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

submitted by

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to

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SUMMARY

Researchers from the University of Texas at Austin, University of Nevada Reno, University of California San Diego, with funding from the U.S. National Science Foundation (NSF), propose to conduct high-energy seismic surveys from Research Vessel (R/V) *Marcus G. Langseth* (*Langseth*) in the Northeast Pacific Ocean during summer 2019. The NSF-owned *Langseth* is operated by Columbia University's Lamont-Doherty Earth Observatory-Observatory (L-DEO) under an existing Cooperative Agreement. The proposed two-dimensional (2-D) and three-dimensional (3-D) seismic surveys would occur in International Waters outside of the U.S. Exclusive Economic Zone (EEZ). The 2-D survey would use a 36-airgun towed array with a total discharge volume of ~6600 in^3; the 3-D survey would employ an 18-airgun array with a discharge volume of ~3300 in^3. The surveys would occur in water depths ranging from 1400 to 2800 m. This request is submitted pursuant to Section 101 (a)(5)(D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371(a)(5).

Numerous species of marine mammals inhabit the proposed project area in the northeastern Pacific Ocean. Under the U.S. ESA, several of these species are listed as ***endangered***, including the North Pacific right, humpback (Central America Distinct Population Segment or DPS), sei, fin, blue, and sperm whales. The ***threatened*** Mexico DPS of the humpback whale could also occur in the proposed project area. ESA-listed sea turtle species that could occur in the project area include the ***endangered*** leatherback turtle and the ***threatened*** green turtle. Three ESA-listed seabirds, the ***endangered*** short-tailed albatross, the ***endangered*** Hawaiian petrel, and the ***threatened*** pink-footed shearwater, could occur in the project area. In addition, several ESA-listed fish species/populations could potentially occur in the offshore survey area, including the ***endangered*** Puget Sound/Georgia Basin DPS of bocaccio, several ***threatened*** DPSs of steelhead trout, and various ***endangered*** and ***threatened*** evolutionarily significant units (ESUs) of chinook, chum, coho, and sockeye salmon.

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

I. OPERATIONS TO BE CONDUCTED

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

Overview of the Activity

The proposed study consists of two seismic surveys in the Northeast Pacific Ocean—a 2-D and a 3-D survey to study the Axial volcano/seamount and associated rift axes off the coast of the Pacific Northwest (Fig. 1). The proposed surveys would occur within ~45.5–46.5°N, ~129.5–130.5°W. Representative survey tracklines are shown in Figure 1. As described further in this document, however, some 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, the tracklines could occur anywhere within the coordinates noted above. The surveys are proposed to occur in International Waters ranging in depth from 1400 to 2800 m.

The proposed surveys would be expected to last for 33 days, including ~19 days of seismic operations (~16 days for the 3-D survey; 3 days for the 2-D survey), 7 days of equipment deployment/retrieval, ~3 days of operational contingency time (e.g., infill, weather delays, etc.), ~2 days for turns (no airguns firing) during the 3-D survey, and ~2 days of transit. R/V *Langseth* would leave out of and return to port in Astoria, OR, during summer (July/August) 2019.

The primary objectives of the surveys proposed by researchers from the University of Texas at Austin Institute for Geophysics (UTIG), the Nevada Seismological Laboratory at the University of Nevada Reno (UNR) and Scripps Institution of Oceanography (SIO) at the University of California San Diego, is to create a detailed 3-D image of the main and satellite magma reservoirs that set the Axial volcano's framework, image the 3-D fracture network and how they influence the magma bodies, and to connect the subsurface observations to the surface features. The main goal of the seismic program is to explore linkages between complex magma chamber structure, caldera dynamics, fluid pathways, and hydrothermal venting. Seismic data acquired during the proposed study could be used to evaluate earthquake, tsunami, and submarine landslide hazards.

To achieve the project goals, the Principal Investigators (PI) Drs. A. Arnulf (UTIG), G. Kent and A. Kell (UNevada), and A. Harding (SIO) propose to conduct a 3-D multichannel seismic survey (MCS) of the Axial volcano and associated rift axes, plus eight 15-km-long source-receiver offset 2-D reflection profiles to look at the deep-seated structure of magma delivery.

R/V *Langseth* would first deploy four 6-km streamers and 18 airguns to conduct the 3-D MCS survey to examine the Axial volcano and associated rift axes within an approximate 17x40 km area. The 3-D survey would consist of a racetrack formation with 57 40-km long lines and a turning diameter of 8.5 km; no airguns would be firing during turns. The survey speed would be ~4.5 kt for the 3-D survey. The airgun array and streamers would then be recovered, and one 15-km streamer would be deployed along with 36 airguns to acquire eight ~26-km-long source-receiver offset 2-D reflection profiles that would look at deep-seated structure of magma delivery. During the 2-D survey, the airguns would be firing during turns to the next line, and the survey speed would be ~4.2 kt. As previously noted, the location of the survey lines could shift from what is currently depicted in Figure 1 depending on factors such as science drivers, poor data quality, weather, etc.

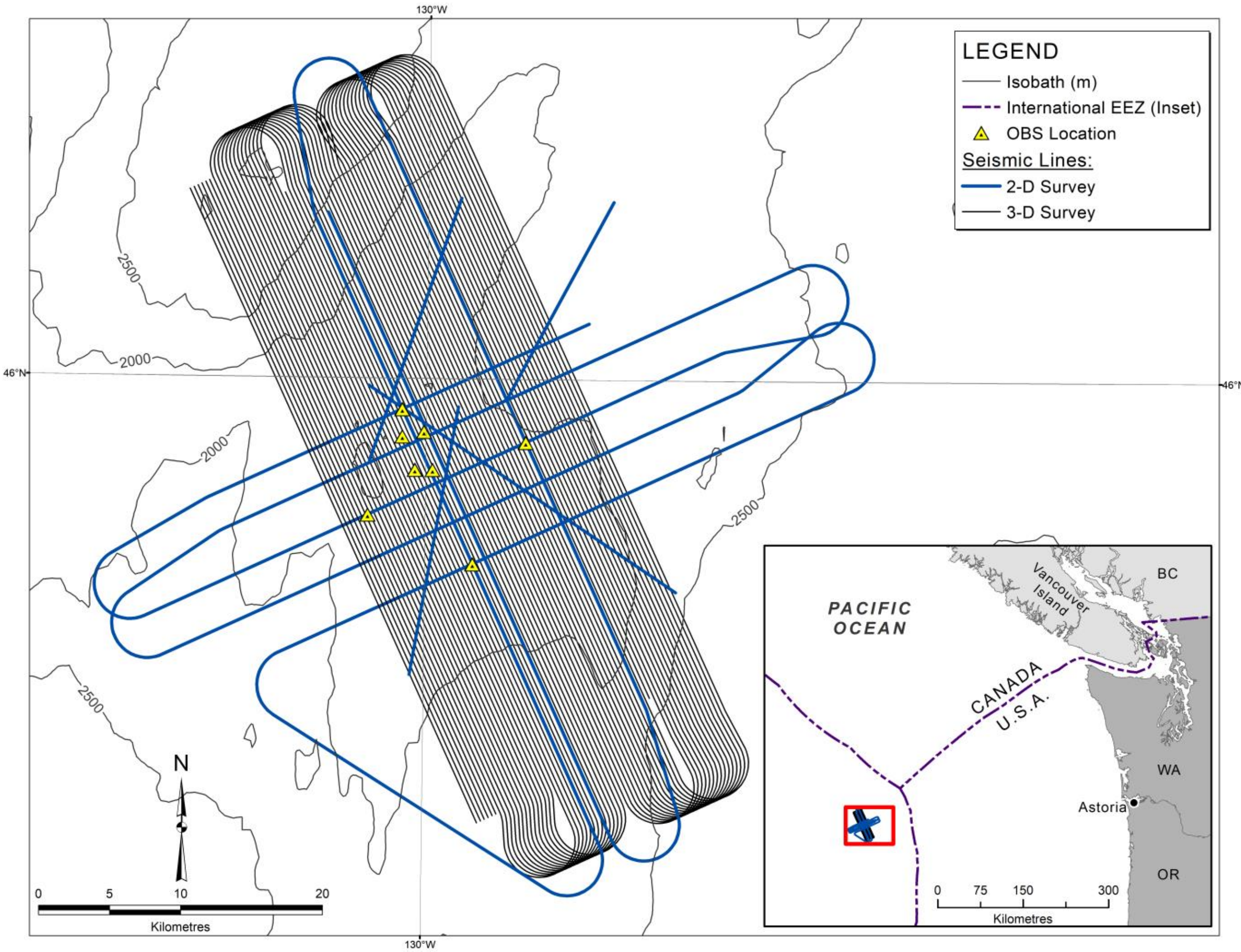

FIGURE 1. Location of the proposed seismic surveys in International Waters of the Northeast Pacific Ocean. EEZ = Exclusive Economic Zone. OBS = Ocean Bottom Seismometer.

A total of ~3760 km of transect lines would be surveyed in the Northeast Pacific Ocean: ~3196 km during the 3-D survey (including run ins and run outs) and 564 km during the 2-D survey. There could be additional seismic operations associated with turns, airgun testing, and repeat coverage of any areas where initial data quality is sub-standard. The entire survey would occur in deep (>1000 m) water.

In addition to the operations of the airgun array, a multibeam echosounder (MBES), a sub-bottom profiler (SBP), and an Acoustic Doppler Current Profiler (ADCP) would be operated from R/V *Langseth* continuously during the seismic surveys, but not during transit to and from the survey area. 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.

Source Vessel Specifications

R/V *Marcus G. Langseth* is described in § 2.2.2.1 of the Final Programmatic Environmental Impact Statement (PEIS)/Overseas Environmental Impact Statement (OEIS) for Marine Seismic Research funded by the National Science Foundation or Conducted by the U.S. Geological Survey (NSF and USGS 2011) and Record of Decision (NSF 2012), referred to herein as the PEIS. The vessel speed during seismic operations would be ~4.2 kt (~7.8 km/h) during the 2-D survey and ~4.5 km kt (~8.3 km/h) during the 3-D survey.

Airgun Description

During the surveys, R/V *Langseth* would tow four strings with 36 airguns (plus 4 spares). During the 2-D survey, all four strings, totaling 36 active airguns with a total discharge volume of 6600 in^3, would be used. During the 3-D survey, two strings consisting of 18 airguns with a total volume of ~3300 in^3, would fire alternately. The airgun arrays are described in § 2.2.3.1 of the PEIS, and the airgun configurations are illustrated in Figures 2-11 to 2-13 of the PEIS. The array would be towed at a depth of 10 m for the 3-D survey and at a depth of 10–12 m for the 2-D survey; the shot interval would be 37.5 m.

Predicted Sound Levels

Mitigation zones for the proposed marine seismic surveys 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 3-D survey would acquire data with the 18-airgun array at a maximum tow depth of 10 m, and the 2-D survey would employ 36 airguns with a tow depth of up to 12 m. L-DEO model results are used to determine the 160-dB_{rms} radius for the 18- and 36-airgun arrays and 40-in^3 (mitigation) airgun in deep water (>1000 m) down to a maximum water depth of 2000 m. Table 1 shows the distances at which the 160-dB re $1\mu Pa_{rms}$ sound levels are expected to be received for the airgun arrays and the 40-in^3 (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

TABLE 1. Level B. Predicted distances to which sound levels ≥160-dB re 1 μPa_{rms} could be received during the proposed surveys in the Northeast Pacific Ocean. The 160-dB criterion applies to all hearing groups of marine mammals.

Source and Volume	Maximum Tow Depth (m)	Water Depth (m)	Predicted distances (in m) to the 160-dB Received Sound Level[1]
Single Bolt airgun, 40 in^3	12	>1000 m	431
2 strings, 18 airguns, 3300 in^3	10	>1000 m	3758
4 strings, 36 airguns, 6600 in^3	12	>1000 m	6733

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

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 3 shows the distances at which the 175- and 195-dB re 1μPa_{rms} sound levels are expected to be received for the 18- and 36-airgun arrays 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 in § XI.

OBS Description and Deployment

Up to eight ocean bottom seismometers (OBSs) would be deployed at the start of operations. The OBSs are long-term broadband instruments that would be left out for ~1 year and recovered by another vessel. They have a height and diameter of ~1 m, with an 80 kg anchor. To retrieve OBSs, an acoustic release transponder (pinger) is used to interrogate the instrument at a frequency of 8–11 kHz, and a response is received at a frequency of 11.5–13 kHz. The burn-wire release assembly is then activated, and the instrument is released to float to the surface from the anchor which is not retrieved.

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

	Level A Threshold Distances (m) for Various Hearing Groups				
	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
18-airgun array; 3300 in^3					
PTS SEL_{cum}	**75.6**	0	0.3	2.9	0
PTS Peak	23.2	**11.2**	**118.7**	**25.1**	**9.9**
36-airgun array; 6600 in^3					
PTS SEL_{cum}	**426.9**	0	1.3	13.9	0
PTS Peak	38.9	**13.6**	**268.3**	**43.7**	**10.6**

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 surveys in the Northeast Pacific Ocean in water depths >1000 m.

Source and Volume	Tow Depth (m)	Predicted distances (in m) to Received Sound Levels[1]	
		195 dB	175 dB
Single mitigation airgun, 40 in^3	12	8 (100[2])	77
2 strings, 18 airguns, 3300 in^3	10	76 (100[3])	814
4 strings, 36 airguns, 6600 in^3	12	181	1864

[1] Distance is based on L-DEO model results.
[2] 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.
[3] Although this is not a low-energy source, an EZ of 100 m would be used as the shut-down distance for sea turtles.

Description of Operations

The procedures to be used for the proposed surveys would be similar to those used during previous seismic surveys by L-DEO and would use conventional seismic methodology. The surveys would involve one source vessel, R/V *Langseth*, which is owned by NSF and operated on its behalf by L-DEO. For the 2-D survey, R/V *Langseth* would deploy an array of 36 airguns as an energy source with a total volume of ~6600 in^3. For the 3-D survey, R/V *Langseth* would deploy an array of 18 airguns with a total volume of ~3300 in^3. The receiving system would consist of hydrophone streamers and up to eight OBSs. Four 6-km long hydrophone streamers would be used during 3-D data acquisition and one 15-km long streamer would be employed for 2-D data acquisition. As the airguns are towed along the survey lines, the hydrophone streamer(s) would transfer the data to the on-board processing system, and the OBSs would receive and store the returning acoustic signals internally for later analysis.

A total of ~3760 km of transect lines would be surveyed in the Northeast Pacific Ocean: ~3196 km during the 3-D survey (including run ins and run outs) and 564 km during the 2-D survey. 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 (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. In addition to the operations of the airgun array, the ocean floor would be mapped with the Kongsberg EM 122 MBES and a Knudsen Chirp 3260 SBP. A Teledyne RDI 75 kHz Ocean Surveyor ADCP would be used to measure water current velocities. These sources are described in § 2.2.3.1 of the PEIS.

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 surveys would occur within ~45.5–46.5°N, ~129.5–130.5°W. Representative survey tracklines are shown in Figure 1. As described further in this document, however, some deviation in actual track lines, including the order of survey operations, could be necessary for reasons such as science drivers, poor data quality, inclement weather, or mechanical issues with the research vessel and/or equipment. Thus, the tracklines could occur anywhere within the coordinates noted above. The proposed surveys would be conducted in International Waters.

The proposed surveys would be expected to last for 33 days, including ~19 days of seismic operations (~16 days for the 3-D survey; 3 days for the 2-D survey), 7 days of equipment deployment/retrieval, ~3 days of operational contingency time (e.g., infill, weather delays, etc.), ~2 days for turns (no airguns firing) during the 3-D survey, and ~2 days of transit. R/V *Langseth* would leave out of and return to port in Astoria, OR, during summer (July/August) 2019.

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. Few marine mammals are expected to occur in the proposed offshore survey area. Although baleen whales are likely more common in the region during the summer, most are expected to occur closer to shore.

III. Species and Numbers of Marine Mammals in Area

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

Thirty-two marine mammal species could occur or have been documented to occur in the marine waters off Oregon and Washington, excluding extralimital sightings or strandings (Fiscus and Niggol 1965; Green et al. 1992, 1993; Barlow 1997, 2003; Mangels and Gerrodette 1994; Von Saunder and

Barlow 1999; Barlow and Taylor 2001; Buchanan et al. 2001; Calambokidis et al. 2004; Calambokidis and Barlow 2004). The following seven species/populations are generally found in coastal waters and are not considered further: the sea otter, gray whale (Eastern North Pacific DPS), Southern Resident and Northern Resident DPSs of the killer whale, harbor porpoise, harbor seal, California sea lion, and Steller sea lion. It is also very unlikely that gray whales from the ***endangered*** Western North Pacific DPS would occur in the proposed survey area. Although Steller sea lions sometimes forage in deeper slope and pelagic waters, they generally remain near rookeries during the breeding season, and are unlikely to occur as far offshore as the study area even during dispersal. These species could be encountered during transit to and from Astoria. Vagrant ringed seals, hooded seals, and ribbon seals have been sighted or stranded on the coast of California (see Mead 1981; Reeves et al. 2002) and presumably passed through Washington/Oregon waters. A vagrant beluga whale was seen off the coast of Washington (Reeves et al. 2002). In addition, records exist for Perrin's beaked whale (*Mesplodon perrini*), pygmy beaked whale (*M. peruvianus*), and gingko-toothed beaked whale (*M. ginkgodens*) off the coast of California and/or Baja California (MacLeod et al. 2006). These species are unlikely to be seen in the proposed survey area and are not addressed in the summaries below.

Knowledge on the distribution of marine mammals in the pelagic waters where the proposed survey would take place is scarce. However, since 1996, NOAA NMFS Southwest Fisheries Science Center (SWFSC) has periodically conducted large-scale vessel surveys of marine mammals in the California Current Ecosystem (CCE) that include waters off Washington and Oregon out to ~300 n.mi. (~550 km), including the proposed survey area. Sightings from the 1996, 2001, 2005, and 2008 surveys are archived in the Ocean Biogeographic Information System (OBIS) database; those occurring in the vicinity of the proposed survey area were extracted and are reported below in the individual species descriptions in § IV.

Protected species observer sightings from previous L-DEO seismic surveys off Oregon and Washington in 2012 are also provided in the species descriptions below. Those surveys were of the Cascadia thrust zone off Oregon (43–45°N, 124–125°W), southeast of the proposed survey area, the Cascadia subduction zone off Washington (46–47.5°N, 124–126.5°W), northeast of the proposed survey area, and the Juan de Fuca plate (43–38°N, 124–130°W), which extended offshore to near the proposed survey area (RPS 2012a,b,c). Sightings from the August–September 2009 L-DEO Endeavour Tomography (ETOMO) seismic survey in and adjacent to the Endeavour Hydrothermal Vent Marine Protected Area are also provided in the species descriptions below; that survey occurred north of the proposed survey area, ~250 km southwest of Vancouver Island, Canada (Holst 2017).

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

IV. Status, Distribution and Seasonal Distribution of Affected Species or Stocks of Marine Mammals

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

Sections III and IV are integrated here to minimize repetition.

Of the 32 marine mammal species that could occur off the coasts of Washington and Oregon, only 26 species could occur within the offshore survey area, including 6 mysticetes (baleen whales), 18 odontocetes (toothed whales, such as dolphins), and 2 pinnipeds (seals and sea lions) (Table 4).

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

Species	Occurrence in Area	Habitat	Abundance[1]	U.S. *ESA*[2]	IUCN[3]	CITES[4]
Mysticetes						
North Pacific right whale	Rare	Coastal, shelf, offshore	400-500[5]	EN	EN	I
Humpback whale	Uncommon	Mainly nearshore and banks	1,918	EN/T[6]	LC	I
Common minke whale	Uncommon	Nearshore, offshore	636	NL	LC	I
Sei whale	Rare	Mostly pelagic	519	EN	EN	I
Fin whale	Common	Slope, pelagic	9029	EN	EN	I
Blue whale	Uncommon	Pelagic and coastal	1647	EN	EN	I
Odontocetes						
Sperm whale	Common	Pelagic, steep topography	1997	EN	VU	I
Pygmy sperm whale	Rare	Deep, off shelf	4111[7]	NL	DD	II
Dwarf sperm whale	Rare	Deep, shelf, slope	4111[7]	NL	DD	II
Cuvier's beaked whale	Uncommon	Pelagic	3274	NL	LC	II
Baird's beaked whale	Uncommon	Pelagic	2697	NL	DD	I
Blainville's beaked whale	Rare	Pelagic	3044[8]	NL	DD	II
Hubb's beaked whale	Rare	Slope, offshore	3044[8]	NL	DD	II
Stejneger's beaked whale	Uncommon	Slope, offshore	3044[8]	NL	DD	II
Common bottlenose dolphin	Rare	Coastal, shelf, deep	1924	NL	LC	II
Striped dolphin	Rare	Off continental shelf	29,211	NL	LC	II
Short-beaked common dolphin	Uncommon	Shelf, pelagic, mounts	969,861	NL	LC	II
Pacific white-sided dolphin	Common	Offshore, slope	26,814	NL	LC	II
Northern right whale dolphin	Common	Slope, offshore waters	26,556	NL	LC	II
Risso's dolphin	Common	Shelf, slope, mounts	6336	NL	LC	II
False killer whale	Rare	Pelagic	N.A.	NL	NT	II
Killer whale	Common	Widely distributed	240[9] 240[10]	NL[11]	DD	II
Short-finned pilot whale	Rare	Pelagic, high-relief	836	NL	LC	II
Dall's porpoise	Common	Shelf, slope, offshore	25,750	NL	LC	II
Pinnipeds						
Northern fur seal	Uncommon	Pelagic, offshore	637,561[12] 14,050[13]	NL	VU	N.A.
Northern elephant seal	Common	Coastal, pelagic in migration	179,000[14]	NL	LC	N.A.

N.A. - Species status was not assessed.
[1] Abundance for the California/Oregon/Washington, Eastern North Pacific, or U.S. stock from Carretta et al. (2018), unless otherwise stated.
[2] U.S. *Endangered Species Act* (NMFS 2018b): EN = Endangered, T = Threatened, NL = Not listed.
[3] Classification from the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2018); EN = Endangered; VU = Vulnerable; LC = Least Concern; DD = Data Deficient.
[4] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2018): Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled.
[5] North Pacific (Jefferson et al. 2015).
[6] The Central America DPS is endangered; the Mexico DPS is threatened.
[7] Combined *Kogia* spp.
[8] All mesoplodont whales (Moore and Barlow 2017; Carretta et al. 2018).
[9] Eastern North Pacific Offshore stock.
[10] West Coast Transient stock; minimum estimate (Muto et al. 2018).
[11] The Southern Resident DPS is listed as endangered; no other stocks are listed.
[12] Eastern Pacific stock (Muto et al. 2018).
[13] California stock (Carretta et al. 2018).
[14] California breeding stock (Carretta et al. 2018).

General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of marine mammals are given in § 3.6.1, § 3.7.1, and § 3.8.1 of the PEIS. One of the qualitative analysis areas (QAAs) defined in the PEIS, the BC Coast, is located to the north of the proposed survey area. The general distribution of mysticetes, odontocetes, and pinnipeds off the BC Coast is discussed in § 3.6.3.2, § 3.7.3.2, and § 3.8.3.2 of the PEIS, respectively. In addition, one of the detailed analysis areas (DAAs), S California, is located to the south of the proposed survey area. The general distribution of mysticetes, odontocetes, and pinnipeds off southern California is discussed in § 3.6.2.3, § 3.7.2.3, and § 3.8.2.3 of the PEIS, respectively. The rest of this section deals specifically with species distribution in the proposed survey area.

Mysticetes

North Pacific Right Whale (*Eubalaena japonica*)

The North Pacific right whale is one of the most endangered species of whale in the world (Brownell et al. 2001; NMFS 2013a). It summers in the northern North Pacific and Bering Sea, apparently feeding off southern and western Alaska from May to September (e.g., Tynan et al. 2001). The wintering areas for the population are unknown, but have been suggested to include the Hawaiian Islands and the Ryukyu Islands (Allen 1942; Banfield 1974; Gilmore 1978; Reeves et al. 1978; Herman et al. 1980). Whaling records indicate that right whales once ranged across the entire North Pacific north of 35ºN and occasionally occurred as far south as 20ºN (Kenney 2009). Although right whales were historically reported off the coast of Oregon, occasionally in large numbers (Scammon 1874; Rice and Fiscus 1968), extensive shore-based and pelagic commercial whaling operations never took large numbers of the species south of Vancouver Island (Rowlett et al. 1994). Nonetheless, Gilmore (1956) proposed that the main wintering ground for North Pacific right whales was off the Oregon coast and possibly northern California, postulating that the inherent inclement weather in those areas discouraged winter whaling (Rice and Fiscus 1968).

In the eastern North Pacific Ocean south of 50ºN, only 29 reliable sightings were recorded from 1900 to 1994 (Scarff 1986, 1991; Carretta et al. 1994). Rowlett et al. (1994) photographically identified one right whale off Washington on 24 May 1992, 65 km west of Cape Elizabeth, over a water depth of ~1200 m; the same whale was subsequently photographically identified again ~6 h later 48 km west of Destruction Island, in water ~500 m deep. Despite many miles of systematic aerial and ship-based surveys for marine mammals off the coasts of Washington/Oregon/California over the years, only seven documented sightings of right whales were made from 1990 to 2000 (Waite et al. 2003). Two North Pacific right whale calls were detected on a bottom-mounted hydrophone (located in waters 1390 m deep) off the Washington coast on 29 June 2013; no calls by this species were detected at this site in the two previous years of monitoring (Širović et al. 2014). There are no sightings of North Pacific right whales in the OBIS database near the proposed survey area (OBIS 2018).

Because of the small population size and the fact that North Pacific right whales spend the summer feeding in high latitudes, it is unlikely that any would be present in the proposed project area during the period of operations.

Humpback Whale (*Megaptera novaeangliae*)

The humpback whale is found throughout all of the oceans of the world (Clapham 2009). The worldwide population of humpbacks is divided into northern and southern ocean populations, but genetic analyses suggest some gene flow (either past or present) between the North and South Pacific (e.g., Baker et al. 1993; Caballero et al. 2001). Geographical overlap of these populations has been documented only off Central America (Acevedo and Smultea 1995; Rasmussen et al. 2004, 2007).

Although considered to be mainly a coastal species, humpback whales often traverse deep pelagic areas while migrating (Clapham and Mattila 1990; Norris et al. 1999; Calambokidis et al. 2001).

Humpback whales migrate between summer feeding grounds in high latitudes and winter calving and breeding grounds in tropical waters (Clapham and Mead 1999). North Pacific humpback whales summer in feeding grounds along the Pacific Rim and in the Bering and Okhotsk seas (Pike and MacAskie 1969; Rice 1978; Winn and Reichley 1985; Calambokidis et al. 2000, 2001, 2008). 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; Bettridge et al. 2015). These breeding areas have been designated as DPSs, but feeding areas have no DPS status (Bettridge et al. 2015; NMFS 2016b). Individuals encountered in the proposed survey area most likely would come from the Central America and Mexico DPSs, although some individuals from the Hawaii DPS may also feed in these waters. There is a low level of interchange of whales among the main wintering areas and among feeding areas (e.g., Darling and Cerchio 1993; Salden et al. 1999; Calambokidis et al. 2001, 2008).

The humpback whale is the most common species of large cetacean reported off the coasts of Oregon and Washington from May to November (Green et al. 1992; Calambokidis et al. 2000, 2004). The highest numbers have been reported off Oregon during May and June and off Washington during July–September. However, off Oregon and Washington, humpbacks occur primarily over the continental shelf and slope during the summer, with few reported in offshore pelagic waters (Green et al. 1992; Calambokidis et al. 2004, 2015; Becker et al. 2012; Menza et al. 2016). Biologically important areas (BIAs) for feeding humpback whales along the coasts of Oregon and Washington, which have been designated from May to November, are all within ~80 km offshore (Calambokidis et al. 2015).

Six humpback whale sightings (8 animals) were made off Washington/Oregon during the June–July 2012 L-DEO Juan de Fuca plate seismic survey; all were well inshore of the proposed survey area (RPS 2012b). There were 98 humpback whale sightings (213 animals) made during the July 2012 L-DEO seismic survey off southern Washington, northeast of the proposed survey area (RPS 2012a), and 11 sightings (23 animals) during the July 2012 L-DEO seismic survey off Oregon, southeast of the proposed survey area (RPS 2012c). There are no sightings of humpback whales near the proposed survey area in the OBIS database (OBIS 2018). No sightings were made near the proposed survey area in the 2014 SWFSC CCE vessel survey (Barlow 2016). Because of their largely coastal distribution in the waters off Oregon and Washington at feeding aggregations during the summer, humpback whales are likely to be uncommonly encountered, if at all, during the proposed survey.

Common Minke Whale (*Balaenoptera acutorostrata*)

The minke whale has a cosmopolitan distribution that spans from tropical to polar regions in both hemispheres (Jefferson et al. 2015). In the Northern Hemisphere, the minke whale is usually seen in coastal areas, but can also be seen in pelagic waters during its northward migration in spring and summer and southward migration in autumn (Stewart and Leatherwood 1985). In the North Pacific, the summer range of the minke whale extends to the Chukchi Sea; in the winter, the whales move farther south to within 2º of the Equator (Perrin and Brownell 2009).

The International Whaling Commission (IWC) recognizes three stocks of minke whales 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). Minke whales are relatively common in the Bering and Chukchi seas and in the Gulf of Alaska, but are not considered abundant in any other part of the eastern

Pacific (Brueggeman et al. 1990). In the far north, minke whales are thought to be migratory, but they are believed to be year-round residents in coastal waters off the U.S. west coast (Dorsey et al. 1990).

Sightings have been made off Oregon and Washington in shelf and deeper waters (Green et al. 1992; Adams et al. 2014; Carretta et al. 2017). An estimated abundance of 211 minke whales was reported for the Oregon/Washington region based on sightings data from 1991–2005 (Barlow and Forney 2007), whereas a 2008 survey did not record any minke whales while on survey effort (Barlow 2010). The abundance for Oregon/Washington for 2014 was estimated at 507 minke whales (Barlow 2016). There were no sightings of minke whales off Washington/Oregon during the June–July 2012 L-DEO Juan de Fuca plate seismic survey or during the July 2012 L-DEO seismic survey off Oregon, southeast of the proposed survey area (RPS 2012b,c). One minke whale was seen during the July 2012 L-DEO seismic survey off southern Washington, north of the proposed survey area (RPS 2012a). There are no sightings of minke whales near the proposed survey area in the OBIS database (OBIS (2018). No sightings of minke whales were made near the proposed survey area during the 2014 SWFSC CCE vessel survey (Barlow 2016). Because of their largely coastal distribution in the waters off Oregon and Washington, minke whales are unlikely to be encountered during the proposed survey.

Sei Whale (*Balaenoptera borealis*)

The distribution of the sei whale is not well known, but it is found in all oceans and appears to prefer mid-latitude temperate waters (Jefferson et al. 2015). The sei whale is pelagic and generally not found in coastal waters (Jefferson et al. 2015). It is found 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. 1999a). Sei whales migrate from temperate zones occupied in winter to higher latitudes in the summer, where most feeding takes place (Gambell 1985a). During summer in the North Pacific, the sei whale can be found from the Bering Sea to the Gulf of Alaska and down to southern California, as well as in the western Pacific from Japan to Korea. Its winter distribution is concentrated at ~20°N (Rice 1998).

Sei whales are rare in the waters off California, Oregon, and Washington (Brueggeman et al. 1990; Green et al. 1992; Barlow 1994, 1997). Only 16 confirmed sightings were reported for California, Oregon, and Washington during extensive surveys from 1991–2014 (Green et al. 1992, 1993; Hill and Barlow 1992; Carretta and Forney 1993; Mangels and Gerrodette 1994; Von Saunder and Barlow 1999; Barlow 2003; Forney 2007; Barlow 2010; Carretta et al. 2017). Based on surveys conducted in 1991–2008, the estimated abundance of sei whales off the coasts of Oregon and Washington was 52 (Barlow 2010); for 2014, the abundance estimate was 468 (Barlow 2016). Two sightings of four individuals were made during the June–July 2012 L-DEO Juan de Fuca plate seismic survey off Washington/Oregon (RPS 2012b); these were well inshore of the proposed survey area (~125°W). No sei whales were sighted during the July 2012 L-DEO seismic surveys north and south of the proposed survey area (RPS 2012a,c). There are no sightings of sei whales near the proposed survey area in the OBIS database (OBIS 2018). Sei whales could be encountered during the proposed survey, although this species is generally considered to be rare in these waters.

Fin Whale (*Balaenoptera physalus*)

The fin whale is widely distributed in all the world’s oceans (Gambell 1985b), but typically occurs in temperate and polar regions from 20–70° north and south of the Equator (Perry et al. 1999b). Northern and southern fin whale populations are distinct and are sometimes recognized as different subspecies

(Aguilar 2009). Fin whales occur in coastal, shelf, and oceanic waters. Sergeant (1977) suggested that fin whales tend to follow steep slope contours, either because they detect them readily or because biological productivity is high along steep contours because of tidal mixing and perhaps current mixing. Stafford et al. (2009) noted that sea-surface temperature is a good predictor variable for fin whale call detections in the North Pacific.

Fin whales appear to have complex seasonal movements and are seasonal migrants; they mate and calve in temperate waters during the winter and migrate to feed at northern latitudes during the summer (Gambell 1985b). The North Pacific population summers from the Chukchi Sea to California and winters from California southwards (Gambell 1985b). Aggregations of fin whales are found year-round off southern and central California (Dohl et al. 1980, 1983; Forney et al. 1995; Barlow 1997) and in the summer off Oregon (Green et al. 1992; Edwards et al. 2015). Vocalizations from fin whales have also been detected year-round off northern California, Oregon, and Washington (Moore et al. 1998, 2006; Watkins et al. 2000a,b; Stafford et al. 2007, 2009; Edwards et al. 2015). Based on surveys conducted in 1991–2008, the estimated abundance of fin whales off the coasts of Oregon and Washington was 416 (Barlow 2010); the estimate for 2014 was 3458 (Barlow 2016).

Fin whales are routinely sighted during surveys off Oregon and Washington (Barlow and Forney 2007; Barlow 2010; Adams et al. 2014; Calambokidis et al. 2015; Edwards et al. 2015; Carretta et al. 2017), including in coastal as well as offshore waters. They have also been detected acoustically near the proposed study area during June–August (Edwards et al. 2015). There is one sighting of a fin whale in the OBIS database within the proposed survey area, which was made in August 2005 during the SWFSC Collaborative Survey of Cetacean Abundance and the Pelagic Ecosystem (CSCAPE) Marine Mammal Survey, and several other sightings in adjacent waters (OBIS 2018). Eight fin whale sightings (19 animals) were made off Washington/Oregon during the June–July 2012 L-DEO Juan de Fuca plate seismic survey, including two sightings (4 animals) in the vicinity of the proposed survey area; sightings were made in waters 2369–3940 m deep (RPS 2012b). Fourteen fin whale sightings (28 animals) were made during the July 2012 L-DEO seismic surveys off southern Washington, northeast of the proposed survey area (RPS 2012a). No fin whales were sighted during the July 2012 L-DEO seismic survey off Oregon, southeast of the proposed survey area (RPS 2012c). Fin whales were also seen off southern Oregon during July 2012 in water >2000 m deep during surveys by Adams et al. (2014). 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). Although it has been suggested that there are at least five subpopulations of blue whales in the North Pacific (NMFS 1998), analysis of blue whale calls monitored from the U.S. Navy Sound Surveillance System (SOSUS) and other offshore hydrophones (see 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 western North Pacific (Sears and Perrin 2009). Broad-scale acoustic monitoring indicates that blue whales occurring in the northeast Pacific during summer and fall may winter in the eastern tropical Pacific (Stafford et al. 1999, 2001).

The distribution of the species, at least during times of the year when feeding is a major activity, occurs in areas that provide large seasonal concentrations of euphausiids (Yochem and Leatherwood 1985). The eastern North Pacific stock feeds in California waters from June–November (Calambokidis et al. 1990; Mate et al. 1999). There are nine BIAs for feeding blue whales off the coast of California (Calambokidis et al. 2015), and core areas have also been identified there (Irvine et al. 2014). Blue whales have been detected acoustically off Oregon (McDonald et al. 1995; Stafford et al. 1998; Von Saunder and Barlow 1999), but sightings are uncommon (Carretta et al. 2018). Densities along the U.S. west coast, including Oregon, were predicted to be highest in shelf waters, with lower densities in deeper offshore areas (Becker et al. 2012; Calambokidis et al. 2015). Buchanan et al. (2001) considered blue whales to be rare off Oregon and Washington. However, based on the absolute dynamic topography of the region, blue whales could occur in relatively high densities off Oregon during July–December (Pardo et al. 2015).

There are no sightings of blue whales within the proposed survey area in the OBIS database; however, the nearest sighting is ~55 km to the southwest (OBIS 2018), and there are several other sightings in adjacent waters (Carretta et al. 2018; OBIS 2018). Satellite telemetry suggests that blue whales are present in waters offshore of Oregon and Washington during fall and winter (Bailey et al. 2009; Hazen et al. 2017). Blue whales could be encountered in the proposed survey area.

Odontocetes

Sperm Whale (*Physeter macrocephalus*)

The sperm whale is the largest of the toothed whales, with an extensive worldwide distribution (Rice 1989). Sperm whale distribution is linked to social structure: mixed groups of adult females and juvenile animals of both sexes generally occur in tropical and subtropical waters, whereas adult males are commonly found alone or in same-sex aggregations, often occurring in higher latitudes outside the breeding season (Best 1979; Watkins and Moore 1982; Arnbom and Whitehead 1989; Whitehead and Waters 1990). Males can migrate north in the summer to feed in the Gulf of Alaska, Bering Sea, and waters around the Aleutian Islands (Kasuya and Miyashita 1988). Mature male sperm whales migrate to warmer waters to breed when they are in their late twenties (Best 1979).

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; Whitehead 2009). They are often found far from shore, but can be found closer to oceanic islands that rise steeply from deep ocean waters (Whitehead 2009). Adult males can occur in water depths <100 m and as shallow as 40 m (Whitehead et al. 1992; Scott and Sadove 1997). They can dive as deep as ~2 km and possibly deeper on rare occasions for periods of over 1 h; however, most of their foraging occurs at depths of ~300–800 m for 30–45 min (Whitehead 2003).

Sperm whales are distributed widely across the North Pacific (Rice 1989). Off California, they occur year-round (Dohl et al. 1983; Barlow 1995; Forney et al. 1995), with peak abundance from April to mid-June and from August to mid-November (Rice 1974). Off Oregon, sperm whales are seen in every season except winter (Green et al. 1992).

Oleson et al. (2009) noted a significant diel pattern in the occurrence of sperm whale clicks at offshore and inshore monitoring locations off Washington, whereby clicks were more commonly heard during the day at the offshore site and were more common at night at the inshore location, suggesting possible diel movements up and down the slope in search of prey. Sperm whale acoustic detections were also reported at the inshore site from June through January 2009, with an absence of calls during February to May (Ŝirović et al. 2012). In addition, sperm whales were sighted during surveys off Washington in June 2011 and off Oregon in October 2011 (Adams et al. 2014). There is one sighting of a sperm whale in the vicinity of the survey area in the OBIS database that was made in July 1996 during the SWFSC ORCAWALE Marine Mammal Survey (OBIS 2018), and several other sightings in adjacent waters (Carretta et al. 2018; OBIS 2018). Sperm whale sightings were also made in the vicinity of the proposed survey area during the 2014 SWFSC vessel survey (Barlow 2016). A single sperm whale was sighted during the 2009 ETOMO survey, north of the proposed survey area (Holst 2017). Sperm whales were detected acoustically in waters near the proposed survey area in August 2016 during the SWFSC Passive Acoustics Survey of Cetacean Abundance Levels (PASCAL) study using drifting acoustic recorders (Keating et al. 2018). Sperm whales are likely to be encountered in the proposed survey area.

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

The pygmy and dwarf sperm whales are distributed widely throughout tropical and temperate seas, but their precise distributions are unknown as most information on these species comes from strandings (McAlpine 2009). They are difficult to sight at sea, perhaps because of their avoidance reactions to ships and behavior changes in relation to survey aircraft (Würsig et al. 1998). The two species are difficult to distinguish from one another when sighted (McAlpine 2009).

Both *Kogia* species are sighted primarily along the continental shelf edge and slope and over deeper waters off the shelf (Hansen et al. 1994; Davis et al. 1998). Several studies have suggested that pygmy sperm whales live mostly beyond the continental shelf edge, whereas dwarf sperm whales tend to occur closer to shore, often over the continental shelf (Rice 1998; Wang et al. 2002; MacLeod et al. 2004). Barros et al. (1998), on the other hand, suggested that dwarf sperm whales could be more pelagic and dive deeper than pygmy sperm whales. It has also been suggested that the pygmy sperm whale is more temperate and the dwarf sperm whale more tropical, based at least partially on live sightings at sea from a large database from the eastern tropical Pacific (Wade and Gerrodette 1993). This idea is also supported by the distribution of strandings in South American waters (Muñoz-Hincapié et al. 1998).

Pygmy and dwarf sperm whales are rarely sighted off Oregon and Washington, with only one sighting of an unidentified *Kogia* sp. beyond the U.S. EEZ, during the 1991–2014 NOAA vessel surveys (Carretta et al. 2017). This sighting was made in October 1993 during the SWFSC PODS Marine Mammal Survey ~150 km to the south of the proposed survey area (OBIS 2018). Norman et al. (2004) reported eight confirmed stranding records of pygmy sperm whales for Oregon and Washington, five of which occurred during autumn and winter. It is possible that pygmy or dwarf sperm whales could be encountered within the proposed project area.

Cuvier's Beaked Whale (*Ziphius cavirostris*)

Cuvier's beaked whale is probably the most widespread of the beaked whales, although it is not found in polar waters (Heyning 1989). Cuvier's beaked whale appears to prefer steep continental slope waters (Jefferson et al. 2015) and is most common in water depths >1000 m (Heyning 1989). It is mostly known from strandings and strands more commonly than any other beaked whale (Heyning 1989). Its inconspicuous blows, deep-diving behavior, and tendency to avoid vessels all help to explain the infrequent sightings (Barlow and Gisiner 2006). The population in the California Current Large Marine Ecosystem seems to be declining (Moore and Barlow 2013).

MacLeod et al. (2006) reported numerous sightings and strandings along the Pacific coast of the U.S. Cuvier's beaked whale is the most common beaked whale off the U.S. west coast (Barlow 2010), and it is the beaked whale species that has stranded most frequently on the coasts of Oregon and Washington. From 1942–2010, there were 23 reported Cuvier's beaked whale strandings in Oregon and Washington (Moore and Barlow 2013). Most (75%) Cuvier's beaked whale strandings reported occurred in Oregon (Norman et al. 2004).

Four beaked whale sightings were reported in water depths >2000 m off Oregon/Washington during surveys in 2008 (Barlow 2010). None were seen in 1996 or 2001 (Barlow 2003), and several were recorded from 1991 to 1995 (Barlow 1997). One Cuvier's beaked whale sighting was made east of the proposed survey area during 2014 (Barlow 2016). Acoustic monitoring in Washington offshore waters detected Cuvier's beaked whale pulses between January and November 2011 (Ŝirović et al. 2012b *in* USN

2015). There is one sighting of a Cuvier's beaked whale near the proposed survey area in the OBIS database that was made in July 1996 during the SWFSC ORCAWALE Marine Mammal Survey (OBIS 2018), and several other sightings were made in adjacent waters, primarily to the south and east of the proposed survey area (Carretta et al. 2018; OBIS 2018). Cuvier's beaked whales were detected acoustically in waters near the proposed survey area in August 2016 during the SWFSC PASCAL study using drifting acoustic recorders (Keating et al. 2018). Cuvier's beaked whales could be encountered during the proposed survey.

Blainville's Beaked Whale (*Mesoplodon densirostris*)

Blainville's beaked whale is found in tropical and warm temperate waters of all oceans (Pitman 2009). It has the widest distribution throughout the world of all mesoplodont species and appears to be relatively common (Pitman 2009). Like other beaked whales, Blainville's beaked whale is generally found in waters 200–1400 m deep (Gannier 2000; Jefferson et al. 2015). Occasional occurrences in cooler, higher-latitude waters are presumably related to warm-water incursions (Reeves et al. 2002). MacLeod et al. (2006) reported stranding and sighting records in the eastern Pacific ranging from 37.3°N to 41.5°S. However, none of the 36 beaked whale stranding records in Oregon and Washington during 1930–2002 included Blainville's beaked whale (Norman et al. 2004). One Blainville's beaked whale was found stranded (dead) on the Washington coast in November 2016 (COASST 2016).

There are no sightings of Blainville's beaked whales near the proposed survey area in the OBIS database (OBIS 2018). There is one sighting of an unidentified species of Mesoplodont whale near the survey area in the OBIS database that was made in July 1996 during the SWFSC ORCAWALE Marine Mammal Survey (OBIS 2018). There was one acoustic encounter with Blainville's beaked whales recorded in Quinault Canyon off Washington in waters 1400 m deep during 2011 (Baumann-Pickering et al. 2014). Blainville's beaked whales were not detected acoustically in waters near the proposed survey area in August 2016 during the SWFSC PASCAL study using drifting acoustic recorders (Keating et al. 2018). Although Blainville's beaked whales could be encountered during the proposed survey, an encounter would be unlikely because the proposed survey area is beyond the northern limits of this tropical species' usual distribution.

Stejneger's Beaked Whale (*Mesoplodon stejnegeri*)

Stejneger's beaked whale occurs in subarctic and cool temperate waters of the North Pacific Ocean (Mead 1989). In the eastern North Pacific Ocean, it is distributed from Alaska to southern California (Mead et al. 1982; Mead 1989). Most stranding records are from Alaskan waters, and the Aleutian Islands appear to be its center of distribution (MacLeod et al. 2006). After Cuvier's beaked whale, Stejneger's beaked whale was the second most commonly stranded beaked whale species in Oregon and Washington (Norman et al. 2004).

Stejneger's beaked whale calls were detected during acoustic monitoring offshore Washington between January and June 2011, with an absence of calls from mid-July to November 2011 (Ŝirović et al. 2012b *in* USN 2015). Analysis of these data suggest that this species could be more than twice as prevalent in this area than Baird's beaked whale (Baumann-Pickering et al. 2014). Stejneger's beaked whales were also detected acoustically in waters near the proposed survey area in August 2016 during the SWFSC PASCAL study using drifting acoustic recorders (Keating et al. 2018). There are no sightings of Stejneger's beaked whales near the proposed survey area in the OBIS database (OBIS 2018). There is one sighting of an unidentified species of Mesoplodont beaked whale near the survey area in the OBIS database that was made during July 1996 during the SWFSC ORCAWALE Marine Mammal Survey (OBIS 2018). Stejneger's beaked whales could be encountered during the proposed survey.

Hubb's Beaked Whale (*Mesoplodon carlhubbsi*)

Hubbs' beaked whale occurs in temperate waters of the North Pacific (Mead 1989). Its distribution appears to be correlated with the deep subarctic current (Mead et al. 1982). Numerous stranding records have been reported for the west coast of the U.S. (MacLeod et al. 2006). Most of the records are from California, but it has been sighted as far north as Prince Rupert, BC (Mead 1989). Two strandings are known from Washington/Oregon (Norman et al. 2004). Hubbs' beaked whales are often killed in drift gillnets off California (Reeves et al. 2002).

There are no sightings of Hubbs' beaked whales near the proposed survey area in the OBIS database (OBIS 2018). There is one sighting of an unidentified species of Mesoplodont whale near the survey area in the OBIS database that was made in July 1996 during the SWFSC ORCAWALE Marine Mammal Survey (OBIS 2018). During the 2016 SWFSC PASCAL study using drifting acoustic recorders, detections were made of beaked whale sounds presumed to be from Hubbs' beaked whales near the proposed survey area during August (Griffiths et al. submitted manuscript cited in Keating et al. 2018). In addition, at least two sightings just to the south of the proposed survey area were reported in Carretta et al. (2018). This species seems to be less common in the proposed survey area than some of the other beaked whales, but it could be encountered during the survey.

Baird's Beaked Whale (*Berardius bairdii*)

Baird's beaked whale has a fairly extensive range across the North Pacific, with concentrations occurring in the Sea of Okhotsk and Bering Sea (Rice 1998; Kasuya 2009). In the eastern Pacific, Baird's beaked whale is reported to occur as far south as San Clemente Island, California (Rice 1998; Kasuya 2009). Baird's beaked whales that occur off the U.S. west coast are of the gray form, unlike some *Berardius* individuals that are found in Alaska and Japan, which are of the black form and thus could be a new species (Morin et al. 2017).

Baird's beaked whale is sometimes seen close to shore where deep water approaches the coast, but its primary habitat is over or near the continental slope and oceanic seamounts (Jefferson et al. 2015). Along the U.S. west coast, Baird's beaked whales have been sighted primarily along the continental slope (Green et al. 1992; Becker et al. 2012; Carretta et al. 2018) from late spring to early fall (Green et al. 1992). The whales move out from those areas in winter (Reyes 1991). In the eastern North Pacific Ocean, Baird's beaked whales apparently spend the winter and spring far offshore, and in June, they move onto the continental slope, where peak numbers occur during September and October. Green et al. (1992) noted that Baird's beaked whales on the U.S. west coast were most abundant in the summer, and were not sighted in the fall or winter. MacLeod et al. (2006) reported numerous sightings and strandings of *Berardius* spp. off the U.S. west coast.

Green et al. (1992) sighted five groups during 75,050 km of aerial survey effort in 1989–1990 off Washington/Oregon spanning coastal to offshore waters: two in slope waters and three in offshore waters. Two groups were sighted during summer/fall 2008 surveys off Washington/Oregon, in waters >2000 m deep (Barlow 2010). Acoustic monitoring offshore Washington detected Baird's beaked whale pulses during January through November 2011, with peaks in February and July (Ŝirović et al. 2012b *in* USN 2015). Baird's beaked whales were detected acoustically near the proposed survey area in August 2016 during the SWFSC PASCAL study using drifting acoustic recorders (Keating et al. 2018). There is one sighting of a Baird's beaked whale near the survey area in the OBIS database that was made in August 2005 during the SWFSC CSCAPE Marine Mammal Survey (OBIS 2018). Baird's beaked whales could be encountered in the proposed survey area.

Common Bottlenose Dolphin (*Tursiops truncatus*)

The bottlenose dolphin is distributed worldwide in coastal and shelf waters of tropical and temperate oceans (Jefferson et al. 2015). There are two distinct bottlenose dolphin types: a shallow water type, mainly found in coastal waters, and a deep water type, mainly found in oceanic waters (Duffield et al. 1983; Hoelzel et al. 1998; Walker et al. 1999). Coastal common bottlenose dolphins exhibit a range of movement patterns including seasonal migration, year-round residency, and a combination of long-range movements and repeated local residency (Wells and Scott 2009).

Bottlenose dolphins occur frequently off the coast of California, and sightings have been made as far north as 41ºN, but few records exist for Oregon/Washington (Carretta et al. 2017). Three sightings and one stranding of bottlenose dolphins have been documented in Puget Sound since 2004 (Cascadia Research 2011 *in* USN 2015). It is possible that offshore bottlenose dolphins may range as far north as the proposed survey area during warm-water periods (Carretta et al. 2017). Adams et al. (2014) made one sighting off Washington during September 2012. There are no sightings of bottlenose dolphins near the proposed survey area in the OBIS database (OBIS 2018). It is possible, although unlikely, that bottlenose dolphins could be encountered in the proposed survey area.

Short-beaked Common Dolphin (*Delphinus delphis*)

The short-beaked common dolphin is found in tropical and warm temperate oceans around the world (Perrin 2009). It ranges as far south as 40°S in the Pacific Ocean, is common in coastal waters 200–300 m deep and is also associated with prominent underwater topography, such as seamounts (Evans 1994). Short-beaked common dolphins have been sighted as far as 550 km from shore (Barlow et al. 1997).

The distribution of short-beaked common dolphins along the U.S. west coast is variable and likely related to oceanographic changes (Heyning and Perrin 1994; Forney and Barlow 1998). It is the most abundant cetacean off California; some sightings have been made off Oregon, in offshore waters (Carretta et al. 2017). During surveys off the west coast in 2014 and 2017, sightings were made as far north as 44°N (Barlow 2016; SIO n.d.). Based on the absolute dynamic topography of the region, short-beaked common dolphins could occur in relatively high densities off Oregon during July–December (Pardo et al. 2015). In contrast, habitat modeling predicted moderate densities of common dolphins off the Columbia River mouth during summer, with lower densities off southern Oregon (Becker et al. 2014). There are no sightings of short-beaked dolphins near the proposed survey area in the OBIS database (OBIS 2018). It is possible that short-beaked dolphins could be encountered in the proposed survey area.

Striped Dolphin (*Stenella coeruleoalba*)

The striped dolphin has a cosmopolitan distribution in tropical to warm temperate waters (Perrin et al. 1994) and is generally seen south of 43ºN (Archer 2009). However, in the eastern North Pacific, its distribution extends as far north as Washington (Jefferson et al. 2015). The striped dolphin is typically found in waters outside the continental shelf and is often associated with convergence zones and areas of upwelling (Archer 2009). However, it has also been observed approaching shore where there is deep water close to the coast (Jefferson et al. 2015).

Striped dolphins regularly occur off California (Becker et al. 2012), where they have been seen as far as the ~300 n.mi. limit during the NOAA Fisheries vessel surveys (Carretta et al. 2017). Very few sightings have been made off Oregon, and no sightings have been reported for Washington (Carretta et al. 2017). However, strandings have occurred along the coasts of Oregon and Washington (Carretta et al. 2016). During surveys off the U.S. west coast in 2014, striped dolphins were seen as far north as 44ºN; based on those sightings, Barlow (2016) calculated an abundance estimate of 13,171 striped dolphins for the Oregon/Washington region. The abundance estimates for 2001, 2005, and 2008 were zero (Barlow 2016). There are no sightings of striped dolphins near the proposed survey area in the OBIS database (OBIS 2018). It is possible, although unlikely, that striped dolphins could be encountered in the proposed survey area.

Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*)

The Pacific white-sided dolphin is found in cool temperate waters of the North Pacific from the southern Gulf of California to Alaska. Across the North Pacific, it appears to have a relatively narrow distribution between 38°N and 47°N (Brownell et al. 1999). In the eastern North Pacific Ocean, including waters off Oregon, the Pacific white-sided dolphin is one of the most common cetacean species, occurring primarily in shelf and slope waters (Green et al. 1993; Barlow 2003, 2010). It is known to occur close to shore in certain regions, including (seasonally) southern California (Brownell et al. 1999).

Results of aerial and shipboard surveys strongly suggest seasonal north–south movements of the species between California and Oregon/Washington; the movements apparently are related to oceanographic influences, particularly water temperature (Green et al. 1993; Forney and Barlow 1998; Buchanan et al. 2001). During winter, this species is most abundant in California slope and offshore areas; as northern 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). The highest encounter rates off Oregon and Washington have been reported during March–May in slope and offshore waters (Green et al. 1992). Similarly, Becker et al. (2014) predicted relatively high densities off southern Oregon in shelf and slope waters.

Based on year-round aerial surveys off Oregon/Washington, the Pacific white-sided dolphin was the most abundant cetacean species, with nearly all (97%) sightings occurring in May (Green et al. 1992, 1993). Barlow (2003) also found that the Pacific white-sided dolphin was one of the most abundant marine mammal species off Oregon/Washington during 1996 and 2001 ship surveys, and it was the second most abundant species reported during 2008 surveys (Barlow 2010). Adams et al. (2014) reported numerous offshore sightings off Oregon during summer, fall, and winter surveys in 2011 and 2012. Based on surveys conducted during 2014, the abundance was estimated at 20,711 for Oregon/Washington (Barlow 2016).

Fifteen Pacific white-sided dolphin sightings (231 animals) were made off Washington/Oregon during the June–July 2012 L-DEO Juan de Fuca plate seismic survey; none were near the proposed survey area (RPS 2012b). There were fifteen Pacific white-sided dolphin sightings (462 animals) made during the July 2012 L-DEO seismic surveys off southern Washington, northeast of the proposed survey area (RPS 2012a). This species was not sighted during the July 2012 L-DEO seismic survey off Oregon, southeast of the proposed survey area (RPS 2012c). There is one sighting of Pacific white-sided dolphins in the OBIS database that was made in August 2005, ~40 km to the southwest of the survey area during the SWFSC CSCAPE Marine Mammal Survey (OBIS 2018). One group of 10 Pacific white-sided dolphins was sighted during the 2009 ETOMO survey north of the proposed survey area (Holst 2017). Pacific white-sided dolphins are likely to be common in the proposed survey area.

Northern Right Whale Dolphin (*Lissodelphis borealis*)

The northern right whale dolphin is found in cool temperate and sub-arctic waters of the North Pacific, from the Gulf of Alaska to near northern Baja California, ranging from 30°N to 50°N (Reeves et al. 2002). In the eastern North Pacific Ocean, including waters off Oregon, the northern right whale dolphin is one of the most common marine mammal species, occurring primarily in shelf and slope waters

~100 to >2000 m deep (Green et al. 1993; Barlow 2003). The northern right whale dolphin comes closer to shore where there is deep water, such as over submarine canyons (Reeves et al. 2002).

Aerial and shipboard surveys suggest seasonal inshore–offshore and north–south movements in the eastern North Pacific Ocean between California and Oregon/Washington; the movements are believed to be related to oceanographic influences, particularly water temperature and presumably prey distribution and availability (Green et al. 1993; Forney and Barlow 1998; Buchanan et al. 2001). Green et al. (1992, 1993) found that northern right whale dolphins were most abundant off Oregon/Washington during fall, less abundant during spring and summer, and absent during winter, when this species presumably moves south to warmer California waters (Green et al. 1992, 1993; Forney 1994; Forney et al. 1995; Buchanan et al. 2001; Barlow 2003). Considerable interannual variations in abundance also have been found.

Becker et al. (2014) predicted relatively high densities off southern Oregon, and moderate densities off northern Oregon and Washington. Based on year-round aerial surveys off Oregon/Washington, the northern right whale dolphin was the third most abundant cetacean species, concentrated in slope waters but also occurring in water out to ~550 km offshore (Green et al. 1992, 1993). Barlow (2003, 2010) also found that the northern right whale dolphin was one of the most abundant marine mammal species off Oregon/Washington during 1996, 2001, 2005, and 2008 ship surveys. Offshore sightings were made in the waters of Oregon during summer, fall, and winter surveys in 2011 and 2012 (Adams et al. 2014).

Seven northern right whale dolphin sightings (231 animals) were made off Washington/Oregon during the June–July 2012 L-DEO Juan de Fuca plate seismic survey; none were seen near the proposed survey area (RPS 2012b). There were eight northern right whale dolphin sightings (278 animals) made during the July 2012 L-DEO seismic surveys off southern Washington, northeast of the proposed survey area (RPS 2012a). This species was not sighted during the July 2012 L-DEO seismic survey off Oregon, southeast of the proposed survey area (RPS 2012c). There is one sighting of northern right whale dolphins in the OBIS database that was made during August 2001 ~40 km to the south of the survey area during the SWFSC ORCAWALE Marine Mammal Survey (OBIS 2018). Northern right whale dolphins are likely to be encountered in the proposed survey area.

Risso's Dolphin (*Grampus griseus*)

Risso's dolphin is distributed worldwide in temperate and tropical oceans (Baird 2009), although it shows a preference for mid-temperate waters of the shelf and slope between 30° and 45° (Jefferson et al. 2014). Although it is known to occur in coastal and oceanic habitats (Jefferson et al. 2014), it appears to prefer steep sections of the continental shelf, 400–1000 m deep (Baird 2009), and is known to frequent seamounts and escarpments (Kruse et al. 1999). Off the U.S. west coast, 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).

The distribution and abundance of Risso's dolphins are highly variable from California to Washington, presumably in response to changing oceanographic conditions on both annual and seasonal time scales (Forney and Barlow 1998; Buchanan et al. 2001). The highest densities were predicted along the coasts of Washington, Oregon, and central and southern California (Becker et al. 2012). Off Oregon and Washington, Risso's dolphins are most abundant over continental slope and shelf waters during spring and summer, less so during fall, and rare during winter (Green et al. 1992, 1993). Green et al. (1992, 1993) reported most Risso's dolphin groups off Oregon between ~45 and 47ºN. Several sightings were made off southern Oregon during surveys in 1991–2014 (Carretta et al. 2017). Sightings during ship surveys in summer/fall 2008 were mostly between ~30 and 38ºN; none were reported in

Oregon/Washington (Barlow 2010). Based on 2014 survey data, the abundance for Oregon/Washington was estimated at 430 (Barlow 2016)

Two sightings of 38 individuals were recorded off Washington from August 2004 to September 2008 (Oleson et al. 2009). Risso's dolphins were sighted off Oregon, in June and October 2011 (Adams et al. 2014). There were three Risso's dolphin sightings (31 animals) made during the July 2012 L-DEO seismic surveys off southern Washington, northeast of the proposed survey area (RPS 2012a). This species was not sighted during the July 2012 L-DEO seismic survey off Oregon, southeast of the proposed survey area (RPS 2012c), or off Washington/Oregon during the June–July 2012 L-DEO Juan de Fuca plate seismic survey (RPS 2012b). There is one sighting of Risso's dolphins in the OBIS database that was made in July 1996 ~35 km to the northeast of the survey area during the SWFSC ORCAWALE Marine Mammal Survey (OBIS 2018). Risso's dolphins could be encountered in the proposed survey area.

False Killer Whale (*Pseudorca crassidens*)

The false killer whale is found in all tropical and warmer temperate oceans, especially in deep, offshore waters (Odell and McClune 1999). However, it is also known to occur in nearshore areas (e.g., Stacey and Baird 1991). In the eastern North Pacific, it has been reported only rarely north of Baja California (Leatherwood et al. 1982, 1987; Mangels and Gerrodette 1994); however, the waters off the U.S. west coast all the way north to Alaska are considered part of its secondary range (Jefferson et al. 2015). Its occurrence in Washington/Oregon is associated with warm-water incursions (Buchanan et al. 2001). However, no sightings of false killer whales were made along the U.S. west coast during surveys conducted from 1986 to 2001 (Ferguson and Barlow 2001, 2003; Barlow 2003) or in 2005 and 2008 (Forney 2007; Barlow 2010). One pod of false killer whales occurred in Puget Sound for several months during the 1990s (USN 2015). Two were reported stranded along the Washington coast during 1930–2002, both in El Niño years (Norman et al. 2004). One sighting was made of southern California during 2014 (Barlow 2016). There are no sightings of false killer whales near the survey area in the OBIS database (OBIS 2018). This species is unlikely to be encountered during the proposed survey.

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). Currently, there are eight killer whale stocks recognized in the Pacific U.S.: (1) Alaska Residents, occurring from southeast Alaska to the Aleutians and Bering Sea; (2) Northern Residents, from BC through parts of southeast Alaska; (3) Southern Residents, mainly in inland waters of Washington State and southern BC; (4) Gulf of Alaska, Aleutians, and Bering Sea Transients, from Prince William Sound (PWS) through to the Aleutians and Bering Sea; (5) AT1 Transients, from PWS through the Kenai Fjords; (6) West Coast Transients, from California through southeast Alaska; (7) Offshore, from California through Alaska; and (8) Hawaiian (Carretta et al. 2018). Individuals from the Offshore and West Coast Transient stocks could be encountered in the proposed project area.

Green et al. (1992) noted that most groups seen during their surveys off Oregon and Washington were likely transients; during those surveys, killer whales were sighted only in shelf waters. Eleven sightings of ~536 individuals were reported off Oregon/Washington during the 2008 SWFSC vessel survey (Barlow 2010). Killer whales were sighted offshore Washington during surveys from August 2004 to September 2008 (Oleson et al. 2009). Keating et al. (2015) analysed cetacean whistles from recordings made during 2000–2012; several killer whale acoustic detections were made offshore

Washington. Killer whales were sighted off Washington in July and September 2012 (Adams et al. 2014). Two of 17 killer whales that stranded in Oregon were confirmed as transient (Stevens et al. 1989 *in* Norman et al. 2004). There are no sightings of killer whales near the proposed survey area in the OBIS database (OBIS (2018). However, killer whales could be encountered during the proposed survey.

Short-finned Pilot Whale (*Globicephala macrorhynchus*)

The short-finned pilot whale is found in tropical, subtropical, and warm temperate waters (Olson 2009); it is seen as far south as ~40ºS and as far north as ~50ºN (Jefferson et al. 2015). Pilot whales are generally nomadic, but may be resident in certain locations, including California and Hawaii (Olson 2009). Short-finned pilot whales were common off southern California (Dohl et al. 1980) until an El Niño event occurred in 1982–1983 (Carretta et al. 2017). Few sightings were made off California/ Oregon/Washington in 1984–1992 (Green et al. 1992; Carretta and Forney 1993; Barlow 1997), and sightings remain rare (Barlow 1997; Buchanan et al. 2001; Barlow 2010). No short-finned pilot whales were seen during surveys off Oregon and Washington in 1989–1990, 1992, 1996, and 2001 (Barlow 2003). A few sightings were made off California during surveys in 1991–2014 (Barlow 2010). Carretta et al. (2017) reported one sighting off Oregon during 1991–2008. Several stranding events in Oregon/southern Washington have been recorded over the past few decades, including in March 1996, June 1998, and August 2002 (Norman et al. 2004). There are no sightings of short-finned whales near the proposed survey area in the OBIS database (OBIS (2018). This species is unlikely to be encountered in the proposed survey area.

Dall's Porpoise (*Phocoenoides dalli*)

Dall's porpoise is found in temperate to subantarctic waters of the North Pacific and adjacent seas (Jefferson et al. 2015). It is widely distributed across the North Pacific over the continental shelf and slope waters, and over deep (>2500 m) oceanic waters (Hall 1979). It is probably the most abundant small cetacean in the North Pacific Ocean, and its abundance changes seasonally, likely in relation to water temperature (Becker 2007).

Off Oregon and Washington, Dall's porpoise is widely distributed over shelf and slope waters, with concentrations near shelf edges, but is also commonly sighted in pelagic offshore waters (Morejohn 1979; Green et al. 1992; Becker et al. 2014; Carretta et al. 2018). Combined results of various surveys out to ~550 km offshore indicate that the distribution and abundance of Dall's porpoise varies between seasons and years. North–south movements are believed to occur between Oregon/Washington and California in response to changing oceanographic conditions, particularly temperature and distribution and abundance of prey (Green et al. 1992, 1993; Mangels and Gerrodette 1994; Barlow 1995; Forney and Barlow 1998; Buchanan et al. 2001). Becker et al. (2014) predicted high densities off southern Oregon throughout the year, with moderate densities to the north. According to predictive density distribution maps, the highest densities off southern Washington and Oregon occur along the 500-m isobath (Menza et al. 2016).

Encounter rates reported by Green et al. (1992) during aerial surveys off Oregon/Washington were highest in fall, lowest during winter, and intermediate during spring and summer. Encounter rates during the summer were similarly high in slope and shelf waters, and somewhat lower in offshore waters (Green et al. 1992). Dall's porpoise was the most abundant species sighted off Oregon/Washington during 1996, 2001, 2005, and 2008 ship surveys up to ~550 km from shore (Barlow 2003, 2010). Oleson et al. (2009) reported 44 sightings of 206 individuals off Washington during surveys form August 2004 to September 2008. Dall's porpoise were seen in the waters off Oregon during summer, fall, and winter surveys in 2011 and 2012 (Adams et al. 2014).

Nineteen Dall's porpoise sightings (144 animals) were made off Washington/Oregon during the June–July 2012 L-DEO Juan de Fuca plate seismic survey; none were in near the proposed survey area (RPS 2012b). There were 16 Dall's porpoise sightings (54 animals) made during the July 2012 L-DEO seismic surveys off southern Washington, northeast of the proposed survey area (RPS 2012a). This species was not sighted during the July 2012 L-DEO seismic survey off Oregon, southeast of the proposed survey area (RPS 2012c). There are five sightings of Dall's porpoises near the proposed survey area in the OBIS database that were made in July and August of 1996, 2001, and 2008 during SWFSC marine mammal surveys (OBIS 2018). Dall's porpoise was the most frequently sighted marine mammal species (5 sightings or 28 animals) during the 2009 ETOMO survey north of the proposed survey area (Holst 2017). This species is likely to be encountered during the proposed seismic survey.

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, Sea of Okhotsk, and Sea of Japan (Jefferson et al. 2015). The worldwide population of northern fur seals has declined substantially from 1.8 million animals in the 1950s (Muto et al. 2018). They were subjected to large-scale harvests on the Pribilof Islands to supply a lucrative fur trade. Two stocks are recognized in U.S. waters: the Eastern North Pacific and the California stocks. The Eastern Pacific stock ranges from southern California during winter to the Pribilof Islands and Bogoslof Island in the Bering Sea during summer (Carretta et al. 2018; Muto et al. 2018). Abundance of the Eastern Pacific Stock has been decreasing at the Pribilof Islands since the 1940s and increasing on Bogoslof Island.

Most northern fur seals are highly migratory. During the breeding season, most of the world's population of northern fur seals occurs on the Pribilof and Bogoslof islands (NMFS 2007). The main breeding season is in July (Gentry 2009). Adult males usually occur onshore from May to August, though some may be present until November; females are usually found ashore from June to November (Muto et al. 2018). Nearly all fur seals from the Pribilof Island rookeries are foraging at sea from fall through late spring. In November, females and pups leave the Pribilof Islands and migrate through the Gulf of Alaska to feeding areas primarily off the coasts of BC, Washington, Oregon, and California before migrating north again to the rookeries in spring (Ream et al. 2005; Pelland et al. 2014). Immature seals can remain in southern foraging areas year-round until they are old enough to mate (NMFS 2007). Adult males migrate only as far south as the Gulf of Alaska or to the west off the Kuril Islands (Kajimura 1984). Pups from the California stock also migrate to Washington, Oregon, and northern California after weaning (Lea et al. 2009).

The northern fur seals spends ~90% of its time at sea, typically in areas of upwelling along the continental slopes and over seamounts (Gentry 1981). The remainder of its life is spent on or near rookery islands or haulouts. While at sea, northern fur seals usually occur singly or in pairs, although larger groups can form in waters rich with prey (Antonelis and Fiscus 1980; Gentry 1981). Northern fur seals dive to relatively shallow depths to feed: 100–200 m for females, and <400 m for males (Gentry 2009). Tagged adult female fur seals were shown to remain within 200 km of the shelf break (Pelland et al. 2014).

Bonnell et al. (1992) noted the presence of northern fur seals year-round off Oregon/Washington, with the greatest numbers (87%) occurring in January–May. Northern fur seals were seen as far out from the coast as 185 km, and numbers increased with distance from land; they were 5–6 times more abundant in offshore waters than over the shelf or slope (Bonnell et al. 1992). The highest densities were seen in the Columbia River plume (~46°N) and in deep offshore waters (>2000 m) off central and southern

Oregon (Bonnell et al. 1992). The waters off Washington are a known foraging area for adult females, and concentrations of fur seals were also reported to occur near Cape Blanco, Oregon, at ~42.8°N (Pelland et al. 2014). Tagged adult fur seals were tracked from the Pribilof Islands to the waters off Washington/Oregon/California, with recorded movement throughout the proposed project area (Pelland et al. 2014).

Thirty-one northern fur seal sightings (63 animals) were made off Washington/Oregon during the June–July 2012 L-DEO Juan de Fuca plate seismic survey north of the proposed survey area (RPS 2012b). There were six sightings (6 animals) made during the July 2012 L-DEO seismic surveys off southern Washington, northeast of the proposed survey area (RPS 2012a). This species was not sighted during the July 2012 L-DEO seismic survey off Oregon, southeast of the proposed survey area (RPS 2012c). There are no sightings of northern fur seals near the proposed survey area in the OBIS database (OBIS 2018). Northern fur seals could be observed in the proposed survey area, though adult males are generally ashore during the reproductive season from May to August, and adult females are generally ashore from June through November.

Northern Elephant Seal (*Mirounga angustirostris*)

The northern elephant seal breeds in California and Baja California, primarily on offshore islands, from Cedros off the west coast of Baja California, north to the Farallons in Central California (Stewart et al. 1994). Pupping has also been observed at Shell Island (~43.3°N) off southern Oregon, suggesting a range expansion (Bonnell et al. 1992; Hodder et al. 1998).

Adult elephant seals engage in two long northward migrations per year, one following the breeding season, and another following the annual molt (Stewart and DeLong 1995). Between the two foraging periods, they return to land to molt, with females returning earlier than males (March–April vs. July–August). After the molt, adults then return to their northern feeding areas until the next winter breeding season. Breeding occurs from December to March (Stewart and Huber 1993). Females arrive in late December or January and give birth within ~1 week of their arrival. Pups are weaned after just 27 days and are abandoned by their mothers. Juvenile elephant seals typically leave the rookeries in April or May and head north, traveling an average of 900–1000 km. Hindell (2009) noted that traveling likely takes place at depths >200 m. Most elephant seals return to their natal rookeries when they start breeding (Huber et al. 1991).

When not at their breeding rookeries, adults feed at sea far from the rookeries. Males may feed as far north as the eastern Aleutian Islands and the Gulf of Alaska, whereas females feed south of 45ºN (Le Boeuf et al. 1993; Stewart and Huber 1993). Adult male elephant seals migrate north via the California current to the Gulf of Alaska during foraging trips, and could potentially be passing through the area off Washington in May and August (migrating to and from molting periods) and November and February (migrating to and from breeding periods), but likely their presence there is transient and short-lived. Adult females and juveniles forage in the California current off California to BC (Le Boeuf et al. 1986, 1993, 2000). Bonnell et al. (1992) reported that northern elephant seals were distributed equally in shelf, slope, and offshore waters during surveys conducted off Oregon and Washington, as far as 150 km from shore, in waters >2000 m deep. Telemetry data indicate that they range much farther offshore than that (Stewart and DeLong 1995).

Off Washington, most elephant seal sightings at sea were made during June, July, and September; off Oregon, sightings were recorded from November through May (Bonnell et al. 1992). Several seals were seen off Oregon during summer, fall, and winter surveys in 2011 and 2012 (Adams et al. 2014). Northern elephant seals were also taken as bycatch off Oregon in the west coast groundfish fishery during

2002–2009 (Jannot et al. 2011). Northern elephant seals were sighted five times (5 animals) during the July 2012 L-DEO seismic surveys off southern Washington, northeast of the proposed survey area (RPS 2012a). This species was not sighted during the July 2012 L-DEO seismic survey off Oregon, southeast of the proposed survey area (RPS 2012c), or off Washington/Oregon during the June–July 2012 L-DEO Juan de Fuca plate seismic survey that included the proposed survey area (RPS 2012b). There are several sightings of northern elephant seals in the OBIS database near the proposed survey area and surrounding waters (OBIS 2018). One northern elephant seal was sighted during the 2009 ETOMO survey north of the proposed survey area (Holst 2017). This species could be encountered during the proposed seismic survey.

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 Northeast Pacific Ocean in summer 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, Dall’s porpoise could be more susceptible to exposure to sound levels that exceed the PTS threshold than other marine mammals, as it 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 Northeast Pacific Ocean. As called for in § VI, this section includes a description of the rationale for the estimates of the potential numbers of harassment "takes" during the planned surveys, as well Level A "takes", 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 (§ 3.6.4.3, § 3.7.4.3, § 3.8.4.3), the effects of sounds from airguns could include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and at least in theory, temporary or permanent hearing impairment, or non-auditory physical or physiological effects (Richardson et al. 1995; Gordon et al. 2004; Nowacek et al. 2007; Southall et al. 2007; Erbe 2012; Peng et al. 2015; Erbe et al. 2016; Kunc et al. 2016; National Academies of Sciences, Engineering, and Medicine 2017; Weilgart 2017). In some cases, a behavioral response to a sound can reduce the overall exposure to that sound (e.g., Finneran et al. 2015; Wensveen et al. 2015).

Permanent hearing impairment (PTS), in the unlikely event that it occurred, would constitute injury, 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 surveys would result in any cases of temporary or permanent hearing impairment, or any significant non-auditory physical or physiological effects. If marine mammals encounter a survey while it is underway, some behavioral disturbance could result, but this would be localized and short-term.

Tolerance

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

Masking

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

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 Austrlian waters 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. 20171). 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 µ$Pa^2 \cdot s$ (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 2007b).

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 µ$Pa^2 \cdot s$, decreased at $CSEL_{10\text{-min}}$ >127 dB re 1 µ$Pa^2 \cdot s$, and whales were nearly silent at $CSEL_{10\text{-min}}$ >160 dB re 1 µ$Pa^2 \cdot s$. 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 (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 2001 seismic program, as well as a subsequent survey in 2010, involved a comprehensive combination of real-time monitoring and mitigation measures designed to avoid exposing western gray whales to received SPLs of sound above about 163 dB re 1 μPa_{rms} (Johnson et al. 2007; Nowacek et al. 2012, 2013b). The lack of strong avoidance or other strong responses was presumably in part a result of the mitigation measures; effects probably would have been more significant without such intensive mitigation efforts. Gray whales in British Columbia exposed to seismic survey sound levels up to ~170 dB re 1 μPa did not appear to be strongly disturbed (Bain and Williams 2006). The few whales that were observed moved away from the airguns but toward deeper water where sound levels were said to be higher due to propagation effects (Bain and Williams 2006).

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

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

Data on short-term reactions by cetaceans to impulsive noises are not necessarily indicative of long-term or biologically significant effects. It is not known whether impulsive sounds affect reproductive rate or distribution and habitat use in subsequent days or years. However, gray whales have continued to migrate annually along the west coast of North America with substantial increases in the population over recent years, despite intermittent seismic exploration (and much ship traffic) in that area for decades. The western Pacific gray whale population did not seem affected by a seismic survey in its feeding ground during a previous year. 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 to 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 to 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 to 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 to 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. (2013b) reported decreased densities and reduced acoustic detections of harbor porpoise in response to a seismic survey in Moray Firth, Scotland, at ranges of 5–10 km (SPLs of 165–172 dB re 1 µPa, SELs of 145–151 dB µPa^2·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. 2013b).

Kastelein et al. (2013a) reported that a harbor porpoise showed no response to an impulse sound with an SEL below 65 dB, but a 50% brief response rate was noted at an SEL of 92 dB and an SPL of 122 dB re 1 µPa$_{0\text{-peak}}$. However, Kastelein et al. (2012c) reported a 50% detection threshold at a SEL of 60 dB to a similar impulse sound; this difference is likely attributable to the different transducers used during the two studies (Kastelein et al. 2013c). Van Beest et al. (2018) exposed five harbor porpoise to a single 10 in^3 airgun for 1 min at 2–3 s intervals at ranges of 420–690 m and levels of 135–147 dB µPa^2·s. One porpoise moved away from the sound source but returned to natural movment 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, Gomez et al. (2016) recommended that a response/no response dichotomous approach be used when assessing behavioral reactions.

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

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

Recent studies have also shown that the SEL necessary to elicit TTS can depend substantially on frequency, with susceptibility to TTS increasing with increasing frequency above 3 kHz (Finneran and Schlundt 2010, 2011; Finneran 2012). When beluga whales were exposed to fatiguing noise with sound levels of 165 dB re 1 μPa for durations of 1–30 min at frequencies of 11.2–90 kHz, the highest TTS with the longest recovery time was produced by the lower frequencies (11.2 and 22.5 kHz); TTS effects also gradually increased with prolonged exposure time (Popov et al. 2013). Additionally, Popov et al. (2015) demonstrated that the impacts of TTS include deterioration of signal discrimination. Kastelein et al. (2015b, 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 as airgun pulses, the thresholds use dual metrics of cumulative SEL (SEL_{cum} over 24 hours) and Peak SPL_{flat}. Onset of PTS is assumed to be 15 dB higher when considering SEL_{cum} and 6 dB higher when considering SPL_{flat}. Different thresholds are provided for the various hearing groups, including LF cetaceans (e.g., baleen whales), MF cetaceans (e.g., most delphinids), HF cetaceans (e.g., porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW).

Nowacek et al. (2013a) concluded that current scientific data indicate that seismic airguns have a low probability of directly harming marine life, except at close range. Several aspects of the planned monitoring and mitigation measures for this project are designed to detect marine mammals occurring near the airgun array, and to avoid exposing them to sound pulses that might, at least in theory, cause hearing impairment. 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 strandings along Ireland's coast increased with seismic surveys operating offshore (McGeady et al. 2106). However, there is no definitive evidence that any of these effects occur even for marine mammals in close proximity to large arrays of airguns. Morell et al. (2017) examined the inner ears of long-finned pilot whales after a mass stranding in Scotland and reported damage to the cochlea compatible with over-exposure from underwater noise; however, no seismic surveys were occurring in the vicinity in the days leading up to the stranding.

Since 1991, there have been 67 Marine Mammal Unusual Mortality Events (UME) in the U.S. (NMFS 2018c). 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 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 survey. 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 § 3.6.4.3, § 3.7.4.3, and § 3.8.4.3 and Appendix E of the PEIS.

There has been some recent attention given to the effects of MBES on marine mammals, as a result of a report issued in September 2013 by an IWC independent scientific review panel linking the operation of an MBES to a mass stranding of melon-headed whales (*Peponocephala electra*; Southall et al. 2013) off Madagascar. During May–June 2008, ~100 melon-headed whales entered and stranded in the Loza Lagoon system in northwest Madagascar at the same time that a 12-kHz MBES survey was being conducted ~65 km away off the coast. In conducting a retrospective review of available information on the event, an independent scientific review panel concluded that the Kongsberg EM 120 MBES was the most plausible behavioral trigger for the animals initially entering the lagoon system and eventually stranding. The independent scientific review panel, however, identified that an unequivocal conclusion on causality of the event was not possible because of the lack of information about the event and a number of potentially contributing factors. Additionally, the independent review panel report indicated that this incident was likely the result of a complicated confluence of environmental, social, and other factors that have a very low probability of occurring again in the future, but recommended that the potential be considered in environmental planning. It should be noted that this event is the first known marine mammal mass stranding closely associated with the operation of an MBES. Leading scientific experts knowledgeable about MBES expressed concerns about the independent scientific review panel analyses and findings (Bernstein 2013).

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

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

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 active sonars (e.g., Miller et al. 2012; Sivle et al. 2012; Samarra and Miller 2016), mid-frequency active sonars (e.g., Tyack et al. 2011; Melcón et al. 2012; Miller et al. 2012, 2014b; Sivle et al. 2012, 2015; DeRuiter et al. 2013a,b; Goldbogen et al. 2013; Antunes et al. 2014; Baird et al. 2014; Kastelein et al. 2012d, 2015a; Wensveen et al. 2015; Friedlaender et al. 2016; Isojunno et al. 2016; Samarra and Miller 2016), and high-frequency active sonars (Kastelein et al. 2015c,d). 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 grey 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. 2016).

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 R/V *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 to 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 has been shown to elicit responses in harbor porpoise (Dyndo et al. 2015). Increased levels of ship noise have been shown to affect foraging by porpoise (Teilmann et al. 2015; Wisniewska et al. 2018); Wisniewska et al. (2018) suggest that a decrease in foraging success could have long-term fitness consequences.

Ship noise, through masking, can reduce the effective communication distance of a marine mammal if the frequency of the sound source is close to that used by the animal, and if the sound is present for a significant fraction of time (e.g., Richardson et al. 1995; Clark et al. 2009; Jensen et al. 2009; Gervaise et al. 2012; Hatch et al. 2012; Rice et al. 2014; Dunlop 2015; Erbe et al. 2016; Jones et al. 2017; Putland et al. 2017). 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). 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).

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

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). Pirotta et al. (2015) noted that the physical presence of vessels, not just ship noise, disturbed the foraging activity of bottlenose dolphins. 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. Information on vessel strikes is reviewed in § 3.6.4.4 and § 3.8.4.4 of the PEIS. Wiley et al. (2016) concluded that reducing ship speed is one of the most reliable ways to avoid ship strikes. However, McKenna et al. (2015) noted the potential absence of lateral avoidance demonstrated by blue whales and perhaps other large whale species to vessels (McKenna et al. 2015). The PEIS concluded that the risk of collision of seismic vessels or towed/deployed equipment with marine mammals exists but is extremely unlikely, because of the relatively slow operating speed (typically 7–9 km/h) of the vessel during seismic operations, and the generally straight-line movement of the seismic vessel. There has been no history of marine mammal vessel strikes with R/V *Langseth*, or its predecessor, R/V *Maurice Ewing* over the last two decades.

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

All takes would be anticipated to be Level B "takes by harassment" as described in § I, involving temporary changes in behavior. As required by NMFS, Level A takes have been requested; given the small EZs and the proposed mitigation measures to be applied, injurious takes would not be expected for most species. (However, as noted earlier and in the PEIS, there is no specific information demonstrating that injurious Level A "takes" would occur even in the absence of the planned mitigation measures.) In the sections below, we describe methods to estimate the number of potential exposures to Level B and Level A sound levels and present estimates of the numbers of marine mammals that could be affected during the proposed seismic surveys. The estimates are based on consideration of the number of marine mammals that could be disturbed appreciably by the seismic surveys in the Northeast Pacific Ocean. 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 (numbers per unit area) of marine mammals expected to occur in the area in the absence of a seismic survey. To the extent that marine mammals tend to move away from seismic sources before the sound level reaches the criterion level and tend not to approach an operating airgun array, these estimates likely overestimate the numbers actually exposed to the specified level of sound. The overestimation is expected to be particularly large when dealing with the higher sound level criteria, i.e., the PTS thresholds (Level A), as animals are more likely to move away when received levels are higher. Likewise, they are less likely to approach within the PTS threshold radii than they are to approach within the considerably larger ≥160 dB (Level B) radius.

Extensive systematic aircraft- and ship-based surveys have been conducted for marine mammals in offshore waters of Oregon and Washington (e.g., Bonnell et al. 1992; Green et al. 1992, 1993; Barlow 1997, 2003; Barlow and Taylor 2001; Calambokidis and Barlow 2004; Forney 2007; Barlow and Forney 2007; Barlow 2010, 2016). The most comprehensive and recent density data available for cetacean species in slope and offshore waters of Oregon and Washington are from the 1991, 1993, 1996, 2001, 2005, 2008, and 2014 NMFS/SWFSC ship surveys as synthesized by Barlow (2016). The surveys were conducted up to ~556 km from shore from June or August to November or December.

Systematic, offshore, at-sea survey data for pinnipeds are more limited. The most comprehensive studies are reported by Bonnell et al. (1992) based on systematic aerial surveys conducted in 1989–1990. USN (2010) calculated density estimates for pinnipeds off Washington at different times of the year using information on breeding and migration, population estimates from shore counts, and areas used by the different species while at sea.

Oceanographic conditions, including occasional El Niño and La Niña events, influence the distribution and numbers of marine mammals present in the North Pacific Ocean, resulting in considerable year-to-year variation in the distribution and abundance of many marine mammal species (Forney and Barlow 1998; Buchanan et al. 2001; Ferrero et al. 2002; Philbrick et al. 2003; Escorza-Treviño 2009). Thus, for some species, the densities derived from past surveys may not be representative of the densities that would be encountered during the proposed seismic surveys. Thus, cetacean densities used here were derived from the pooled results of the 1991–2014 surveys off Oregon and Washington, taken directly from Barlow (2016). The approach used here is based on the best available data.

Table 5 gives the densities for each species of cetacean reported off Oregon and Washington. The densities from NMFS/SWFSC vessel-based surveys have been corrected by the authors for both trackline detection probability and availability bias. Trackline detection probability bias is associated with diminishing sightability with increasing lateral distance from the trackline [$f(0)$]. Availability bias refers to the fact that there is less-than-100% probability of sighting an animal that is present along the survey trackline, and it is measured by $g(0)$. Table 6 also includes mean density information for the two pinniped species that occur in the survey area. Densities were calculated using the methods in USN (2010) with updated population sizes based on Carretta et al. (2018) and Muto et al. (2018), when appropriate.

The estimated numbers of individuals potentially exposed are based on the 160-dB re 1 μPa_{rms} criterion for all marine mammals. It is assumed that marine mammals exposed to airgun sounds that strong could change their behavior sufficiently to be considered “taken by harassment”. Table 6 shows the density estimates calculated as described above and the estimates of the number of marine mammals that potentially could be exposed to ≥160 dB re 1 μPa_{rms} during the proposed seismic surveys if no animals moved away from the survey vessel (see Appendix B for more details). The *Requested Take Authorization* is given in the right-most column. The calculated exposures that are based on these densities are best estimates for the proposed surveys for any time of the year and are based on data collected during the same time of the year (late summer to early fall) as the proposed surveys.

TABLE 5. Densities of marine mammals off Oregon and Washington. Cetacean densities are from Barlow (2016) and are based on ship transect surveys conducted up to 556 km offshore in 1991, 1993, 1996, 2001, 2005, 2007, and 2014. Pinniped densities are from shore counts and calculations in USN (2010). Cetacean densities from Barlow (2016) are corrected for *f*(0) and *g*(0). Species listed as "Endangered" under the ESA are in italics.

Species	Density (#/1000 km^2)	Mean group size	Source
Mysticetes			
North Pacific right whale	*0*	–	–
Humpback whale	*2.1*	*2*	*Barlow (2016)*
Minke whale	1.3	1	Barlow (2016)
Sei whale	*0.4*	*2*	*Barlow (2016)*
Fin whale	*4.2*	*2*	*Barlow (2016)*
Blue whale	*0.3*	*1*	*Barlow (2016)*
Odontocetes			
Sperm whale	*0.9*	*6*	*Barlow (2016)*
Pygmy/dwarf sperm whale	1.6	1	Barlow (2016)
Cuvier's beaked whale	2.8	2	Barlow (2016)
Baird's beaked whale	10.7	8	Barlow (2016)
Mesoplodont (unidentified) [2]	1.2	2	Barlow (2016)
Bottlenose dolphin	0	13	Barlow (2016)
Striped dolphin	7.7	109	Barlow (2016)
Short-beaked common dolphin	69.2	286	Barlow (2016)
Pacific white-sided dolphin	40.7	62	Barlow (2016)
Northern right-whale dolphin	46.4	63	Barlow (2016)
Risso's dolphin	11.8	28	Barlow (2016)
False killer whale	0	5[3]	–
Killer whale	0.9	8	Barlow (2016)
Short-finned pilot whale	0.2	18	Barlow (2016)
Dall's porpoise	54.4	4	Barlow (2016)
Pinnipeds			
Northern fur seal	81.85	–	USN (2010)[4]
Northern elephant seal	83.14	–	USN (2010)[5]

Note: – mean group size not provided in source and species not included in Barlow (2016).
1 Population size in USN (2010) was updated based on Calambokidis et al. (2014).
2 Includes Blainville's, Stejneger's, and Hubbs' beaked whales.
3 Mean group size from Mobley et al. (2000).
4 Population size in USN (2010) was updated based on Carretta et al. (2018) and Muto et al. (2018).
5 Population size in USN (2010) was updated based on Carretta et al. (2018) with the number of adult males proportionally adjusted.

For all species, including those for which densities were not available or expected to be low, we have included a *Requested Take Authorization* for at least the mean group size for species where that number was higher than the calculated take. It should be noted that the exposure estimates assume that the proposed surveys would be completed; in fact, the calculated takes ***have been increased by 25%*** (see below). Thus, the following estimates of the numbers of marine mammals potentially exposed to sounds ≥160 dB re 1 μPa_{rms} are precautionary and probably overestimate the actual numbers of marine mammals that could be involved.

TABLE 6. Densities and estimates of the possible numbers of individual marine mammals that could be exposed to Level B and Level A thresholds for various hearing groups during the proposed seismic surveys in the Northeast Pacific Ocean during summer 2019. Species in italics are listed under the ESA as *endangered*.

Species	Estimated Density[1] (#/1000 km^2)	Calculated Take, NMFS Daily Method[2]		Requested Take Authorization[5]	% of Pop.[6]
		Level A[3]	Level B[4]		
LF Cetaceans					
North Pacific right whale	*0*	*0*	*0*	*0*	*0*
Humpback whale	*2.1*	*3*	*37*	*40*	*2.1*
Minke whale	1.3	2	23	25	3.9
Sei whale	*0.4*	*1*	*7*	*8*	*1.5*
Fin whale	*4.2*	*6*	*74*	*80*	*0.9*
Blue whale	*0.3*	*0*	*6*	*6*	*0.4*
MF Cetaceans					
Sperm whale	*0.9*	*0*	*17*	*17*	*0.9*
Cuvier's beaked whale	2.8	0	53	53	1.6
Baird's beaked whale	10.7	1	201	202	7.5
Mesoplodont (unidentified)[7]	1.2	0	23		0.8
Blainville's beaked whale				4	
Hubbs' beaked whale				4	
Stejneger's beaked whale				15	
Bottlenose dolphin	0	0	0	**13**	0.7
Striped dolphin	7.7	1	145	146	0.5
Short-beaked common dolphin	69.2	7	1299	1306	0.1
Pacific white-sided dolphin	40.7	4	764	768	2.9
Northern right-whale dolphin	46.4	5	871	876	3.3
Risso's dolphin	11.8	1	222	223	3.5
False killer whale	0	0	0	**5**	N.A.
Killer whale[8]	0.9	0	17	17	3.5
Short-finned pilot whale	0.2	0	4	**18**[9]	2.2
HF Cetaceans					
Pygmy/dwarf sperm whale	1.6	2	29	31	0.8
Dall's porpoise	54.4	53	974	1027	4.0
Otariids					
Northern fur seal	83.4	8	1536	1544	0.2
Phocids					
Northern elephant seal	83.1	22	1547	1569	0.9

1 See text for density sources.
2 Take using NMFS daily method for calculating ensonified area: estimated density multiplied by the daily ensonified area on one selected day (187 km for 2-D survey; 200 km for 3-D survey) multiplied by the number of survey days (3 days for the 2-D survey; 16 days for the 3-D survey), times 1.25; see text for more details.
3 Level A takes if there were no mitigation measures.
4 Level B takes, based on the 160-dB criterion, excluding exposures to sound levels equivalent to PTS thresholds.
5 Requested take authorization is Level A plus Level B calculated takes, used by NMFS as proxy for number of individuals exposed; increased by mean group size (in bold) from Barlow (2016).
6 Requested take authorization expressed as % of population off California/Oregon/Washington, Eastern North Pacific, or U.S. stock (see Table 4); N.A. = population size not available.
7 Includes Blainville's, Stejneger's, and/or Hubbs' beaked whales (Barlow 2016). Take authorization is requested for 4 Blainville's, 4 Hubb's, and 15 Stejneger's beaked whales.
8 Includes individuals from the offshore and West Coast transient stocks.
9 Increased to mean group size (2.2% of population).

Consideration should be given to the hypothesis that delphinids are less responsive to airgun sounds than are mysticetes, as referenced in both the PEIS and in this document. The 160-dB (rms) criterion currently applied by NMFS, on which the Level B estimates are based, was developed primarily using data from gray and bowhead whales. The estimates of "takes by harassment" of delphinids are thus considered precautionary. Available data suggest that the current use of a 160-dB criterion could be improved upon, as behavioral response might not occur for some percentage of marine mammals exposed to received levels >160 dB, whereas other individuals or groups might respond in a manner considered as "taken" to sound levels <160 dB (NMFS 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 (187 km for the 2-survey; 200 km for the 3-D 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 were then multiplied by the number of survey days (16 days for the 3-D survey; 3 days for the 2-D survey) increased by 25%; this is equivalent to adding an additional 25% to the proposed line km (see Appendix C for more details). The approach assumes that no marine mammals would move away or toward the trackline in response to increasing sound levels before the levels reach the specific thresholds as R/V *Langseth* approaches.

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 it 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 proposed survey area is 4852 cetaceans and 3113 pinnipeds (Table 6). That total includes 151 marine mammals listed as ***endangered*** or ***threatened*** under the ESA: 80 fin whales, 40 humpback whales, 17 sperm whales, 8 sei whales, and 6 blue whales representing 0.9%, 2.1%, 0.9%, 1.5%, and 0.4% of their regional populations, respectively. In addition, 278 beaked whales could be exposed. Most (69%) of the cetaceans potentially exposed would be delphinids.

Conclusions

The proposed seismic surveys would involve towing a 36-airgun array (2-D survey) or an 18-airgun array (3-D survey), which introduce pulsed sounds into the ocean. Routine vessel operations, other than the proposed seismic operations, are conventionally assumed not to affect marine mammals sufficiently to constitute "taking". In §3.6.7, §3.7.7, and §3.8.7, the PEIS concluded that 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, and pinniped species and that Level A effects were highly unlikely. Nonetheless, 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 recently NSF-funded seismic surveys, NMFS issued small numbers of Level A take for some marine mammal species for the remote possibility of low-level physiological effects; however, NMFS expected neither mortality nor serious injury of marine mammals to result from the surveys (NMFS 2015, 2016c,d, 2017a,b).

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. However, the relatively short-term exposures are unlikely to result in any long-term negative consequences for the individuals or their populations. Therefore, no significant impacts on marine mammals would be anticipated from the proposed activities.

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

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.

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

IX. ANTICIPATED IMPACT ON HABITAT

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

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

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

X. Anticipated Impact of Loss or Modification of Habitat on Marine Mammals

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

The proposed activity is not expected to have any habitat-related effects that could cause significant or long-term consequences for individual marine mammals or their populations, because operations would be limited in duration. However, a small minority of the marine mammals that are present near the proposed activity may be temporarily displaced as much as a few kilometers by the planned 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 area. To minimize the likelihood that impacts would occur to the species and stocks, airgun operations would be conducted in accordance with the MMPA and the ESA, including obtaining permission for incidental harassment or incidental 'take' of marine mammals and other endangered species and following requirements issued in the IHA and associated Incidental Take Statement (ITS). The proposed activities would take place in International Waters of the Northeast Pacific Ocean.

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

Planning Phase

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

1. *Energy Source*—Part of the considerations for the proposed marine seismic surveys was to evaluate whether the research objectives could be met with a smaller energy source. The scientific objectives for the proposed surveys could not be met using a smaller source. During the 2-D survey, a strong reflection source is important in order to fully image the bottom of the magma chamber. For the 3-D survey, the proposed source is reduced from the full 36-airgun array to 18 airguns, which is needed to create a detailed 3-D geologic image at depth.

2. *Survey Location and Timing*—The PIs worked with NSF to consider potential times to carry out the proposed surveys, 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 R/V *Langseth*. Few marine mammals are expected to occur in the proposed offshore survey area. Although baleen whales are likely more common in the region during the summer, most are expected to occur closer to shore.
3. *Mitigation Zones*—The proposed 3-D survey would acquire data with the 18-airgun array at a maximum tow depth of 10 m, and the 2-D survey would employ 36 airguns with a tow depth of up to 12 m. L-DEO model results are used to determine the 160-dB_{rms} radius for the 18- and 36-airgun arrays and 40-in^3 (mitigation) airgun in deep water (>1000 m) down to a maximum water depth of 2000 m. Table 1 shows the distances at which the 160-dB re $1\mu Pa_{rms}$ sound levels are expected to be received for the airgun arrays and the 40-in^3 (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). Enforcement of mitigation zones via power and shut downs would be implemented during operations, as noted below.

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).

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 the 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 would take place in the Northeast Pacific Ocean, and no activities would take place in traditional Arctic subsistence hunting area.

XIII. Monitoring and Reporting Plan

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

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

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

Vessel-based Visual Monitoring

Observations by PSOs would take place during daytime airgun operations and nighttime start ups of the airguns. Airgun operations would be 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 R/V *Langseth* is underway without seismic operations, such as during transits. PSOs would also watch for any potential impacts of the acoustic sources on fish.

During seismic operations, five PSOs would be based aboard R/V *Langseth*. All PSOs would be appointed by L-DEO with NMFS concurrence. During the majority of seismic operations, two PSOs would monitor for marine mammals 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.

R/V *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 (if on duty) when vocalizing cetaceans are detected. It is only useful when marine mammals call, but it can be effective either by day or by night, and does not depend on good visibility. It would be monitored in real time so that the visual observers can be advised when cetaceans are detected.

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

The towed hydrophones would ideally be monitored 24 h per day while at the seismic survey areas during airgun operations, and during most periods when R/V *Langseth* is underway while the airguns are not operating. 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
3. 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 surveys were calculated based on modeling by L-DEO for both the exclusion zones (EZ) for Level A takes and safety zones (160 dB re 1µPa_{rms}) for Level B takes. Received sound levels have been predicted by L-DEO's model (Diebold et al. 2010, provided as Appendix H in the PEIS) as a function of distance from the 36-airgun array, the 18-airgun array, and for a single 1900LL 40-in^3 airgun, which would be used during power downs. The models used a 10-m tow depth for the 18-airgun array to be used during the 3-D survey, and a 12-m tow depth for the 36-airgun array to be used during the 2-D survey and the 40-in^3 mitigation airgun. 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 water, 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 water, 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.

The proposed surveys would acquire data with the 36-airgun array at a maximum tow depth of 12 m (2-D survey) and an 18-airgun array at a tow depth of 10 m (3-D survey). For deep water (>1000 m), we use the deep-water radii obtained from L-DEO model results down to a maximum water depth of 2000 m for the 36-airgun (Fig. A-1) and 18-airgun (Fig. A-2) array. Measurements have not been reported for a 40-in^3 airgun; thus, 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).

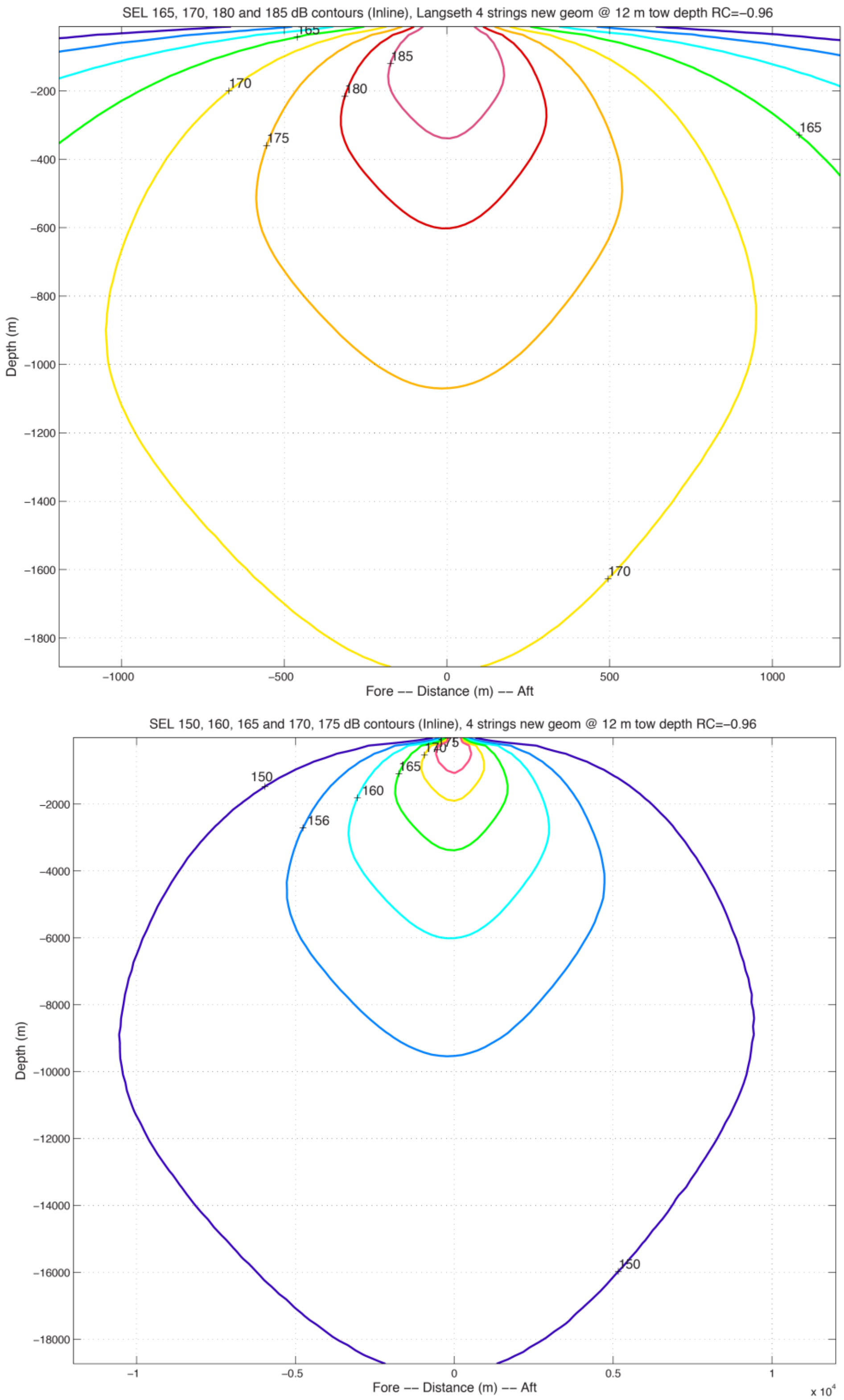

FIGURE A-1. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array at a 12-m tow depth planned for use during the 2-D survey in the Northeast Pacific Ocean. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.

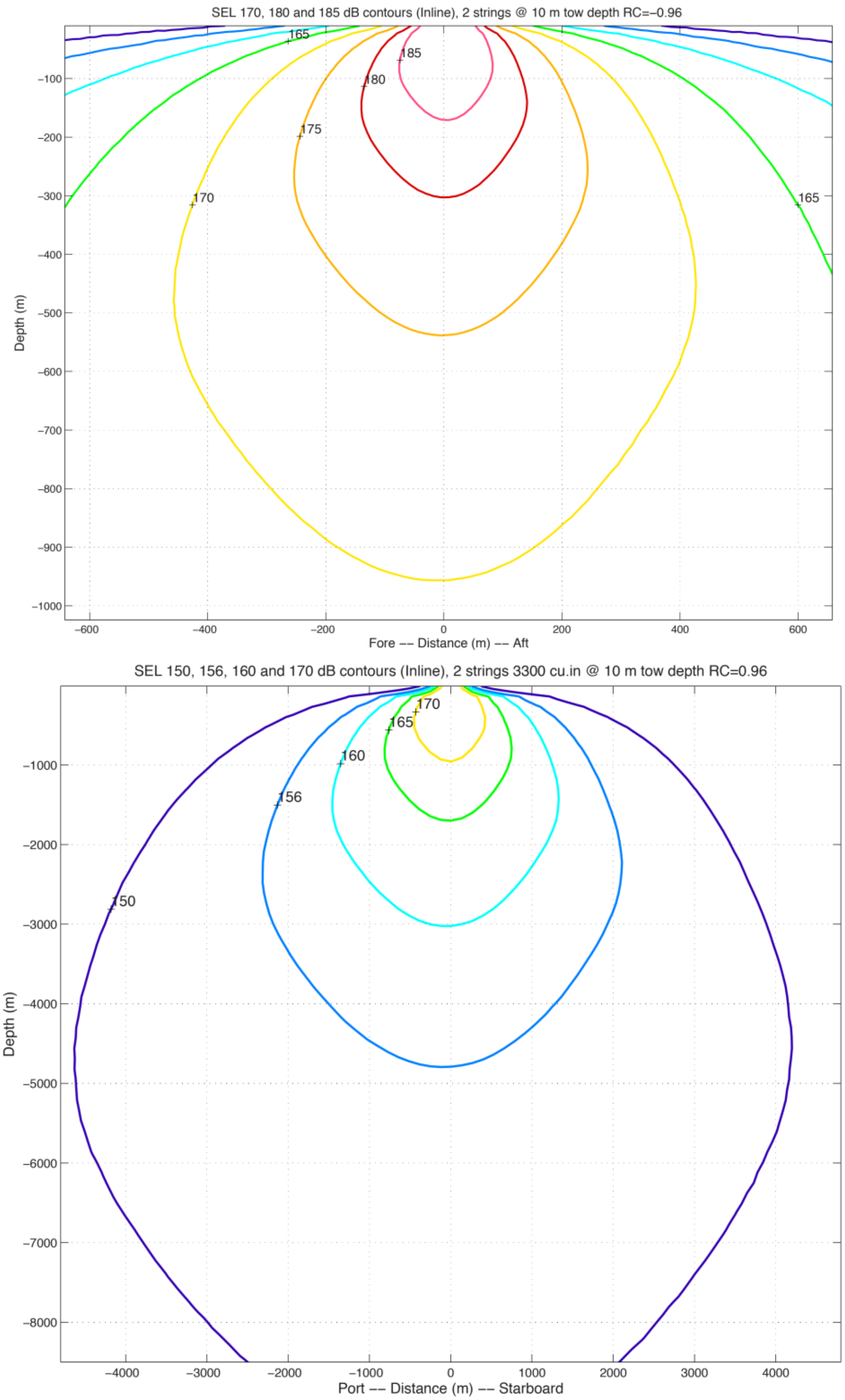

FIGURE A-2. Modeled deep-water received sound exposure levels (SELs) from the 18-airgun array at a 10-m tow depth planned for use during the 3-D survey in the Northeast Pacific Ocean. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.

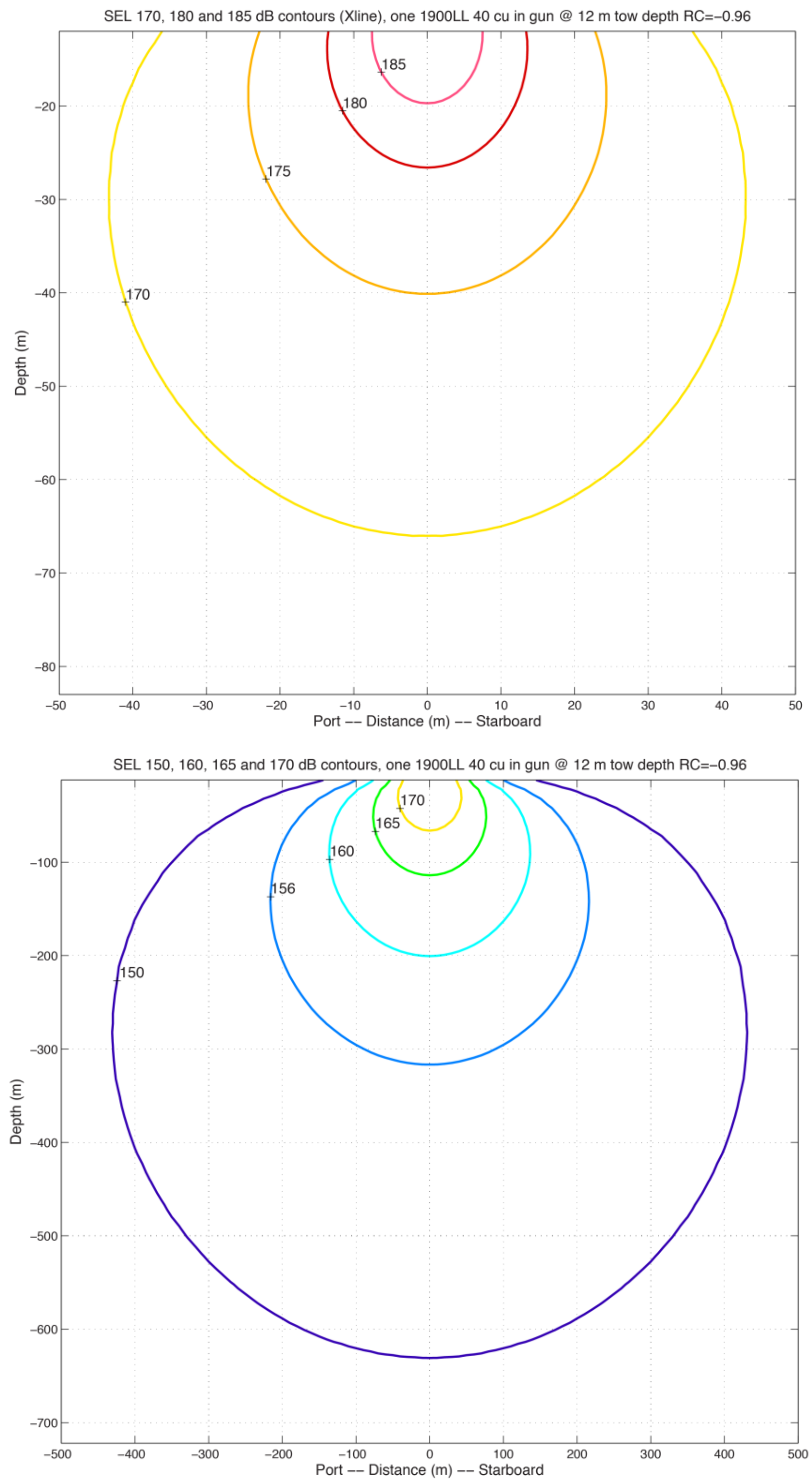

FIGURE A-3. Modeled deep-water received SELs from a single 40-in^3 airgun (towed at a 12-m depth), which is planned for use as a mitigation airgun during the proposed surveys in the Northeast Pacific Ocean. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB 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 18- and 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 R/V *Langseth* sources in a coastal/shelf environment from the Cascadia Margin off Washington suggests that predicted (modeled) radii (using an approach similar to that used here) for R/V *Langseth* sources were 2–3 times larger than measured in shallow water, so in fact, as expected, were very conservative (Crone et al. 2014). Similarly, data collected by Crone et al. (2017) during a survey off New Jersey in 2014 and 2015 confirmed that *in situ* measurements and estimates of the 160- and 180-dB distances collected by R/V *Langseth* hydrophone streamer were 2–3 times smaller than the predicted operational mitigation radii. In fact, five separate comparisons conducted of the L-DEO model with *in situ* received levels[1] 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, 2018). 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, 2018), 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 R/V *Langseth* array is derived from calculating the modified farfield signature. The farfield signature is often used as a theoretical representation of the source level. To compute the farfield signature, the source level is estimated at a large distance directly below the array (e.g., 9 km), and this level is back projected mathematically to a notional distance of 1 m from the array's geometrical center. However, it has been recognized that the source level from the theoretical farfield signature is never physically achieved at the source when the source is an array of multiple airguns separated in space (Tolstoy et al. 2009). Near the source (at short ranges, distances <1 km), the pulses of sound pressure from each individual airgun in the source array do not stack constructively as they do for the theoretical farfield signature. The pulses from the different airguns spread out in time such that the source levels observed or modeled are the result of the summation of pulses from a few airguns, not the full array

[1] 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 surveys in the Northeast Pacific Ocean. The 160-dB criterion applies to all hearing groups of marine mammals.

Source and Volume	Maximum Tow Depth (m)	Water Depth (m)	Predicted distances (in m) to the 160-dB Received Sound Level[1]
Single Bolt airgun, 40 in^3	12	>1000 m	431
2 strings, 18 airguns, 3300 in^3	10	>1000 m	3758
4 strings, 36 airguns, 6600 in^3	12	>1000 m	6733

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

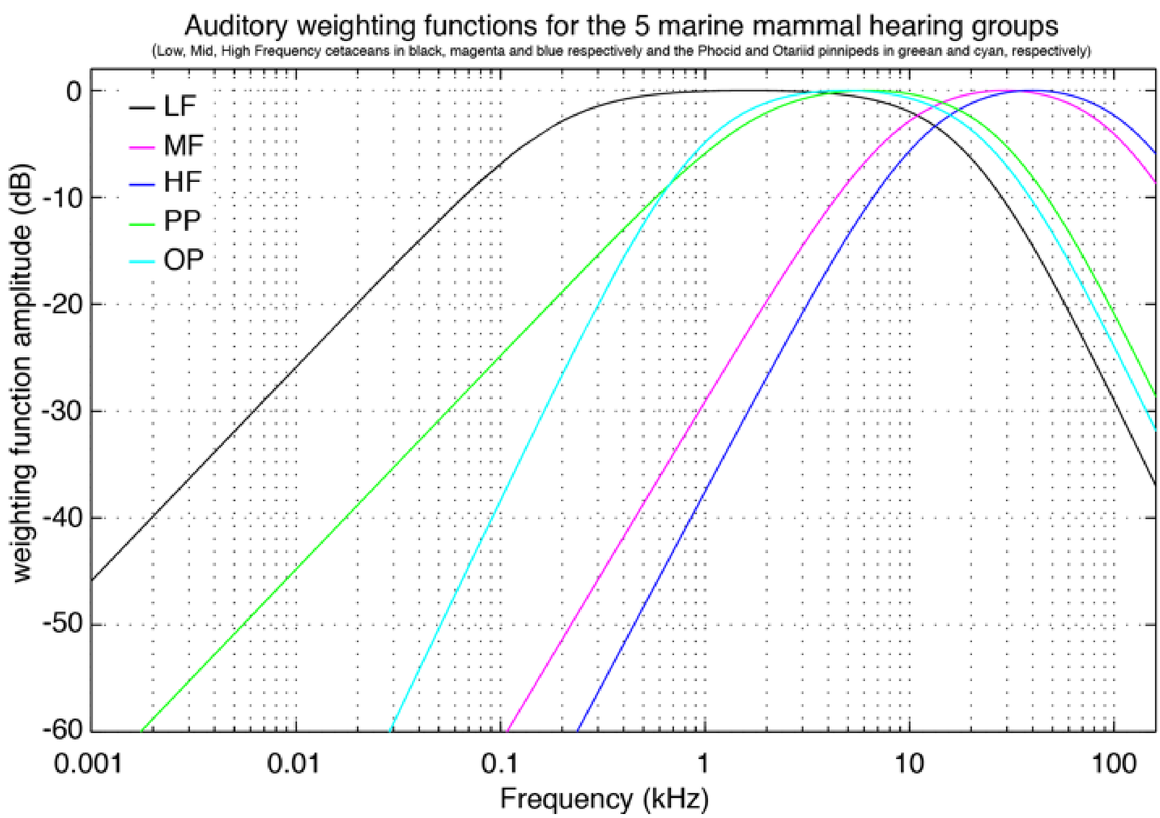

FIGURE A-4. Auditory weighting functions for five marine mammal hearing groups from the NMFS Technical Guidance Spreadsheet.

(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 2.16067 m/s and a 1/Repetition rate of 17.3557 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; a source velocity of 2.315 m/s and a 1/Repetition rate of 16.1987 s were used for the 18-airgun array and the 40-in^3 airgun.

For the LF cetaceans, we estimated a new adjustment value by computing the distance from the geometrical center of the source to where the 183 dB SEL_{cum} isopleth is the largest. We first 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 and assumes a propagation of $20\log_{10}$(Radial distance).

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; an adjustment factor of -12.91 dB was calculated for low-frequency cetaceans. Figure A-5 shows the impact of weighting functions by hearing group on the spectral density of the airgun array farfield signature. 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. Figures A-6–A-8 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure A-9 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.

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)	315.569	246.468	8033.2	246.468	28.441
Modified Farfield SEL	232.982	232.835	233.098	232.835	232.079
Radial Distance (m) (with weighting function)	71.375	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.

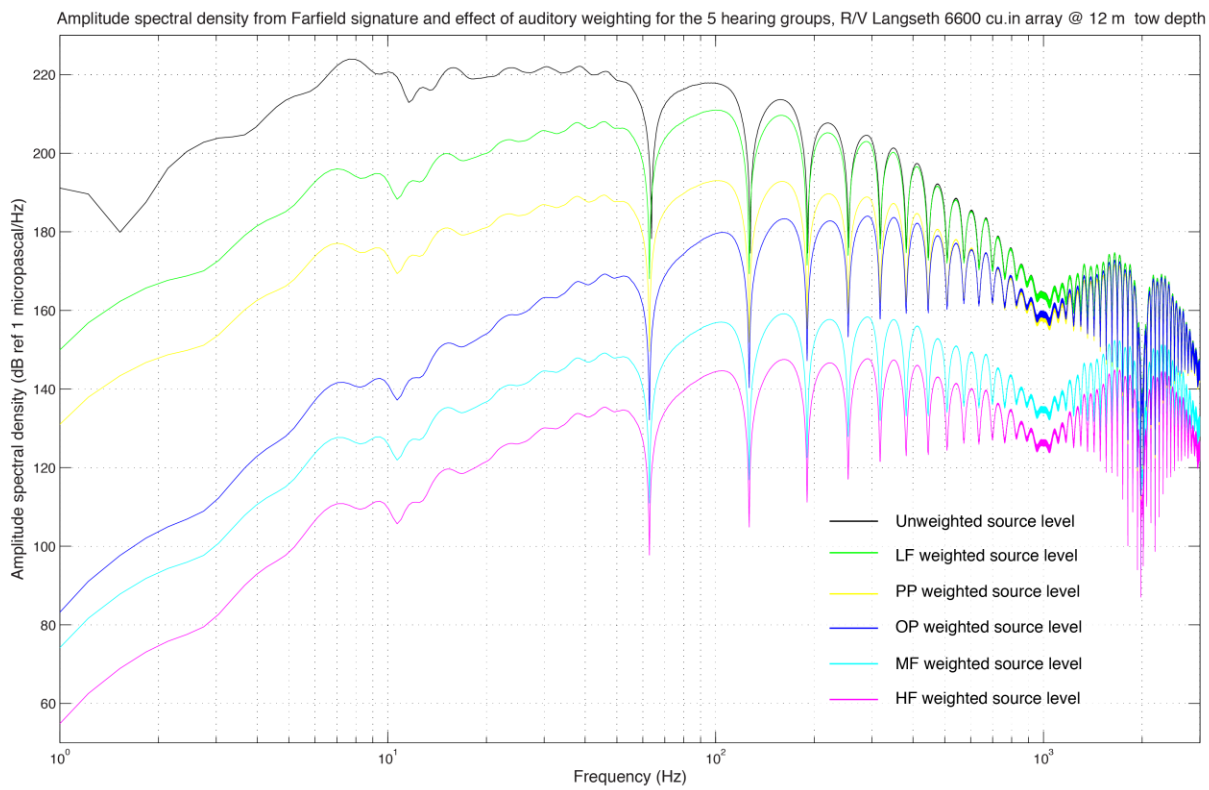

FIGURE A-5. Modeled amplitude spectral density of the 36-airgun array farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral levels are 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.

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 (PI: Arnulf)
PROJECT/SOURCE INFORMATION (Please include any assumptions)	source : 4 string 36 element 6600 cu.in of the R/V Langseth at a 12m towed depth. Shot inteval of 37.5 m. Source velocity of 4.2 knots
PROJECT CONTACT	

STEP 2: WEIGHTING FACTOR ADJUSTMENT — Specify if relying on source-specific WFA, alternative weighting/dB adjustment, or if using default value

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

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

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

*** BROADBAND Sources: Cannot use WFA higher than maximum applicable frequency (See GRAY tab for more information on WFA applicable frequencies)**

STEP 3: SOURCE-SPECIFIC INFORMATION

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

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

SEL_{cum}

Source Velocity (meters/second)	2.16067	4.2 knots
1/Repetition rate^ (seconds)	17.3557	37.5 m /2.16067

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

^Time between onset of successive pulses.

Modified farfield SEL	**232.9819**	**232.8352**	**233.0978**	**232.8352**	**232.079**
Source Factor	**1.14485E+22**	**1.10682E+22**	**1.17581E+22**	**1.10682E+22**	**9.29946E+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)	**426.9**	**0**	**1.3**	**13.9**	**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).

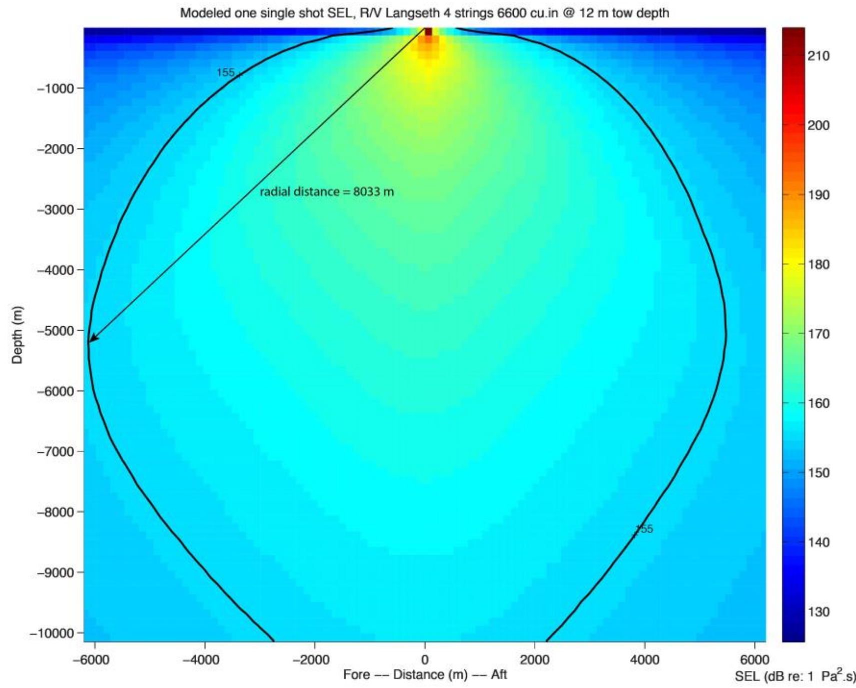

FIGURE A-6. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 155-dB SEL isopleth (8033 m). Radial distance allows us to determine the modified farfield SEL using a propagation of $20\log_{10}$(radial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

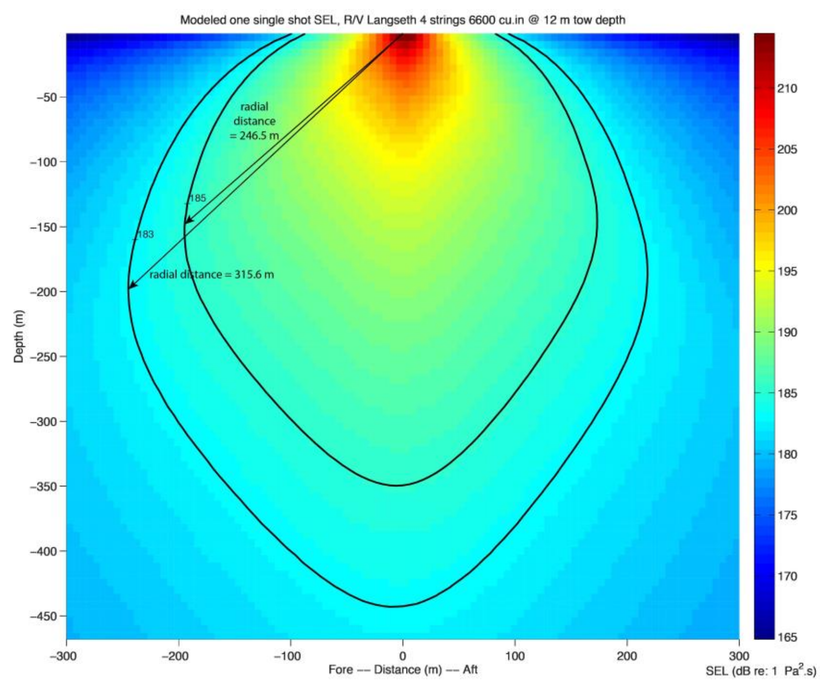

FIGURE A-7. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 183–185-dB SEL isopleths (315.6 and 246.5 m, respectively).

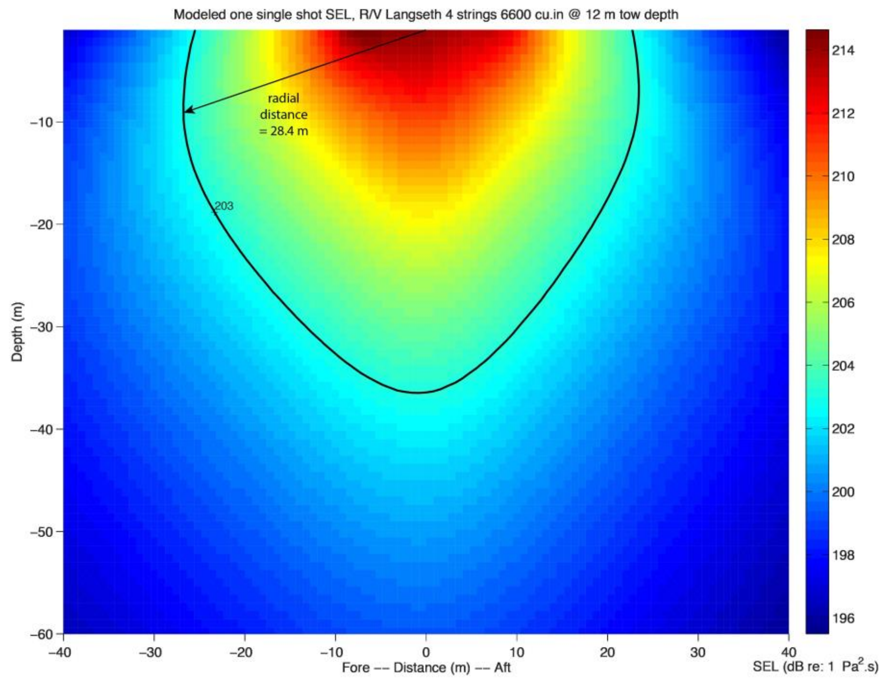

FIGURE A-8. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 203-dB SEL isopleth (28.4 m).

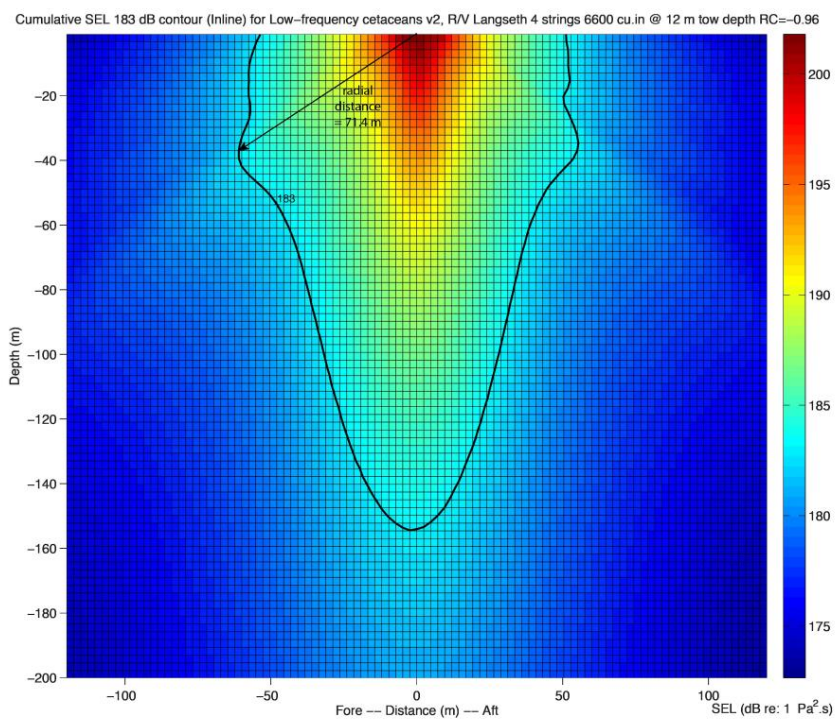

FIGURE A-9. Modeled received sound exposure levels (SELs) from the 36-airgun array at a 12-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one 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 2-D survey in the Northeast Pacific Ocean.

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
Peak Threshold	**219**	**230**	**202**	**218**	**232**
PTS Peak Isopleth (Radius) to Threshold (m)	38.9	13.6	268.3	43.7	10.6

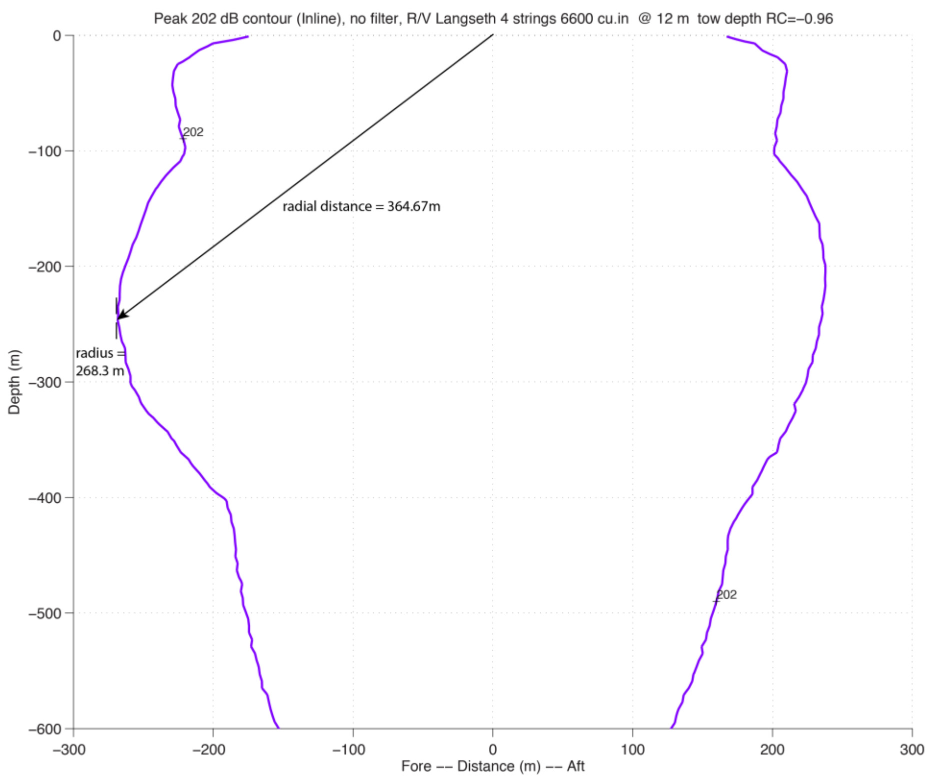

FIGURE A-10. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distance to the 202-dB Peak isopleths.

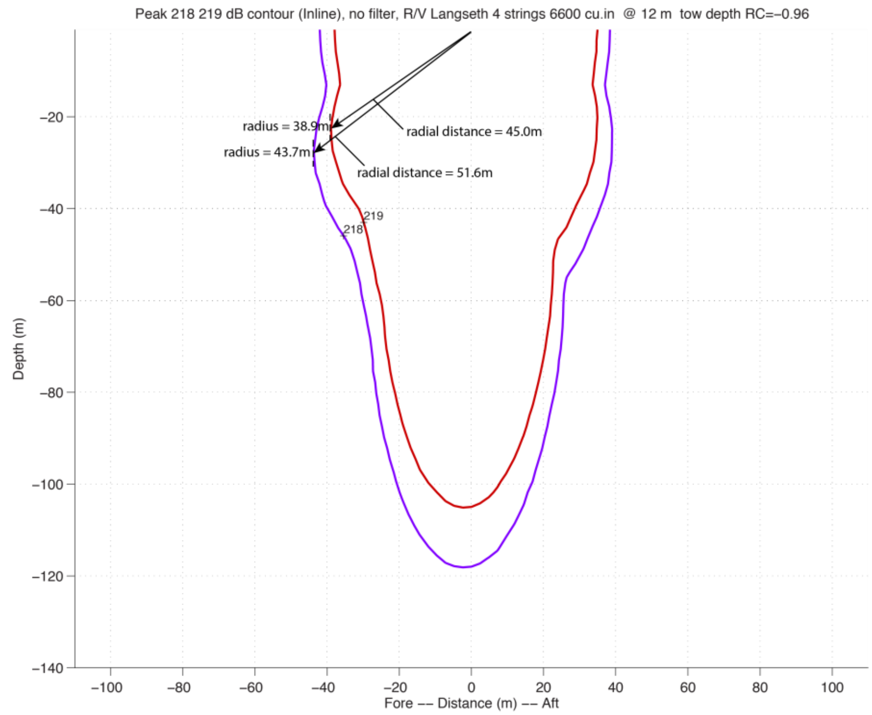

FIGURE A-11. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distances to the 218- and 219-dB Peak isopleths.

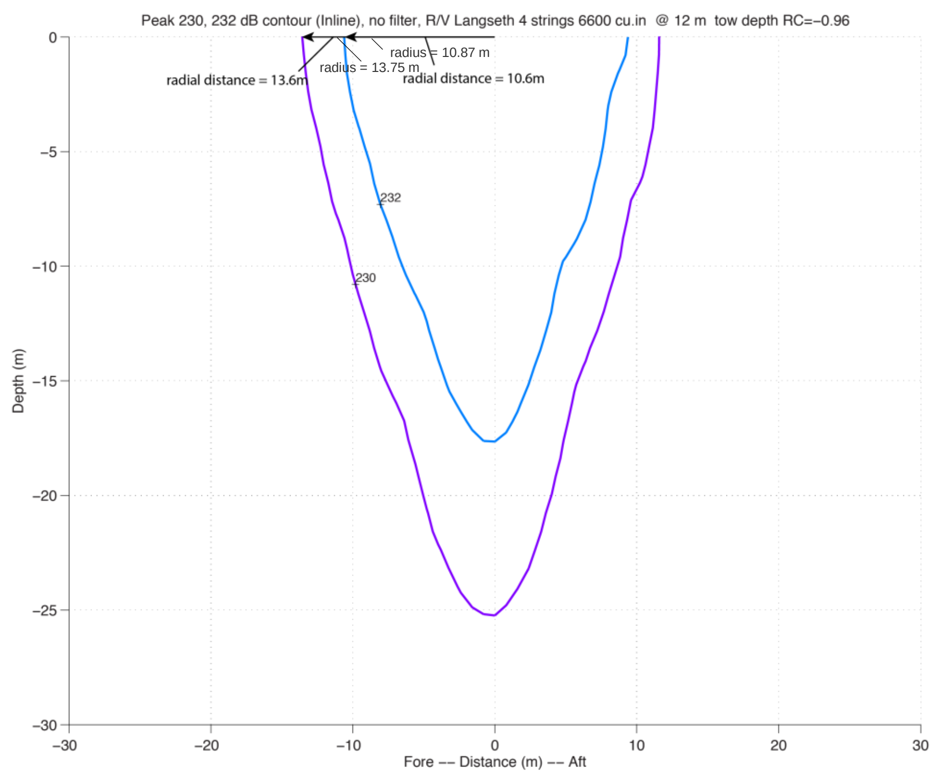

FIGURE A-12. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distances to the 230- and 232-dB Peak isopleths.

For the 18-airgun array, the results for single shot SEL source level modeling are shown in Table A-5; an adjustment factor of -13.82 dB was calculated for low-frequency cetaceans. The weighting function calculations, thresholds for SEL_{cum}, and the distances to the PTS thresholds for the 18-airgun array are shown in Table A-6. Figure A-13 shows the impact of weighting functions by hearing group on the spectral density of the airgun array farfield signature. 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 18-airgun array, as well as the distances to the PTS thresholds, are shown in Table A-7. Figures A-17–A-19 show the modeled received sound levels to the Peak SPL_{flat} thresholds, for a single shot. A summary of the Level A threshold distances for the 18- and 36-airgun arrays are shown in Table A-8.

For the single 40 in^3 mitigation airgun, the results for single shot SEL source level modeling are shown in Table A-9. Figure A-20 shows the impact of weighting functions by hearing group on the spectral density of the airgun farfield signature. 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-10. Figures A-21–A-22 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure A-23 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-11. Figures A-24–A-25 show the modeled received sound levels to the Peak SPL_{flat} thresholds, for a single shot.

Table A-12 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-5. Results for single SEL source level modeling for the 18-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)	147.580	116.495	3826.4	116.495	15.969
Modified Farfield SEL	226.381	226.326	226.656	226.326	227.066
Radial Distance (m) (with weighting function)	29.897	N/A	N/A	N/A	N/A
Adjustment (dB)	-13.82	N/A	N/A	N/A	N/A

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

TABLE A-6. Results for single shot SEL source level modeling for the 18-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 (PI: Arnulf)
PROJECT/SOURCE INFORMATION Please include any assumptions	source: 2 string 18 element 3300 cu.in of the R/V Langseth at a 10-m tow depth. Shot interval of 37.5 m. Source velocity of 4.5 knots.
PROJECT CONTACT	

STEP 2: WEIGHTING FACTOR ADJUSTMENT — Specify if relying on source-specific WFA, alternative weighting/dB adjustment, or if using default value

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

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

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

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	(4.5 knots)
1/Repetition rate^ (seconds)	16	37.5/2.315

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

^Time between onset of successive pulses.

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
Modified farfield SEL	226	226	227	226	227
Source Factor	2.68E+21	2.65E+21	2.86E+21	2.65E+21	3.14E+21
SEL_{cum} Threshold	183	185	155	185	203
PTS SEL_{cum} Isopleth to threshold (meters)	75.6	0	0.3	2.9	0

WEIGHTING FUNCTION CALCULATIONS

Weighting Function Parameters	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
a	1	2	2	1	2
b	2	2	2	2	2
f_1	0	9	12	2	1
f_2	19	110	140	30	25
C	0	1	1	1	1
Adjustment (dB)†	-14	-57	-66	-26	-33

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-13).

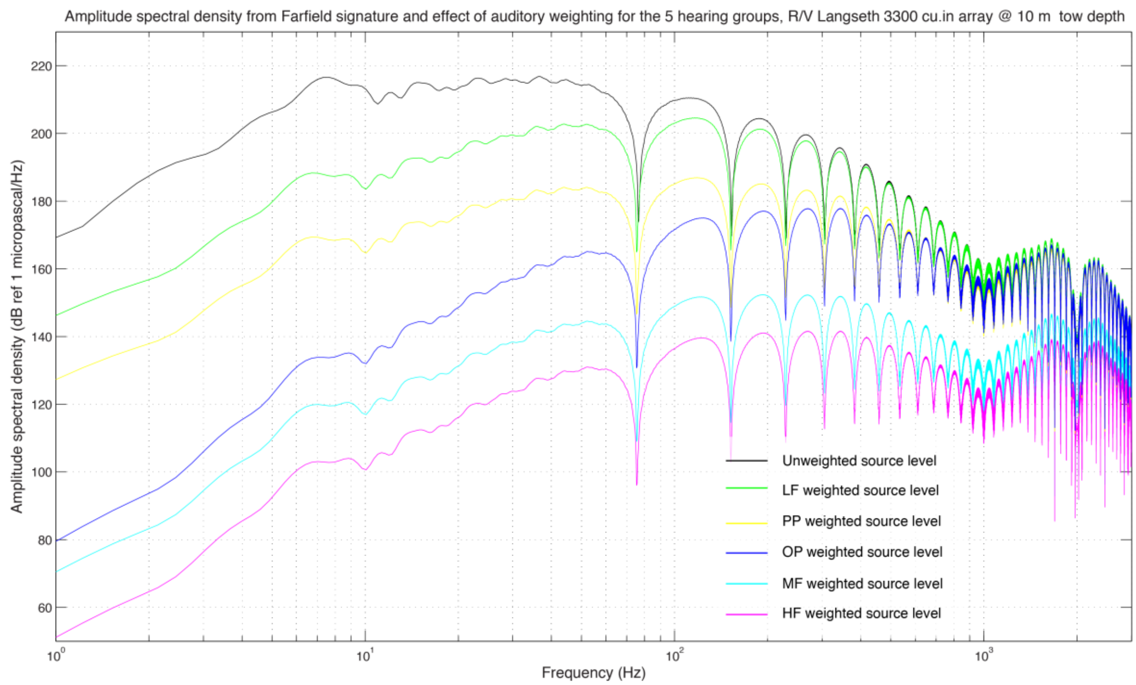

FIGURE A-13. Modeled amplitude spectral density of the 18-airgun array farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral levels are used to calculate the difference between the unweighted and weighted source level at each frequency.

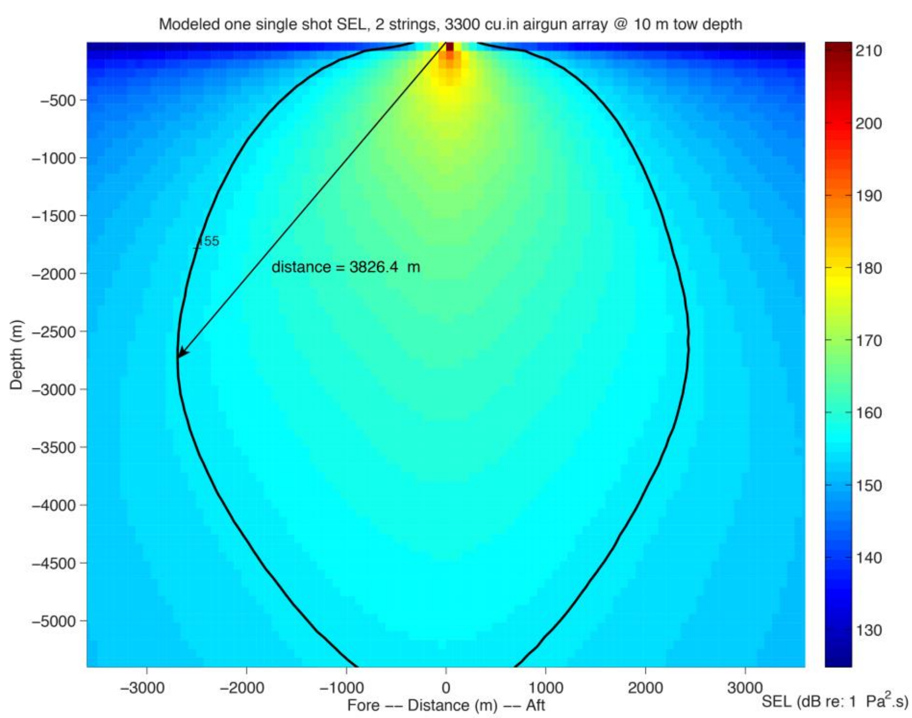

FIGURE A-14. Modeled received sound levels (SELs) in deep water from the 18-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 155-dB SEL isopleth (3826 m). Radial distance allows us to determine the modified farfield SEL using a propagation of $20\log_{10}$(radial distance).

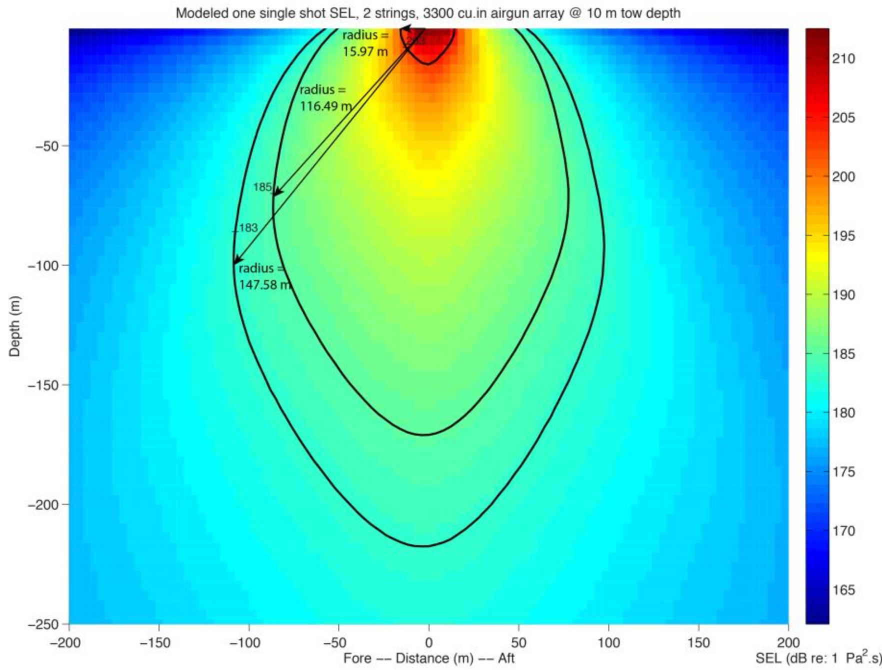

FIGURE A-15. Modeled received sound levels (SELs) in deep water from the 18-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 183-, 185-, and 203-dB SEL isopleths.

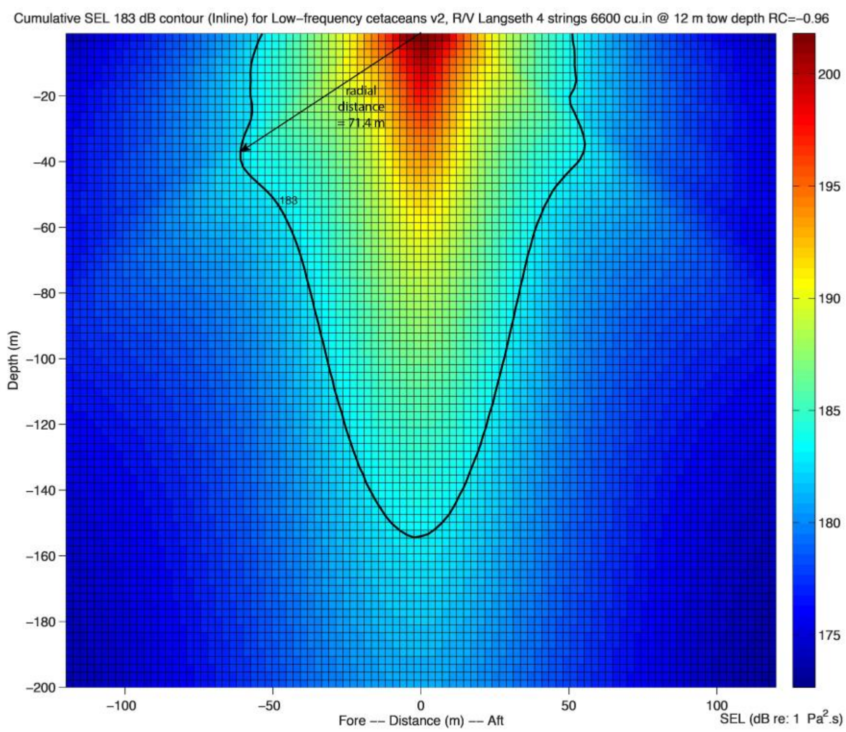

FIGURE A-16. Modeled received sound exposure levels (SELs) from the 18-airgun array at a 10-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one shot. The difference in radial distances between Fig. A-15 (11.3 m) and this figure (4.96 m) allows us to estimate the adjustment in dB.

TABLE A-7. 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 18-airgun array during the proposed 3-D survey in the Northeast Pacific Ocean.

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
Peak Threshold	**219**	**230**	**202**	**218**	**232**
PTS Peak Isopleth (Radius) to Threshold (m)	23.15	11.8	118.7	25.13	9.91

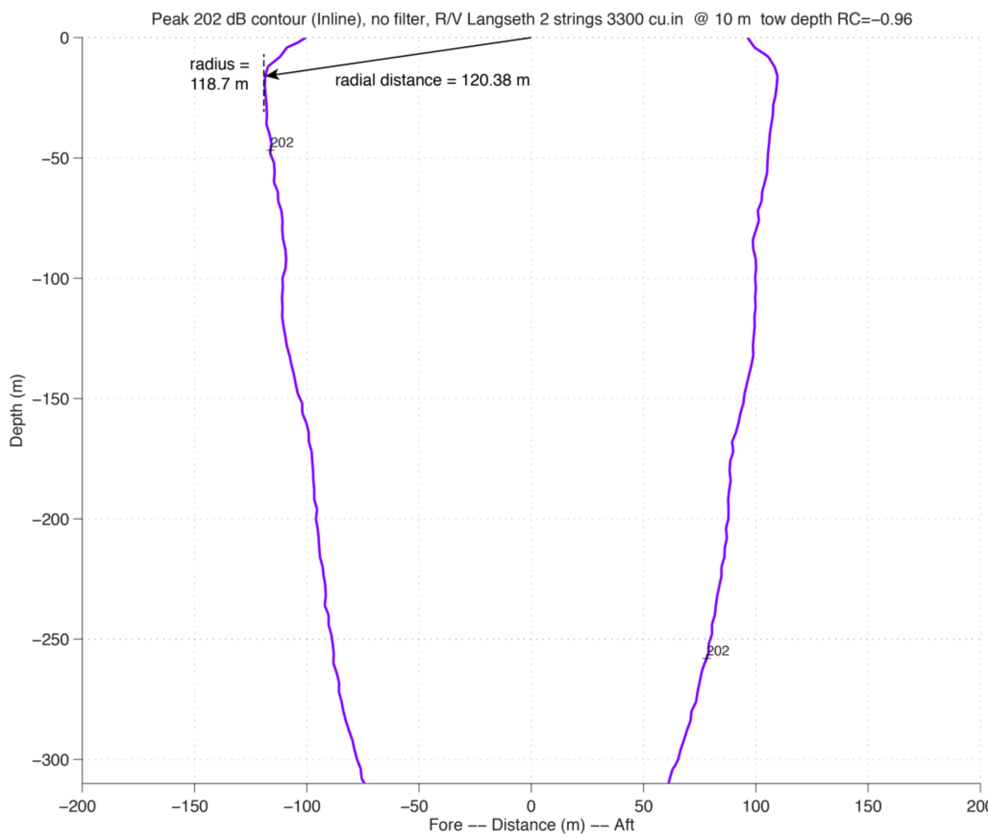

FIGURE A-17. Modeled deep-water received Peak SPL from the 18-airgun array at a 10-m tow depth. The plot provides the distance to the 202-dB Peak isopleths.

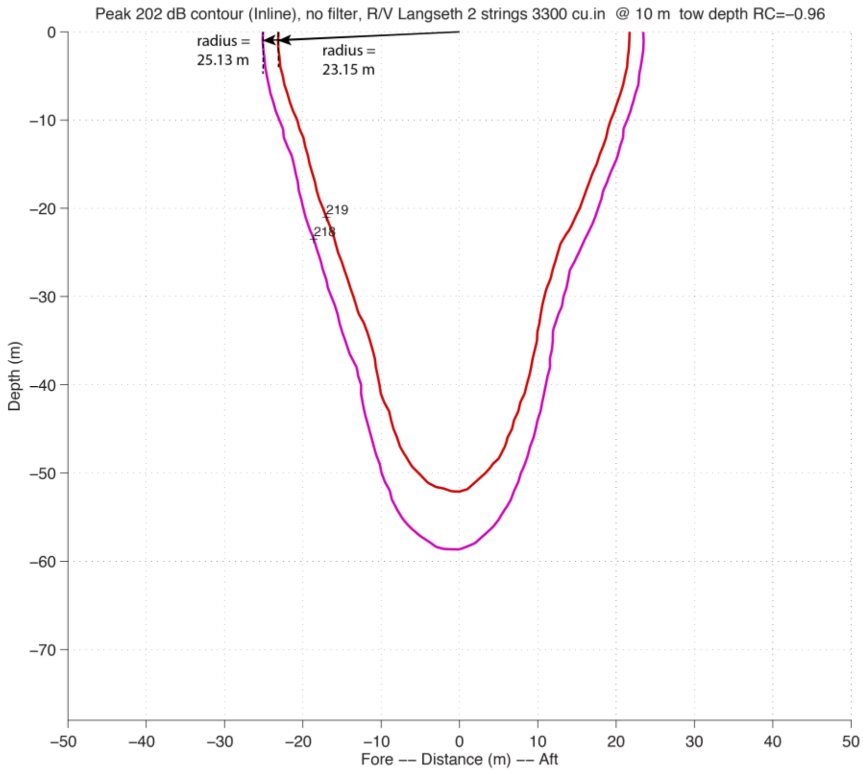

FIGURE A-18. Modeled deep-water received Peak SPL from the 18-airgun array at a 10-m tow depth. The plot provides the distances to the 218- and 219-dB Peak isopleths.

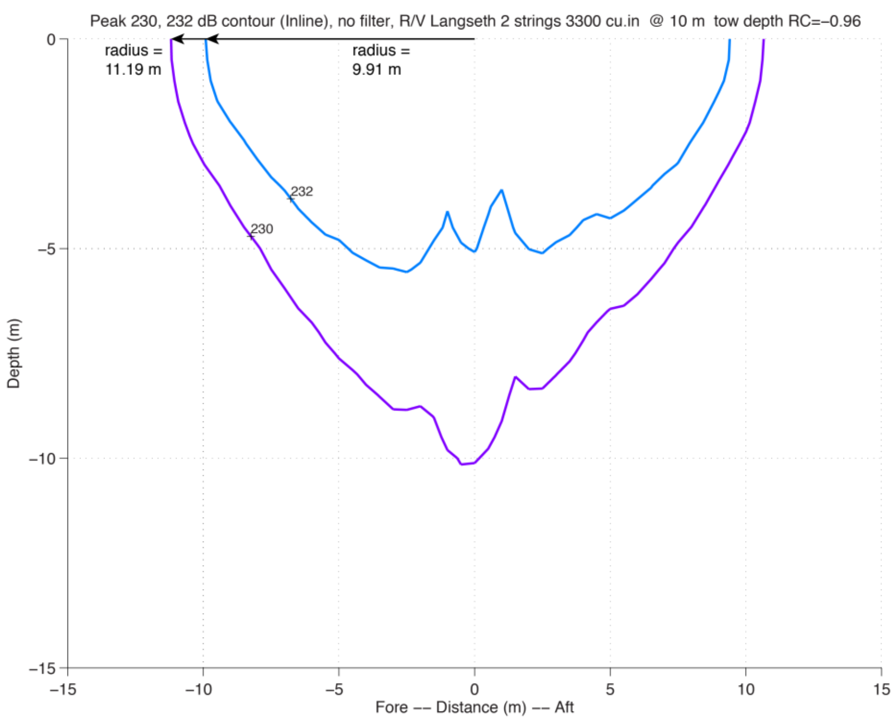

FIGURE A-19. Modeled deep-water received Peak SPL from the 18-airgun array at a 10-m tow depth. The plot provides the distances to the 230- and 232-dB Peak isopleths.

TABLE A-8. Level A threshold distances for different marine mammal hearing groups. As required by NMFS (2016, 2018), the largest distance (in bold) of the dual criteria (SEL_{cum} or Peak SPL_{flat}) was used to calculate takes and Level A threshold distances.

	Level A Threshold Distances (m) for Various Hearing Groups				
	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
18-airgun array; 3300 in^3					
PTS SEL_{cum}	**75.6**	0	0.3	2.9	0
PTS Peak	23.2	**11.2**	**118.7**	**25.1**	**9.9**
36-airgun array; 6600 in^3					
PTS SEL_{cum}	**426.9**	0	1.3	13.9	0
PTS Peak	38.9	**13.6**	**268.3**	**43.7**	**10.6**

TABLE A-9. 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.

TABLE A-10. Results for single shot SEL source level modeling for the single 40 in^3 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 (Arnulf)
PROJECT/SOURCE INFORMATION	one 40 cu.in 1900LL airgun @ a 12 m tow depth - speed of 4.5 knots and shot interval of 37.5 m
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.

*** BROADBAND Sources: Cannot use WFA higher than maximum applicable frequency (See GRAY tab for more information on WFA applicable frequencies)**

STEP 3: SOURCE-SPECIFIC INFORMATION

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

NOTE: LDEO modeling relies on Method F2

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

SEL_{cum}

Source Velocity (meters/second)	2.315	4.5 knots
1/Repetition rate^ (seconds)	16.1987	37.5/2.21211

†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	1.22911E+19	1.20226E+19	1.6878E+19	1.20226E+19	1.0603E+19

RESULTANT ISOPLETHS*

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

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
SEL_{cum} Threshold	183	185	155	185	203
PTS SEL_{cum} Isopleth to threshold (meters)	**0.5**	**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*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-20).

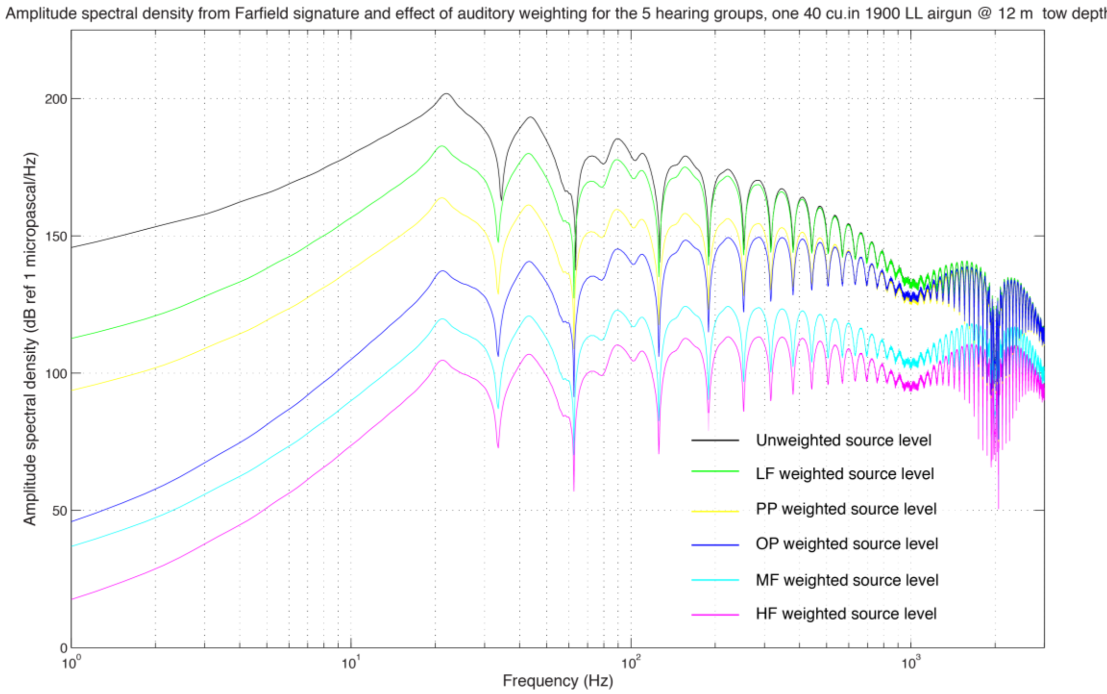

FIGURE A-20. Modeled amplitude spectral density of the 40 in^3 airgun farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP).

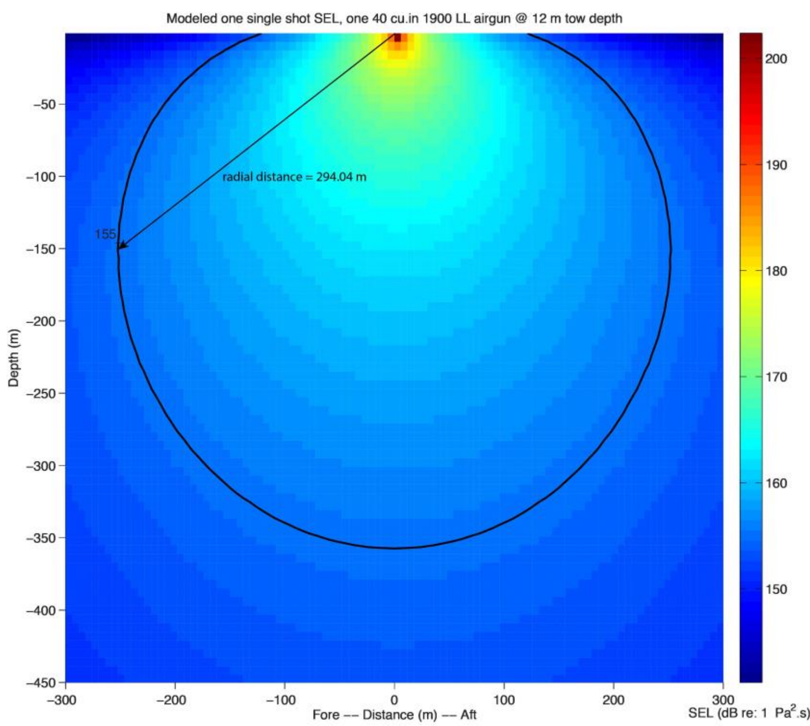

FIGURE A-21. Modeled received sound levels (SELs) in deep water from one 40-in^3 airgun at a 12-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (294.04 m).

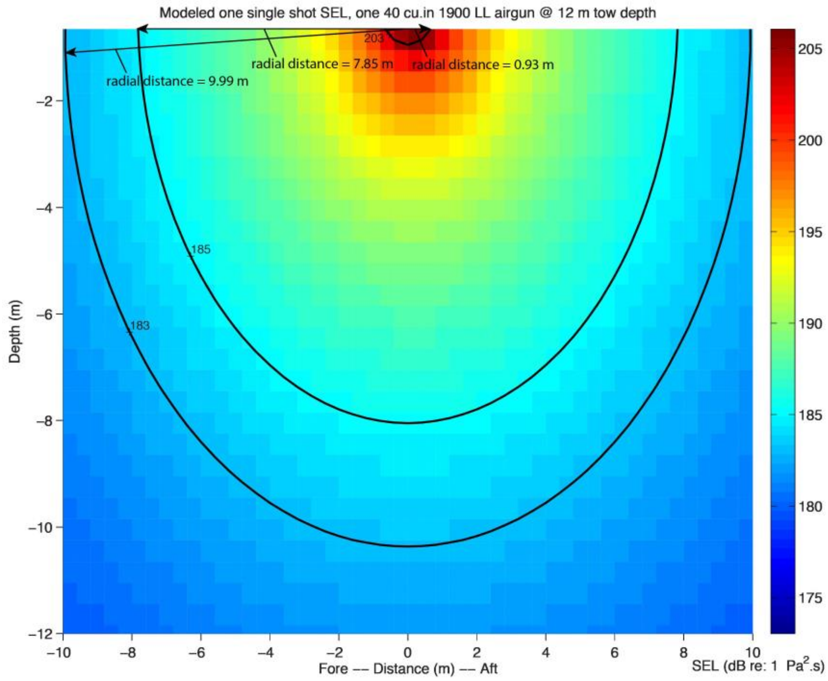

FIGURE A-22. Modeled received sound levels (SELs) in deep water from one 40-in^3 airgun at a 12-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183-, 185-, and 203-dB SEL isopleths.

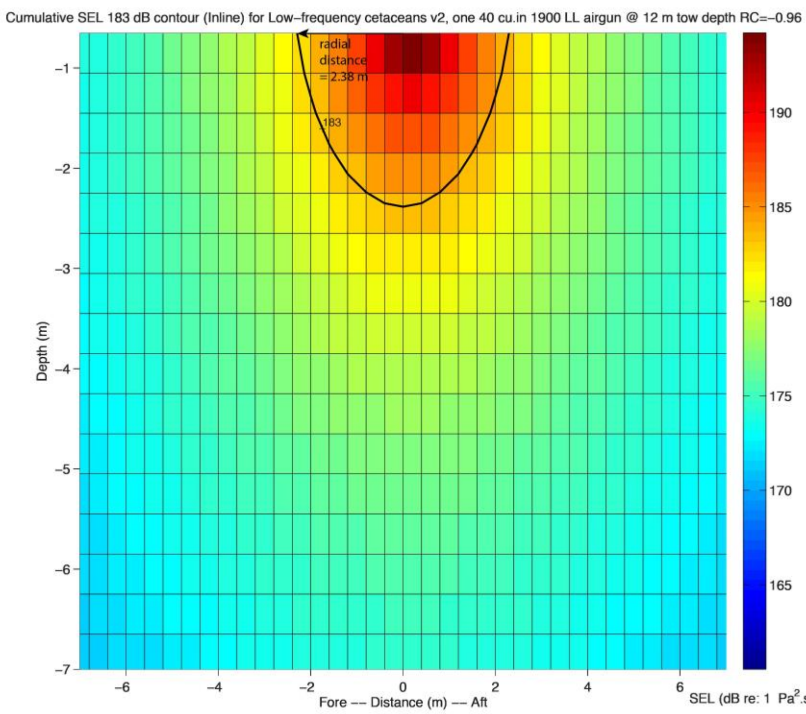

FIGURE A-23. Modeled received sound exposure levels (SELs) from one 40-in^3 mitigation at a 12-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one shot. The difference in radial distances between Fig. A-21 and this figure allows us to estimate the adjustment in dB.

TABLE A-11. 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-in^3 airgun during the proposed seismic surveys in the Northeast Pacific Ocean.

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
Peak Threshold	**219**	**230**	**202**	**218**	**232**
PTS Peak Isopleth (Radius) to Threshold (m)	1.76	0.51	12.5	1.98	0.40

N.A. means not applicable or not available.

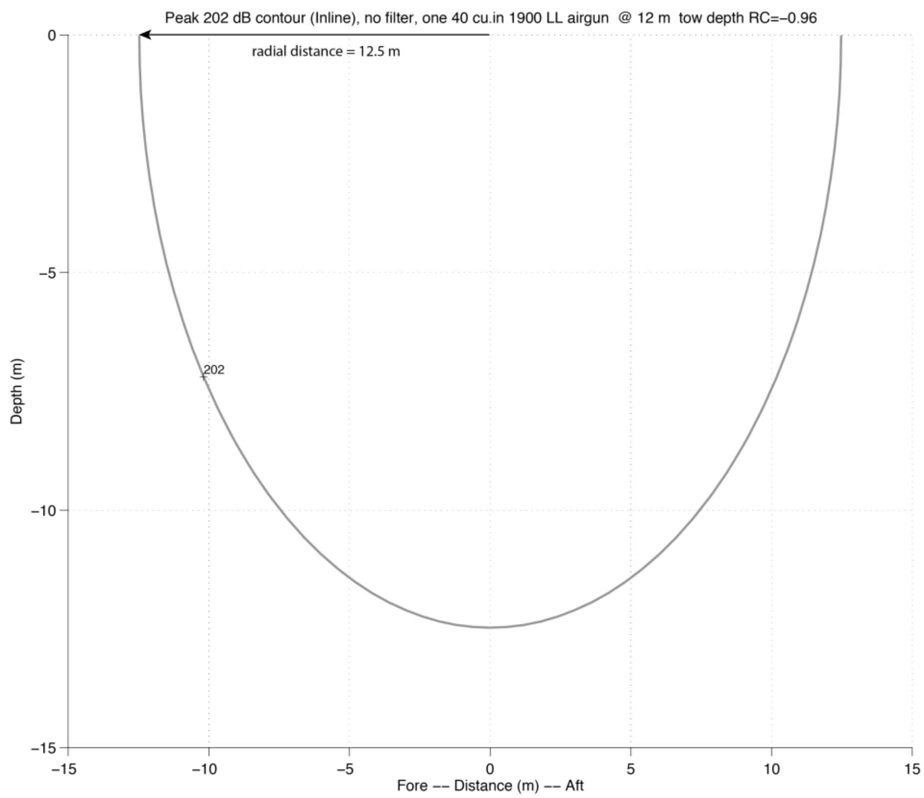

FIGURE A-24. Modeled deep-water received Peak SPL from one 40 in^3 airgun at a 12-m tow depth. The plot provides the radial distance from the source geometrical center to the 202-dB Peak isopleth.

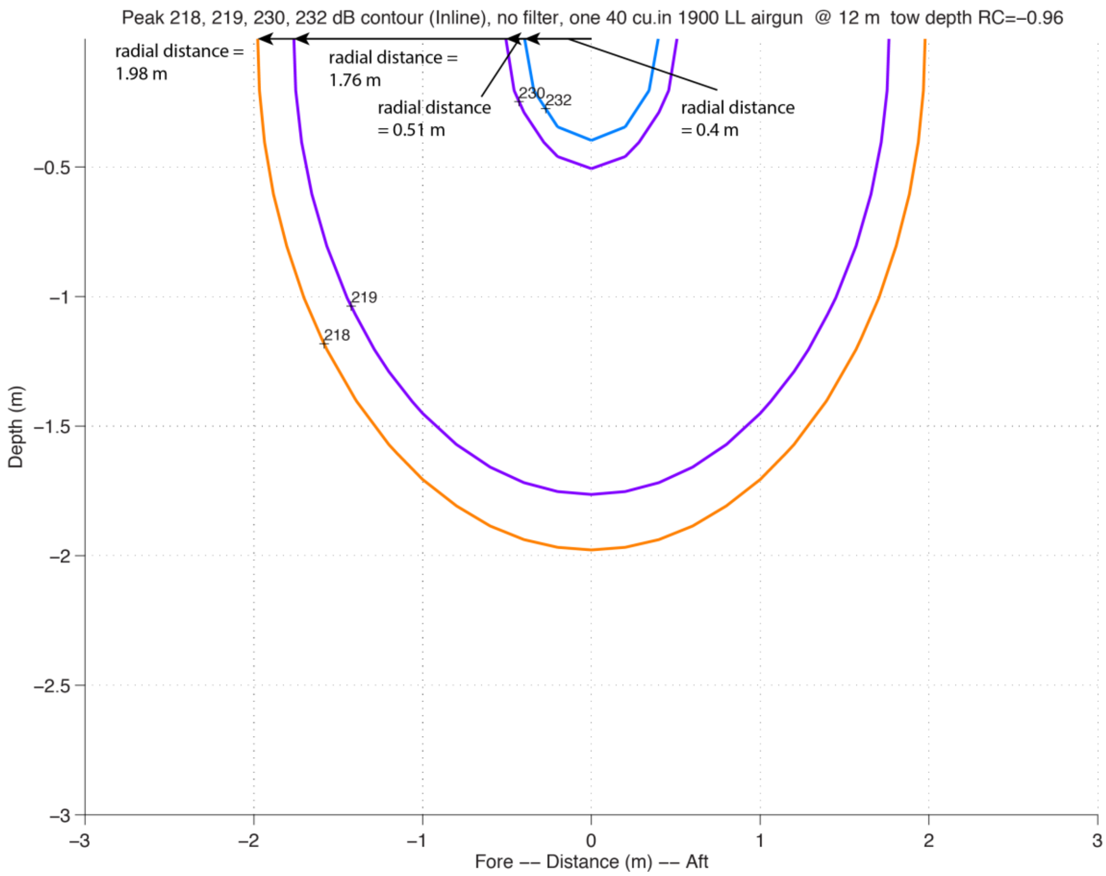

FIGURE A-25. Modeled deep-water received Peak SPL from one 40 in³ airgun at a 12-m tow depth. The plot provides the radial distances from the source geometrical center to the 218-, 219-, 230-, and 232-dB Peak isopleths.

TABLE A-12. 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 surveys in the Northeast Pacific Ocean in water depths >1000 m.

Source and Volume	Tow Depth (m)	Predicted distances (in m) to Received Sound Levels[1]	
		195 dB	175 dB
Single mitigation airgun, 40 in³	12	8 (100[2])	77
2 strings, 18 airguns, 3300 in³	10	76 (100[3])	814
4 strings, 36 airguns, 6600 in³	12	181	1864

[1] Distance is based on L-DEO model results.
[2] 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.
[3] Although this is not a low-energy source, an EZ of 100 m would be used as the shut-down distance for sea turtles.

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APPENDIX B: MARINE MAMMAL TAKE CALCULATIONS

Species	Estimated Density (#/1000 km^2)	Population Size	Hearing Group	NMFS Level B 160 dB Ensonified Area (km^2)	Level A Ensonified Area (km^2)	Total Takes	Level A Takes	Level B Takes	% of Population (Total Takes)
Mysticetes									
North Pacific right whale	*0*	*0*	*LF*	*18861.26*	*1542.75*	*0*	*0*	*0*	*0*
Humpback whale	*2.10*	*1,918*	*LF*	*18861.26*	*1542.75*	*40*	*3*	*37*	*2.09%*
Minke whale	1.30	636	LF	18861.26	*1542.75*	25	2	23	3.93%
Sei whale	*0.40*	*519*	*LF*	*18861.26*	*1542.75*	*8*	*1*	*7*	*1.54%*
Fin whale	*4.20*	*9,029*	*LF*	*18861.26*	*1542.75*	*80*	*6*	*74*	*0.89%*
Blue whale	*0.30*	*1,647*	*LF*	*18861.26*	*1542.75*	*6*	*0*	*6*	*0.36%*
Odontocetes									
Sperm whale	*0.90*	*1,997*	*MF*	*18861.26*	*107.98*	*17*	*0*	*17*	*0.85%*
Pygmy/dwarf sperm whale	1.60	4,111	HF	18861.26	976.71	31	2	29	0.75%
Cuvier's beaked whale	2.80	3,274	MF	18861.26	107.98	53	0	53	1.62%
Baird's beaked whale	10.70	2,697	MF	18861.26	107.98	202	1	201	7.49%
Mesoplodont (unidentified)	1.20	3,044	MF	18861.26	107.98	23	0	23	0.76%
Bottlenose dolphin	0.00	1,924	MF	18861.26	107.98	0	0	0	N.A.
Striped dolphin	7.70	29,211	MF	18861.26	107.98	146	1	145	0.50%
Short-beaked common dolphin	69.20	969,861	MF	18861.26	107.98	1,306	7	1,299	0.13%
Pacific white-sided dolphin	40.70	26,814	MF	18861.26	107.98	768	4	764	2.86%
Northern right-whale dolphin	46.40	26,556	MF	18861.26	107.98	876	5	871	3.30%
Risso's dolphin	11.80	6,336	MF	18861.26	107.98	223	1	222	3.52%
False killer whale	0.00	N.A.	MF	18861.26	107.98	0	0	0	N.A.
Killer whale	0.90	480	MF	18861.26	107.98	17	0	17	3.54%
Short-finned pilot whale	0.20	836	MF	18861.26	107.98	4	0	4	0.48%
Dall's porpoise	54.40	25,750	HF	18861.26	976.71	1,027	53	974	3.99%
Pinnipeds									
Northern fur seal	81.85	651,611	Otariid	18861.26	93.46	1,544	8	1,536	0.24%
Northern elephant seal	83.14	179,000	Phocid	18861.26	260.55	1,569	22	1,547	0.88%

N.A. means not available.

APPENDIX C: ENSONIFIED AREAS FOR MARINE MAMMAL TAKE CALCULATIONS

Survey	Criteria	Relevant Isopleth (m)	Daily Ensonified Area (km^2)	Total Survey Days	25% Increase	Total Ensonified Area (km^2)
2-D Survey	160-dB	6733	1346.90	3	1.25	5050.86
	LF Cetaceans	426.9	158.67	3	1.25	595.01
	HF Cetaceans	268.3	99.77	3	1.25	374.12
	Phocids	43.7	16.26	3	1.25	60.96
	MF Cetaceans	13.6	5.06	3	1.25	18.97
	Otariids	10.6	3.94	3	1.25	14.79
3-D Survey	160-dB	3758	690.52	16	1.25	13810.40
	LF Cetaceans	118.7	47.39	16	1.25	947.74
	HF Cetaceans	75.6	30.13	16	1.25	602.59
	Phocids	25.1	9.98	16	1.25	199.59
	MF Cetaceans	11.2	4.45	16	1.25	89.01
	Otariids	9.9	3.93	16	1.25	78.67