	441.1	40.1
All zones	MF Cetacean	6.6	18	1.25	149.6	13.6
All zones	HF Cetacean	131.1	18	1.25	2,950.8	268.3
All zones	Otariid	5.2	18	1.25	116.6	10.6
All zones	Phocid	21.4	18	1.25	480.6	43.7

[1] Includes area ensonified above 160 dB in waters <100 m deep using an isopleth distance of 25,493 m.

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