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* of the Cascadia Subduction Zone in the Northeast Pacific Ocean, Late Spring/Summer 2020

submitted by

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to

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SUMMARY

Researchers from Lamont-Doherty Earth Observatory (L-DEO) of Columbia University, Woods Hole Oceanographic Institution (WHOI), and the University of Texas at Austin Institute of Geophysics (UTIG), with funding from the U.S. National Science Foundation (NSF), and in collaboration with researchers from Dalhousie University and Simon Fraser University (SFU), propose to conduct high-energy seismic surveys from the Research Vessel (R/V) *Marcus G. Langseth* (*Langseth*) in combination with Ocean Bottom Seismometers (OBS) and Nodes (OBN) at the Cascadia Subduction Zone in the Northeast Pacific Ocean during late spring/summer 2020. The NSF-owned *Langseth* is operated by L-DEO under an existing Cooperative Agreement. The proposed two-dimensional (2-D) seismic surveys would occur within Exclusive Economic Zones (EEZ) of Canada and the U.S., including U.S. state waters and Canadian Territorial Waters. 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, sperm, and Southern Resident DPS of killer whales. It is unlikely that a gray whale from the ***endangered*** Western North Pacific DPS would occur in the project area at the time of the surveys. In addition, the ***threatened*** Mexico DPS of the humpback whale and the ***threatened*** Guadalupe fur seal could occur in the proposed project area. The North Pacific right whale, the Pacific populations of sei and blue whales, and Southern Resident killer whales are also listed as *endangered* under Canada's Species at Risk Act (SARA); the Pacific population of fin whale, and all other populations of killer whales in the Pacific Ocean are listed as *threatened*. The northern sea otter is the one marine mammal species mentioned in this document that, in the U.S., is managed by the USFWS; all others are managed by NMFS. Formal consultation from the USFWS is being sought for sea otters.

ESA-listed sea turtle species that could occur in the project area include the ***endangered*** leatherback turtle and ***threatened*** East Pacific DPS of the green turtle; the Pacific population of leatherback turtle is also listed as *endangered* under SARA, but the green turtle is not listed. ESA-listed seabirds that could be encountered in the area include the ***endangered*** short-tailed albatross (also *endangered* under SARA) and Hawaiian petrel, and the ***threatened*** marbled murrelet (also *threatened* under SARA); the Hawaiian petrel is not listed under SARA. In addition, the tufted puffin could also occur in the project area; it is currently under review by the USFWS for listing under the ESA and has no status under SARA.

In addition, several ESA-listed fish species occur in the area, including the ***endangered*** Puget Sound/Georgia Basin DPS of bocaccio; the ***threatened*** Pacific eulachon (Southern DPS), green sturgeon (Southern DPS), yelloweye rockfish, and several DPSs of steelhead trout; and various ***endangered*** and

threatened evolutionary significant units (ESUs) of chinook, chum, coho, and sockeye salmon. None of these species are listed under SARA, but the basking shark and northern abalone are listed as *endangered*.

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 would use 2-D seismic surveying and OBSs and OBNs to investigate the Cascadia Subduction Zone and provide data necessary to illuminate the depth, geometry, and physical properties of the seismogenic portion and updip extent of the megathrust zone between the subducting Juan de Fuca plate and the overlying accretionary wedge/North American plate providing essential constraints for earthquake and tsunami hazard assessment in this heavily populated region of the Pacific Northwest. The portion of the megathrust targeted for this survey is the source region for great earthquakes that occurred at Cascadia in pre-historical times, comparable in size to the Tohoku M9 earthquake in 2011; an earthquake of similar size is possible at Cascadia within the next century.

The proposed surveys would occur within ~42–51°N, ~124–130°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 within the EEZs of the U.S. and Canada, as well as in U.S. state waters and Canadian Territorial Waters, ranging in depth 60–4400 m. The proposed surveys would be expected to last for 40 days, including ~37 days of seismic operations, 2 days of equipment deployment, and 1 day of transit. R/V *Langseth* would likely leave out of and return to port in Astoria, OR, during late spring/summer (June–July) 2020.

The primary objectives of the surveys proposed by researchers from L-DEO, WHOI, and UTIG is to characterize: 1) the deformation and topography of the incoming plate; 2) the depth, topography, and reflectivity of the megathrust; 3) sediment properties and amount of sediment subduction; and 4) the structure and evolution of the accretionary wedge, including geometry and reflectivity of fault networks, and how these properties vary along strike, spanning the full length of the margin and down dip across what may be the full width of the Cascadia Subduction Zone. To achieve the project goals, the Principal Investigators (PI) Drs. S. Carbotte (L-DEO), P. Canales (WHOI), and S. Han (UTIG) propose to utilize 2-D seismic reflection capabilities of R/V *Langseth* and OBSs and OBNs. Although not funded through NSF, collaborators from the U.S. Geological Survey (USGS), Drs. M. Nedimovic (Dalhousie University), and A. Calvert (Simon Fraser University) would work with the PIs to achieve the research goals, providing assistance, such as through logistical support, and data acquisition and exchange.

OBSs and OBNs would leverage the seismic surveys by R/V *Langseth*. A complementary land-based research effort is also under consideration for NSF-funding. Although the project has independent utility, it would capitalize on proposed R/V *Langseth* marine-based activities and would vastly expand the geophysical dataset available for analysis for the Cascadia region. In addition, the proposed deep-penetration survey would complement the shallow-imaging study by the USGS that is planned for the

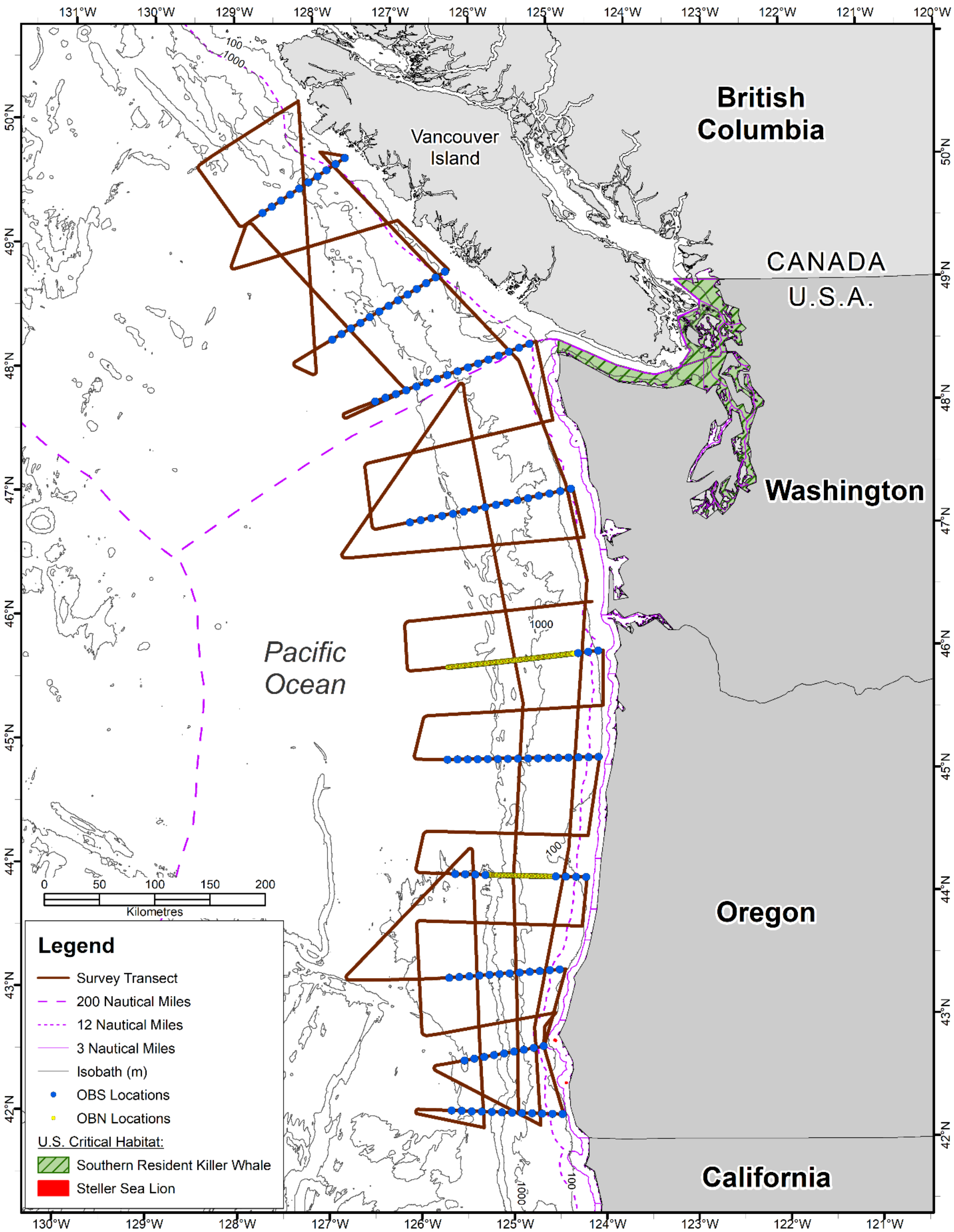

FIGURE 1. Location of the proposed seismic surveys in the Northeast Pacific Ocean and marine mammal critical habitat in the U.S.

region as part of their multi-year hazard assessment study. The collection of seismic data by R/V *Langseth* would also represent an essential step in the development of International Ocean Discovery Program (IODP) activities along the Cascadia margin. The IODP project, which is not part of the Proposed Action, has been reviewed in a pre-proposal by the IODP Science Evaluation Panel. To complete the full proposal and subsequently execute its science plan, seismic data must be collected to identify drilling targets and to evaluate their suitability from both scientific and safety perspectives. The survey would involve one source vessel, R/V *Langseth*, which would tow a 36-airgun array with a discharge volume of ~6600 in^3 at a depth of 12 m, and a shot interval of 37.5 m. The receiving system would consist of a 15-km long hydrophone streamer. OBSs and OBNs would be deployed from a second vessel, R/V *Oceanus*; this program would leverage the seismic surveys by R/V *Langseth*.

Long 15-km-offset MCS data would be acquired along numerous 2-D profiles oriented perpendicular to the margin and located to provide coverage in areas inferred to be rupture patches during past earthquakes and their boundary zones. The survey would also include several strike lines including one continuous line along the continental shelf centered roughly over gravity-inferred fore-arc basins to investigate possible segmentation near the down-dip limit of the seismogenic zone. The margin normal lines would extend ~50 km seaward of the deformation front to image the region of subduction bend faulting in the incoming oceanic plate, and landward of the deformation front to as close to the shoreline as can be safely maneuvered. It is proposed that the southern transects off Oregon are acquired first, followed by the profiles off Washington and Vancouver Island, B.C. A maximum of 6890 km of transect lines would be surveyed in the Northeast Pacific Ocean. Most of the survey (63.2%) would occur in deep water (>1000 m), 26.4% would occur in intermediate water (100–1000 m deep), and 10.4% would take place in shallow water <100 m deep. Approximately 4% of the transect lines (295 km) would be undertaken in Canadian Territorial Waters, with most effort in intermediate waters.

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 survey.

R/V *Oceanus* would be used to deploy OBSs and OBNs. R/V *Oceanus* has a length of 54 m, a beam of 10 m, and a draft of 5.3 m. The ship is powered by one EMD diesel engine, producing 3000 hp, which drives the single screw propeller. The vessel also has a 350 hp bowthruster. The cruising speed is 20 km/h, the endurance is 30 days, and the range is ~13,000 km. Other details of R/V *Oceanus* include the following:

Owner:	National Science Foundation
Operator:	Oregon State University
Flag:	United States of America
Date Built:	1975
Gross Tonnage:	261
Accommodation Capacity:	25 including ~13 scientists

Airgun Description

During the surveys, R/V *Langseth* would tow four strings with 36 airguns (plus 4 spares). During the surveys, all four strings totaling 36 active airguns with a total discharge volume of 6600 in^3 would be used. The airgun array is described in § 2.2.3.1 of the PEIS, and the airgun configuration is illustrated in Figure 2-11 of the PEIS. The array would be towed at a depth of 12 m, and 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 full mitigation 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 surveys would acquire data with the 36-airgun array at a maximum tow depth of 12 m. L-DEO model results are used to determine the 160-dB_{rms} radius for the 36-airgun array and 40-in^3 airgun at a 12-m tow depth in deep water (>1000 m) down to a maximum depth of 2000 m, as animals are generally not anticipated to dive below 2000 m (Costa and Williams 1999). The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor of 1.5. For shallow water (<100 m), radii are based on empirically derived measurements in the Gulf of Mexico (GoM) with scaling applied to account for differences in tow depth (see Appendix A). Table 1 shows the distances at which the 160-dB re $1\mu Pa_{rms}$ sound levels are expected to be received for the 36-airgun array and the single (mitigation) airgun. The 160-dB level is the behavioral disturbance criterion (Level B) that is used by NMFS to estimate anticipated takes for marine mammals.

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

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

The thresholds for permanent threshold shift (PTS) onset or Level A Harassment (injury) for marine mammals for impulsive sounds use dual metrics of cumulative sound exposure level (SEL_{cum} over 24 hours) and peak sound pressure levels (SPL_{flat}). Different thresholds are provided for the various hearing groups, including low-frequency (LF) cetaceans (e.g., baleen whales), mid-frequency (MF) cetaceans (e.g., most delphinids), high-frequency (HF) cetaceans (e.g., harbor porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW; including sea otters) (NMFS 2016a, 2018a). 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 Level A takes and threshold distances for marine mammals. Here, SEL_{cum} is used for LF cetaceans, and Peak SPL is used for all other marine mammal hearing groups (Table 2).

This document has been prepared in accordance with the current National Oceanic and Atmospheric Administration (NOAA) acoustic practices, and the monitoring and mitigation procedures are based on best practices noted by Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013a), Wright (2014), Wright and Cosentino (2015), and Acosta et al. (2017). 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 shutdowns of the single airgun. Enforcement of mitigation zones via power and shutdowns would be implemented as described in § XI.

OBS Description and Deployment

The OBSs would consist of short-period multi-component OBSs from the Ocean Bottom Seismometer Instrument Center (OBSIC) and a large-*N* array of OBNs a commercial provider to record shots along ~11 MCS margin-perpendicular profiles. OBSs would be deployed at 10-km spacing along ~11 profiles from Vancouver Island to Oregon, and OBNs would be deployed at a 500-m spacing along a portion of two profiles off Oregon. Two OBS deployments would occur with a total of 115 instrumented locations. One deployment consisting of 60 OBSs to instrument seven profiles off Oregon, and a second deployment of 55 OBSs to instrument four profiles off Washington and Vancouver Island. The first deployment off Oregon would occur prior to the start of the proposed survey, after which R/V *Langseth* would acquire data in the southern portion of the study area. R/V *Oceanus* would start recovering the OBSs from deployment 1, and then re-deploy 55 OBSs off Washington and Vancouver Island, so that R/V *Langseth* can acquire data in the northern portion of the survey area. The OBSs have a height and diameter of ~1 m, and an ~80 kg anchor.

A total of 350 nodes would be deployed: 229 nodes along one transect off northern Oregon, and 121 nodes along a second transect off central Oregon. The nodes are not connected to each other; each node is independent from each other, and there are no cables attached to them. Each node has internal batteries; all data is recorded and stored internally. The nodes weight weigh 21 kg in air (9.5 kg in water). As the OBNs are small (330 mm x 289 mm x 115 mm), compact, not buoyant, and lack an anchor-release mechanism, they cannot be deployed/recovered by free-fall as with the OBSs. The nodes would be deployed and retrieved using a remotely operated vehicle (ROV); the ROV would be deployed from R/V *Oceanus*. OBNs would be deployed 17 days prior to the start of the R/V *Langseth* cruise. The ROV would be fitted with a skid with capacity for 32 units, lowered to the seafloor, and towed at a speed of 0.6 kt at 5–10 m above the seafloor between deployment sites. After the 32 units are deployed, the ROV would be retrieved, the skid would be reloaded with another 32 units, and sent back to the seafloor for deployment, and so on. The ROV would recover the nodes 3 days after the completion of the R/V *Langseth* cruise. The nodes would be recovered one by one by a suction mechanism.

TABLE 2. Level A threshold distances for different marine mammal hearing groups for the 36-airgun array. 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 Level A takes and threshold distances.

	Level A Threshold Distances (m) for Various Hearing Groups				
	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds and Sea Otters
PTS SEL_{cum}	**426.9**	0	1.3	13.9	0
PTS Peak	38.9	**13.6**	**268.3**	**43.7**	**10.6**

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. R/V *Langseth* would deploy an array of 36 airguns as an energy source with a total volume of ~6600 in^3. The receiving system would consist of one 15-km long hydrophone streamer, OBSs, and OBNs. As the airguns are towed along the survey lines, the hydrophone streamer would transfer the data to the on-board processing system, and the OBSs and OBNs would receive and store the returning acoustic signals internally for later analysis.

A maximum of 6890 km of transect lines would be surveyed in the Northeast Pacific Ocean. Most of the survey (63.2%) would occur in deep water (>1000 m), 26.4% would occur in intermediate water (100–1000 m deep), and 10.4% would take place in shallow water <100 m deep. Approximately 4% of the transect lines (295 km) would be undertaken in Canadian Territorial Waters, with most effort in intermediate waters. 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 ~42–51°N, ~124–130°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 surveys are proposed to occur within the EEZ of the U.S. and Canada, as well as in U.S. state waters and Canadian Territorial Waters, ranging in depth 60–4400 m.

The proposed surveys would be expected to last for 40 days, including ~37 days of seismic operations, 2 days of equipment deployment, and 1 day of transit. R/V *Langseth* would likely leave out of and return to port in Astoria, OR, during late spring/summer (June–July) 2020. The ensuing analysis (including take estimates) focuses on the time of the survey (late spring/summer); the best available species densities for that time of the year have been used.

III. Species and Numbers of Marine Mammals in Area

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

Thirty-three marine mammal species could occur in or near the proposed survey area, including 7 mysticetes (baleen whales), 19 odontocetes (toothed whales), 6 pinnipeds (seals and sea lions), and the northern sea otter (Table 3). Seven of the species are listed under the U.S. ESA as ***endangered***, including the sperm, humpback (Central America DPS), sei, fin, blue, North Pacific right, and Southern Resident DPS of killer whales. The ***threatened*** Mexico DPS of the humpback whale and the ***threatened*** Guadalupe fur seal could also occur in the proposed survey area. It is very unlikely that gray whales from the ***endangered*** Western North Pacific DPS would occur in the proposed survey area.

The long-beaked common dolphin (*D. capensis*) and rough-toothed dolphin (*Steno bredanensis*) are distributed farther to the south. These species are unlikely to be seen in the proposed survey area and are not addressed in the summaries below. Although no sightings of *D. capensis* have been made off Oregon/Washington, Ford (2005) reported seven confirmed *D. capensis* sightings in B.C. waters from 1993–2003. All records occurred in inshore waters; Ford (2005) described *D. capensis* as a “rare visitor” to B.C. waters, more likely to occur during warm-water periods. No other sightings have been made since 2003 (Ford 2014).

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.

General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of marine mammals are given in § 3.6.1, § 3.7.1, § 3.8.1, and § 3.8.1 of the PEIS. One of the qualitative analysis areas (QAAs) defined in the PEIS, the B.C. Coast, is located just to the north of the proposed survey area. The general distribution of mysticetes, odontocetes, pinnipeds, and sea otters off the B.C. Coast is discussed in § 3.6.3.2, § 3.7.3.2, § 3.8.3.2, and § 3.9.3.1 of the PEIS, respectively. Southern California was chosen as a detailed analysis area (DAA) in the PEIS. The general distribution of mysticetes, odontocetes, pinnipeds, and sea otters in southern California is discussed in § 3.6.2.3, § 3.7.2.3, § 3.8.2.3, and § 3.9.2.2 of the PEIS, respectively. The rest of this section deals specifically with species distribution in the proposed survey area. Although Harvey et al. (2007) and Best et al. (2015) provide information on densities and marine mammal hotspots in B.C. waters, their survey areas do not cover the proposed study area.

TABLE 3. 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. N.A. means not available.

Species	Occurrence in Area[1]	Habitat	Abundance[2]	U.S. *ESA*[3]	Canada COSEWIC[4]	Canada SARA[5]	IUCN[6]	CITES[7]
Mysticetes								
North Pacific right whale	Rare	Coastal, shelf, offshore	400-500[8]	EN	EN	EN	CR[9]	I
Gray whale	Common	Coastal, shelf	243[10]; 26,960	DL[11]	EN[12]	NS	LC[13]	I
Humpback whale	Common	Mainly nearshore and banks	2,900; 10,103[14]	EN/T[15]	SC	SC	LC	I
Common minke whale	Uncommon	Nearshore, offshore	636; 20,000[16]	NL	NAR	NS	LC	I
Sei whale	Rare	Mostly pelagic	519; 27,197[17]	EN	EN	EN	EN	I
Fin whale	Common	Slope, pelagic	9,029; 13,620-18,680[18]	EN	SC	T	VU	I
Blue whale	Rare	Pelagic and coastal	1,496[19]	EN	EN	EN	EN	I
Odontocetes								
Sperm whale	Common	Pelagic, steep topography	1,997; 26,300[20]	EN	NAR	NS	VU	I
Pygmy sperm whale	Rare	Deep, off shelf	4111	NL	NAR	NS	DD	II
Dwarf sperm whale	Rare	Deep, shelf, slope	N.A.	NL	NS	NS	DD	II
Cuvier's beaked whale	Uncommon	Pelagic	3,274	NL	NAR	NS	LC	II
Baird's beaked whale	Uncommon	Pelagic	2,697	NL	NAR	NS	DD	I
Blainville's beaked whale	Rare	Pelagic	3,044[21]	NL	NAR	NS	DD	II
Hubbs' beaked whale	Rare	Slope, offshore	3,044[21]	NL	NAR	NS	DD	II
Stejneger's beaked whale	Uncommon	Slope, offshore	3,044[21]	NL	NAR	NS	DD	II
Common bottlenose dolphin	Rare	Coastal, shelf, deep	1,924[22]	NL	NAR	NS	LC	II
Striped dolphin	Rare	Off continental shelf	29,211	NL	NAR	NS	LC	II
Short-beaked common dolphin	Uncommon	Shelf, pelagic, seamounts	969,861	NL	NAR	NS	LC	II
Pacific white-sided dolphin	Common	Offshore, slope	26,814 22,160[42]	NL	NAR	NS	LC	II
Northern right whale dolphin	Common	Slope, offshore waters	26,556	NL	NAR	NS	LC	II
Risso's dolphin	Uncommon	Shelf, slope, seamounts	6,336	NL	NAR	NS	LC	II
False killer whale	Rare	Pelagic	N.A.	NL	NAR	NS	NT	II
Killer whale	Common	Widely distributed	75[23] 243[24] 302[25] 300[26]	EN[27]	EN/T[28]	EN/T[28]	DD	II
Short-finned pilot whale	Rare	Pelagic, high-relief	836	NL	NAR	NS	LC	II
Harbor porpoise	Common	Shelf	21,487[29]; 35,769[30] 8,091[42]	NL	SC	SC	LC	II
Dall's porpoise	Common	Shelf, slope, offshore	25,750 5,303[42]	NL	NAR	NS	LC	II
Pinnipeds								
Guadalupe fur seal	Rare	Mainly coastal, pelagic	34,187	T	NAR	NS	LC	I

Species	Occurrence in Area[1]	Habitat	Abund-ance[2]	U.S. *ESA*[3]	Canada		IUCN[6]	CITES[7]
					COSEWIC[4]	SARA[5]		
Northern fur seal	Uncommon	Pelagic, offshore	14,050[31] 620,660[32]	NL	T	NS	VU	N.A.
Northern elephant seal	Uncommon	Coastal, pelagic in migration	179,000[33]	NL	NAR	NS	LC	N.A.
Harbor seal	Common	Coastal	24,732[34] 105,000[43]	NL	NAR	NS	LC	N.A.
Steller sea lion	Common	Coastal, offshore	77,149[35] 4,037[42]	DL[36]	SC	SC	NT[37]	N.A.
California sea lion	Uncommon	Coastal	257,606[38]	NL	NAR	NS	LC	N.A.
Fissipeds								
Northern Sea Otter	Rare[41]	Coastal	2,785[39] 6,754[44]	NL[40]	SC	SC	EN	II

[1] Occurrence in area at the time of the survey; based on professional opinion and available data.
[2] Abundance for Eastern North Pacific, U.S., or CA/OR/WA stock from Carretta et al. (2019a,b), unless otherwise stated.
[3] U.S. *Endangered Species Act* (ESA; NOAA 2019d): EN = Endangered, T = Threatened, NL = Not listed.
[4] Committee on the Status of Endangered Wildlife in Canada (COSEWIC) status (Government of Canada 2019d); EN = Endangered; T = Threatened; SC = Special Concern; NAR = Not at Risk.
[5] Pacific Population for Canada's *Species at Risk Act* (SARA) Schedule 1 species, unless otherwise noted (Government of Canada 2019d); EN = endangered; T = Threatened; SC = Special Concern; NS = No Status.
[6] Classification from the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2019); CR = Critically Endangered; EN = Endangered; VU = Vulnerable; LC = Least Concern; DD = Data Deficient.
[7] Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES; UNEP-WCMC 2017): Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled.
[8] North Pacific (Jefferson et al. 2015).
[9] The Northeast Pacific subpopulation is critically endangered; globally, the North Pacific right whale is endangered.
[10] Pacific Coast Feeding Group (Carretta et al. 2019a).
[11] Although the Eastern North Pacific DPS was delisted under the ESA, the Western North Pacific DPS is listed as endangered.
[12] Pacific Coast Feeding Aggregation and Western Pacific populations are listed as endangered; the Northern Pacific Migratory population is not at risk.
[13] Globally considered as least concern; western population listed as endangered.
[14] Central North Pacific stock (Muto et al. 2019a,b).
[15] The Central America DPS is endangered, and the Mexico DPS is threatened; the Hawaii DPS was delisted in 2016 (81 FR 62260, 8 September 2016).
[16] Northwest Pacific and Okhotsk Sea (IWC 2018).
[17] Central and Eastern North Pacific (Hakamada and Matsuoka 2015a).
[18] North Pacific (Ohsumi and Wada 1974).
[19] Eastern North Pacific Stock (Carretta et al. 2019b).
[20] Eastern Temperate Pacific; estimate based on visual sightings (Barlow and Taylor 2005).
[21] All mesoplodont whales (Moore and Barlow 2017; Carretta et al. 2019a,b).
[22] California/Oregon//Washington offshore stock (Carretta et al. 2019a,b).
[23] Eastern North Pacific Southern Resident stock (Carretta et al. 2019b).
[24] West Coast Transient stock; minimum estimate (Muto et al. 2019a).
[25] Northern Resident stock (Muto et al. 2019b).
[26] North Pacific Offshore stock (Carretta et al. 2019a,b).
[27] The Southern Resident DPS is listed as endangered; no other stocks are listed.
[28] Southern resident population is as endangered; the northern resident, offshore, and transient populations are threatened.
[29] Northern Oregon/southern Washington stock (Carretta et al. 2019a,b).
[30] Northern California/Southern Oregon stock (Carretta et al. 2019a,b).
[31] California stock (Carretta et al. 2019a,b).
[32] Eastern Pacific stock (Muto et al. 2019a,b).
[33] California breeding stock (Carretta et al. 2019a,b).
[34] Oregon and Washington Coast stock (Carretta et al. 2019a,b).
[35] Eastern U.S. stock (Muto et al. 2019b).
[36] The Eastern DPS was delisted in 2013 (78 FR 66139, 4 November 2013); the Western DPS is listed as endangered.
[37] Globally considered as near threatened; western population listed as endangered.
[38] U.S. stock (Carretta et al. 2019a,b).
[39] Washington (Jeffries et al. 2019).
[40] Southwest Alaska DPS is listed as threatened.
[41] Although it is unlikely that sea otters would be seen during the survey, their habitat is likely to be ensonified to SPLs >160 dB.
[42] Coastal waters of B.C. (Best et al. 2015).
[43] B.C. (Ford 2014).
[44] B.C. (Nichol et al. 2015).

Mysticetes

North Pacific Right Whale (*Eubalaena japonica*)

North Pacific right whales summer in the northern North Pacific, primarily in the Okhotsk Sea (Brownell et al. 2001) and in the Bering Sea (Shelden et al. 2005; Wade et al. 2006). This species is divided into western and eastern North Pacific stocks. The eastern North Pacific stock that occurs in U.S. waters numbers only ~31 individuals (Wade et al. 2011a), and critical habitat has been designated in the eastern Bering Sea and in the Gulf of Alaska, south of Kodiak Island (NOAA 2019b). Wintering and breeding areas are unknown, but have been suggested to include the Hawaiian Islands, Ryukyu Islands, and Sea of Japan (Allen 1942; Banfield 1974; Gilmore 1978; Reeves et al. 1978; Herman et al. 1980; Omura 1986).

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 2018). 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).

Since the 1960s, North Pacific right whale sightings have been relatively rare (e.g., Clapham et al. 2004; Shelden et al. 2005). However, starting in 1996, right whales have been seen regularly in the southeast Bering Sea, including calves in some years (Goddard and Rugh 1998; LeDuc et al. 2001; Moore et al. 2000, 2002a; Wade et al. 2006; Zerbini et al. 2009); they have also been detected acoustically (McDonald and Moore 2002; Munger et al. 2003; 2005, 2008; Berchok et al. 2009). They are known to occur in the Bering Sea from May–December (e.g., Tynan et al. 2001; Hildebrand and Munger 2005; Munger et al. 2005, 2008). In March 1979, a group of four right whales was seen in Yakutat Bay (Waite et al. 2003), but there were no further reports of right whale sightings in the Gulf of Alaska until July 1998, when a single whale was seen southeast of Kodiak Island (Waite et al. 2003). Since 2000, several other sightings and acoustic detections have been made in the western Gulf of Alaska during summer (Waite et al. 2003; Mellinger et al. 2004; RPS 2011; Wade et al. 2011a,b; Rone et al. 2014). A biologically important area (BIA) for feeding for North Pacific right whales was designated east of the Kodiak Archipelago, encompassing the Gulf of Alaska critical habitat and extending south of 56°N and north of 58°N and beyond the shelf edge (Ferguson et al. 2015).

South of 50ºN in the eastern North Pacific, only 29 reliable sightings were recorded from 1900–1994 (Scarff 1986, 1991; Carretta et al. 1994). Despite many miles of systematic aerial and ship-based surveys for marine mammals off the coasts of California/Oregon/Washington over the years, only seven documented sightings of right whales were made from 1990–2000 (Waite et al. 2003). Two North Pacific right whale calls were detected on a bottom-mounted hydrophone (located in water 1390 m deep) off the Washington coast on 29 June 2013 (Širović et al. 2014).

Right whales have been scarce in B.C. since 1900 (Ford 2014). In the 1900s, there were only six records of right whales for B.C., all of which were catches by whalers (Ford et al. 2016). Since 1951, there have only been three confirmed records. A sighting of one individual 15 km off the west coast of Haida Gwaii was made on 9 June 2013 and another sighting occurred on 25 October 2013 on Swiftsure Bank near the entrance to the Strait of Juan de Fuca (Ford 2014; Ford et al. 2016; DFO 2017). The third and most recent sighting was made off Haida Gwaii in June 2018 (CBC 2018). There have been two additional unconfirmed records for B.C., including one off Haida Gwaii in 1970 and another for the Strait of Juan de Fuca in 1983 (Brownell et al. 2001; DFO 2011; Ford 2014).

Based on the very low abundance of this species, its rarity off the coasts of B.C., Washington, and Oregon in recent decades, and the likelihood that animals would be feeding in the Bering Sea and Gulf of Alaska at the time of the survey, it is possible although very unlikely that a North Pacific right whale could be encountered in the proposed survey area during the period of operations.

Gray Whale (*Eschrichtius robustus*)

Two separate populations of gray whales have been recognized in the North Pacific: the eastern North Pacific and western North Pacific (or Korean-Okhotsk) stocks (LeDuc et al. 2002; Weller et al. 2013). However, the distinction between these two populations has been recently debated owing to evidence that whales from the western feeding area also travel to breeding areas in the eastern North Pacific (Weller et al. 2012, 2013; Mate et al. 2015). Thus, it is possible that whales from either the U.S. ESA-listed ***endangered*** Western North Pacific DPS or the delisted Eastern North Pacific DPS could occur in the proposed survey area, although it is unlikely that a gray whale from the Western North Pacific DPS would be encountered during the time of the survey. Gray whale populations were severely reduced by whaling, and the western population has remained highly depleted, but the eastern North Pacific population is considered to have recovered. In 2009, Punt and Wade (2012) estimated that the eastern North Pacific population was at 85% of its carrying capacity of 25,808 individuals.

The eastern North Pacific gray whale breeds and winters in Baja California, and migrates north to summer feeding grounds in the northern Bering Sea, Chukchi Sea, and western Beaufort Sea (Rice and Wolman 1971; Rice 1998; Jefferson et al. 2015). The migration northward occurs from late February–June (Rice and Wolman 1971), with a peak into the Gulf of Alaska during mid-April (Braham 1984). Instead of migrating to arctic and sub-arctic waters, some individuals spend the summer months scattered along the coast from California to Southeast Alaska (Rice and Wolman 1971; Nerini 1984; Darling et al. 1998; Calambokidis and Quan 1999; Dunham and Duffus 2001, 2002; Calambokidis et al. 2002, 2015, 2017). There is genetic evidence indicating the existence of this Pacific Coast Feeding Group (PCFG) as a distinct local subpopulation (Frasier et al. 2011; Lang et al. 2014), and the U.S. and Canada recognize it as such (COSEWIC 2017; Carretta et al. 2019a). However, the status of the PCFG as a separate stock is currently unresolved (Weller et al. 2013). For the purposes of abundance estimates, the PCFG is defined as occurring between 41°N to 52°N from 1 June to 30 November (IWC 2012). The 2015 abundance estimate for the PCFG was 243 whales (Calambokidis et al. 2017); ~100 of those may occur in B.C. during summer (Ford 2014). In B.C., most summer resident gray whales are found in Clayoquot Sound, Barkley Sound, and along the southwestern shore of Vancouver Island, and near Cape Caution, on the mainland (Ford 2014). During surveys in B.C. waters during summer, most sightings were made within 10 km from shore in water shallower than 100 m (Ford et al. 2010a).

BIAs for feeding gray whales along the coasts of Washington, Oregon, and California have been identified, including northern Puget Sound, Northwestern Washington, and Grays Harbor (WA); Depoe Bay and Cape Blanco & Orford Reef (OR), and Point St. George (CA); most of these areas are of importance from late spring through early fall (Calambokidis et al. 2015). Resident gray whales have been observed foraging off the coast of Oregon from May–October (Newell and Cowles 2006) and off Washington from June through November (Scordino et al. 2014). A least 28 gray whales were observed near Depoe Bay, OR (~44.8°N), for three successive summers (Newell and Cowles 2006). BIAs have also been identified for migrating gray whales along the entire coasts of Washington, Oregon, and California; although most whales travel within 10 km from shore, the BIAs were extended out to 47 km from the coastline (Calambokidis et al. 2015). Gray whales from the far north begin to migrate south to breeding grounds on the west coast of Baja California and the southeastern Gulf of California in October and November (Braham 1984; Rugh et al. 2001). Gray whales migrate closest to the Washington/Oregon coastline during spring (April–June), when most strandings are observed (Norman et al. 2004).

Oleson et al. (2009) observed 116 gray whales off the outer Washington coast (~47ºN) during 42 small boat surveys from August 2004 through September 2008; mean distances from shore during the southern migration (December–January), northern migration (February–April), and summer feeding (May–October) activities were 29, 9, and 12 km, respectively; mean bottom depths during these activities were 126, 26, and 33 m, respectively. Ortega-Ortiz and Mate (2008) tracked the distribution and movement patterns of gray whales off Yaquina Head on the central Oregon coast (~44.7°N) during the southbound and northbound migration in 2008. The average distance from shore to tracked whales ranged from 200 m to 13.6 km; average bottom depth of whale locations was 12–75 m. The migration paths of tracked whales seemed to follow a constant depth rather than the shoreline. During aerial surveys over the shelf and slope off Oregon and Washington, gray whales were seen during the months of January, June–July, and September; one sighting was made off the Columbia River estuary in water >200 m during June 2011 (Adams et al. 2014). Two sightings of three whales were seen from R/V *Northern Light* during a survey off southern Washington in July 2012 (RPS 2012a).

In B.C., gray whales are common off Haida Gwaii and western Vancouver Island (Williams and Thomas 2007), in particular during migration. Whales travel southbound along the coast of B.C. during their migration to Baja California between November and January, with a peak off Vancouver Island during late December; during the northbound migration, whales start appearing off Vancouver Island during late February, with a peak in late March, with fewer whales occurring during April and May (Ford 2014). Northbound migrants typically travel within ~5 km from shore (Ford 2014), although some individuals have been sighted more than 10 km from shore (Ford et al. 2010a, 2013). Based on acoustic detections described by Meyer (2017 *in* COSEWIC 2017), the southward migration also takes place in shallow shelf waters. After leaving the waters off Vancouver Island, gray whales typically use Hecate Strait and Dixon Entrance as opposed to the west coast of Haida Gwaii as their main migratory corridor through Southeast Alaska during the northbound migration (Ford et al. 2013); during the southbound migration, gray whales likely migrate past the outer coast of Haida Gwaii (Ford 2014; Mate et al. 2015; COSEWIC 2017).

The proposed surveys would occur during the late spring/summer feeding season, when most individuals from the eastern North Pacific stock occur farther north. Nonetheless, individuals particularly from the PCFG could be encountered in nearshore waters of the proposed project area, although few are expected to be seen more than 10 km from shore. NOAA (2019c) has declared an unusual mortality event (UME) for gray whales in 2019, as an elevated number of strandings have occurred along the coast of the Pacific Northwest since January. As of 30 September 2019, a total of 212 dead gray whales have been reported, including 121 in the U.S. (14 in Washington; 6 in Oregon), 81 in Mexico, and 10 in B.C.; some of the whales were emaciated. UMEs for gray whales were also declared in 1999 and 2000 (NOAA 2019c).

Humpback Whale (*Megaptera novaeangliae*)

The humpback whale is found throughout all oceans of the World (Clapham 2018). Based on genetic data, there could be three subspecies, occurring in the North Pacific, North Atlantic, and Southern Hemisphere (Jackson et al. 2014). Nonetheless, genetic analyses suggest some gene flow (either past or present) between the North and South Pacific (e.g., Jackson et al. 2014; Bettridge et al. 2015). Although considered to be mainly a coastal species, humpback whales often traverse deep pelagic areas while migrating (Calambokidis et al. 2001; Garrigue et al. 2002, 2015; Zerbini et al. 2011). Humpbacks 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; Bettridge et al. 2015). Humpbacks winter in four different breeding areas: (1) the coast of Mexico; (2) 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 are recognized as the Mexico, Central America, Hawaii, and Western Pacific DPSs, but feeding areas have no DPS status (Bettridge et al. 2015; NMFS 2016b). There is potential for mixing of the western and eastern North Pacific humpback populations on their summer feeding grounds, but several sources suggest that this occurs to a limited extent (Muto et al. 2019a,b). NMFS is currently reviewing the global humpback whale stock structure in light of the revisions to their ESA listing and identification of 14 DPSs (NMFS 2016b).

During summer, most eastern North Pacific humpback whales are on feeding grounds in Alaska, with smaller numbers summering off the U.S. west coast and B.C. (Calambokidis et al. 2001, 2008). Individuals encountered in the proposed survey area would be from the Hawaii, Mexico, and/or Central America DPSs (Calambokidis et al. 2008; Ford 2014). The humpback whale is the most common species of large cetacean reported off the coasts of Oregon and Washington from May–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. 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; Barlow 2016). BIAs for feeding humpback whales along the coasts of Oregon and Washington, which have been designated from May–November, are all within ~80 km from shore, and include the waters off northern Washington, and Stonewall and Heceta Bank, OR; another five BIAs occur off California (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. There were 98 humpback whale sightings (213 animals) made during the July 2012 L-DEO seismic survey off southern Washington (RPS 2012a), and 11 sightings (23 animals) during the July 2012 L-DEO seismic survey off Oregon (RPS 2012c).

On 9 October 2019, NMFS issued a proposed rule to designate critical habitat in nearshore waters of the North Pacific Ocean for the ***endangered*** Central America DPS and the ***threatened*** Mexico DPS of humpback whale (NMFS 2019b). Critical habitat for the Central America DPS would include ~43,798 n.mi.^{2} within the CCE off the coasts California, Oregon, and Washington. Critical habitat for the Mexico DPS would include ~175,812 n.mi.^{2} in Alaska and within the CCE off the coasts California, Oregon, and Washington. Off Washington and northern Oregon, the critical habitat would extend from the 50-m isobath out to the 1200-m isobath; off southern Oregon (south of 42°10'), it would extend out to the 2000-m isobath (NMFS 2019b).

Humpback whales are common in the waters of B.C., where they occur in inshore, outer coastal, continental shelf waters, as well as offshore (Ford 2014). Williams and Thomas (2007) estimated an abundance of 1310 humpback whales in inshore coastal waters of B.C. based on surveys conducted in 2004 and 2005. Best et al. (2015) provided an estimate of 1029 humpbacks based on surveys during 2004–2008. In B.C., humpbacks are typically seen within 20 km from the coast, in water <500 m deep (Ford et al. 2010a). They were the most frequently sighted cetacean during DFO surveys in 2002–2008 (Ford et al. 2010a).

Critical habitat for humpbacks has been designated in four locations in B.C. (DFO 2013), including in the waters of the proposed survey area off southwestern Vancouver Island. The other three locations are located north of the proposed survey area at Haida Gwaii (Langara Island and Southeast Moresby Island)

and at Gil Island (DFO 2013). These areas show persistent aggregations of humpback whales and have features such as prey availability, suitable acoustic environment, water quality, and physical space that allow for feeding, foraging, socializing, and resting (DFO 2013). Two of the proposed transect lines intersect the critical habitat on Swiftsure and La Pérouse Banks. Humpbacks were detected acoustically on La Pérouse Bank from May through September 2007 (Ford et al. 2010b).

The greatest numbers are seen in B.C. between April and November, although humpbacks are known to occur there throughout the year (Ford et al. 2010a; Ford 2014). Gregr et al. (2000) also presented evidence of widespread winter foraging in B.C. based on whaling records. Humpback whales are thought to belong to at least two distinct feeding stocks in B.C.; those identified off southern B.C. show little interchange with those seen off northern B.C. (Calambokidis et al. 2001, 2008). Humpback whales identified in southern B.C. show a low level of interchange with those seen off California/Oregon/ Washington (Calambokidis et al. 2001). Humpback whales are likely to be common in the proposed survey area, especially in nearshore waters.

Common Minke Whale (*Balaenoptera acutorostrata scammoni*)

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 south to within 2º of the Equator (Perrin et al. 2018).

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 nearshore waters off west coast of the U.S. (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; Barlow 2016; Carretta et al. 2019a). 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 Oregon/Washington during the June–July 2012 L-DEO Juan de Fuca plate seismic survey or during the July 2012 L-DEO seismic survey off Oregon (RPS 2012b,c). One minke whale was seen during the July 2012 L-DEO seismic survey off southern Washington (RPS 2012a).

Minke whales are sighted regularly in nearshore waters of B.C., but they are not abundant (COSEWIC 2006). They are most frequently sighted around the Gulf Islands and off northeastern Vancouver Island (Ford 2014). They are also regularly seen off the east coast of Moresby Island, and in Dixon Entrance, Hecate Strait, Queen Charlotte Sound, and the west coast of Vancouver Island where they occur in shallow and deeper water (Ford et al. 2010a; Ford 2014). Williams and Thomas (2007) estimated minke whale abundance for inshore coastal waters of B.C. at 388 individuals based on surveys conducted in 2004 and 2005. Best et al. (2015) provided an estimate of 522 minke whales based on surveys during 2004–2008. Most sightings have been made during July and August; although most minke whales are likely to migrate south during the winter, they can be seen in B.C. waters throughout the year; however, few sightings occur from December through February (Ford 2014). Minke whales are expected to be uncommon in the proposed survey area.

Sei Whale (*Balaenoptera borealis*)

The sei whale occurs in all ocean basins (Horwood 2018), but appears to prefer mid-latitude temperate waters (Jefferson et al. 2015). It undertakes seasonal migrations to feed in subpolar latitudes during summer and returns to lower latitudes during winter to calve (Horwood 2018). The sei whale is pelagic and generally not found in coastal waters (Harwood and Wilson 2001). It occurs in deeper waters characteristic of the continental shelf edge region (Hain et al. 1985) and in other regions of steep bathymetric relief such as seamounts and canyons (Kenney and Winn 1987; Gregr and Trites 2001). On feeding grounds, sei whales associate with oceanic frontal systems (Horwood 1987) such as the cold eastern currents in the North Pacific (Perry et al. 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). Less than 20 confirmed sightings were reported in that region during extensive surveys during 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, 2010, 2014; Forney 2007; Carretta et al. 2019a). 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). No sei whales were sighted during the July 2012 L-DEO seismic surveys off Oregon and Washington (RPS 2012a,c).

Off the west coast of B.C., 4002 sei whales were caught from 1908–1967; the majority were taken from 1960–1967 during April–June (Gregr et al. 2000). The pattern of seasonal abundance suggested that the whales were caught as they migrated to summer feeding grounds, with the peak of the migration in July and offshore movement in summer, from ~25 km to ~100 km from shore (Gregr et al. 2000). Historical whaling data show that sei whales used to be distributed along the continental slope of B.C. and over a large area off the northwest coast of Vancouver Island (Gregr and Trites 2001).

Sei whales are now considered rare in Pacific waters of the U.S. and Canada; in B.C., there were no sightings in the late 1900s after whaling ceased (Gregr et al. 2006). A single sei whale was seen off southeastern Moresby Island in Hecate Strait coastal surveys in the summers of 2004/2005 (Williams and Thomas 2007). Ford (2014) only reported two sightings for B.C., both of those far offshore from Haida Gwaii. Possible sei whale vocalizations were detected off the west coast of Vancouver Island during spring and summer 2006 and 2007 (Ford et al. 2010b). Gregr and Trites (2001) proposed that the area off northwestern Vancouver Island and the continental slope may be critical habitat for sei whales because of favorable feeding conditions; however, no critical habitat has been designated (Parks Canada 2016). Sei whales could be encountered during the proposed survey, although this species is considered rare in these waters.

Fin Whale (*Balaenoptera physalus*)

The fin whale is widely distributed in all the World's oceans (Gambell 1985b), although it is most abundant in temperate and cold waters (Aguilar and García-Vernet 2018). Nonetheless, its overall range and distribution are not well known (Jefferson et al. 2015). A review of fin whale distribution in the North

Pacific noted the lack of sightings across pelagic waters between eastern and western winter areas (Mizroch et al. 2009). Fin whales most commonly occur offshore, but can also be found in coastal areas (Jefferson et al. 2015).

Most populations migrate seasonally between temperate waters where mating and calving occur in winter, and polar waters where feeding occurs in summer (Aguilar and García-Vernet 2018). Some animals may remain at high latitudes in winter or low latitudes in summer (Edwards et al. 2015). The northern and southern fin whale populations likely do not interact owing to their alternate seasonal migration; the resulting genetic isolation has led to the recognition of two subspecies, *B. physalus quoyi* and *B. p. physalus* in the Southern and Northern hemispheres, respectively (Anguilar and García-Vernet 2018). The fin whale is known to use the shelf edge as a migration route (Evans 1987). Sergeant (1977) suggested that fin whales tend to follow steep slope contours, either because they detect them readily, or because the contours are areas of high biological productivity. However, fin whale movements have been reported to be complex (Jefferson et al. 2015). Stafford et al. (2009) noted that sea-surface temperature is a good predictor variable for fin whale call detections in the North Pacific.

North Pacific fin whales summer from the Chukchi Sea to California and winter from California southwards (Gambell 1985b). Information about the seasonal distribution of fin whales in the North Pacific has been obtained from the detection of fin whale calls by bottom-mounted, offshore hydrophone arrays along the U.S. Pacific coast, in the central North Pacific, and in the western Aleutian Islands (Moore et al. 1998, 2006; Watkins et al. 2000a,b; Stafford et al. 2007, 2009). Fin whale calls are recorded in the North Pacific year-round (e.g., Moore et al. 2006; Stafford et al. 2007, 2009; Edwards et al. 2015). In the central North Pacific, the Gulf of Alaska, and Aleutian Islands, call rates peak during fall and winter (Moore et al. 1998, 2006; Watkins et al. 2000a,b; Stafford et al. 2009).

Fin whales are routinely sighted during surveys off Oregon and Washington (Barlow and Forney 2007; Barlow 2010, 2016; Adams et al. 2014; Calambokidis et al. 2015; Edwards et al. 2015; Carretta et al. 2019a), including in coastal as well as offshore waters. They have also been detected acoustically in those waters during June–August (Edwards et al. 2015). Eight fin whale sightings (19 animals) were made off Washington/Oregon during the June–July 2012 L-DEO Juan de Fuca plate seismic survey; 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 (RPS 2012a). No fin whales were sighted during the July 2012 L-DEO seismic survey off Oregon (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).

From 1908–1967, 7605 fin whales were caught off the west coast of B.C. by whalers; catches increased gradually from March to a peak in July, then decreased rapidly to very few in September and October (Gregr et al. 2000). Fin whales occur throughout B.C. waters near and past the continental shelf break, as well as in inshore waters (Ford 2014). Williams and Thomas (2007) estimated fin whale abundance in inland coastal B.C. waters at 496 based on surveys conducted in 2004 and 2005. Best et al. (2015) provided an estimate of 329 whales based on surveys during 2004–2008. Although fin whale records exist throughout the year, few sightings have been made from November through March (Ford 2014; Edwards et al. 2015). Fin whales were the second most common cetacean sighted during DFO surveys in 2002–2008 (Ford et al. 2010a). They appear to be more common in northern B.C., but sightings have been made along the shelf edge and in deep waters off western Vancouver Island (Ford et al. 1994, 2010a; Calambokidis et al. 2003; Ford 2014). Acoustic detections have been made throughout the year in pelagic waters west of Vancouver Island (Edwards et al. 2015). Calls were detected from February through July 2006 at Union Seamount off northwestern Vancouver island, and from May through September at La

Pérouse Bank (Ford et al. 2010b). Gregr and Trites (2001) proposed that the area off northwestern Vancouver Island and the continental slope may be critical habitat for fin whales because of favorable feeding conditions; however, no critical habitat has been designated (Parks Canada 2016). Fin whales are likely to be encountered 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 2018). The status of these two populations could differ substantially, as little is known about the population size in the western North Pacific (Branch et al. 2016). 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).

In the North Pacific, blue whale calls are detected year-round (Stafford et al. 2001, 2009; Moore et al. 2002b, 2006; Monnahan et al. 2014). Stafford et al. (2009) reported that sea-surface temperature is a good predictor variable for blue whale call detections in the North Pacific. 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 are considered rare off Oregon, Washington, and B.C. (Buchanan et al. 2001; Gregr et al. 2006; Ford 2014), although satellite-tracked individuals have been reported off the coast (Bailey et al. 2009). Based on modeling of the dynamic topography of the region, blue whales could occur in relatively high densities off Oregon during summer and fall (Pardo et al. 2015: Hazen et al. 2017). 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). Blue whales have been detected acoustically off Oregon (McDonald et al. 1995; Stafford et al. 1998; Von Saunder and Barlow 1999).

Whalers used to take blue whales in offshore waters of B.C.; from 1908–1967, 1398 blue whales were caught (Gregr et al. 2000). Since then, sightings have been rare (Ford 2014; DFO 2017) and there is no abundance estimate for B.C. waters (Nichol and Ford 2012). During surveys of B.C. waters from 2002–2013, 16 sightings of blue whales were made, all of which occurred just to the south or west of Haida Gwaii during June, July, and August (Ford 2014). Seventeen blue whales have been photo identified off Haida Gwaii, B.C., and three were matched with whales occurring off California (Calambokidis et al. 2004b; Nichol and Ford 2012; Ford 2014). There have also been sightings off Vancouver Island during summer and fall (Calambokidis et al. 2004b; Ford 2014), with the most recent one reported off southwestern Haida Gwaii in July 2019 (CBC 2019). Blue whales were regularly detected on bottom-mounted hydrophones deployed off B.C. (Sears and Calambokidis 2002). Blue whale calls off Vancouver Island begin during August, increase in September and October, continue through November–February, and decline by March (Burtenshaw et al. 2004; Ford et al. 2010b; Ford 2014). They were detected on La Pérouse Bank, off southwestern Vancouver Island, during September 2007 but no calls were detected at Union Seamount, offshore from northwestern Vancouver Island (Ford et al. 2010b). Blue whales could be encountered in the proposed survey area, but are considered rare in the region.

Odontocetes

Sperm Whale (*Physeter macrocephalus*)

The sperm whale is widely distributed, occurring from the edge of the polar pack ice to the Equator in both hemispheres, with the sexes occupying different distributions (Whitehead 2018). In general, it is distributed over large temperate and tropical areas that have high secondary productivity and steep underwater topography, such as volcanic islands (Jaquet and Whitehead 1996). Its distribution and relative abundance can vary in response to prey availability, most notably squid (Jaquet and Gendron 2002). Females generally inhabit waters >1000 m deep at latitudes <40º where sea surface temperatures are <15ºC; adult males move to higher latitudes as they grow older and larger in size, returning to warm-water breeding grounds according to an unknown schedule (Whitehead 2018).

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). Sperm whales were sighted during surveys off Oregon in October 2011 and off Washington in June 2011 (Adams et al. 2014). Sperm whale sightings were also made off Oregon and Washington during the 2014 Southwest Fisheries Science Center (SWFSC) vessel survey (Barlow 2016). Sperm whales were detected acoustically in waters off Oregon and Washington in August 2016 during the SWFSC Passive Acoustics Survey of Cetacean Abundance Levels (PASCAL) study using drifting acoustic recorders (Keating et al. 2018). 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 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 an inshore site from June through January 2009, with an absence of calls during February–May (Širović et al. 2012).

From 1908–1967, 6158 sperm whales were caught off the west coast of B.C. They were taken in large numbers in April, with a peak in May. Analysis of data on catch locations, sex of the catch, and fetus lengths indicated that males and females were both 50–80 km from shore while mating in April and May, and that by July and August, adult females had moved to waters >100 km offshore to calve), and adult males had moved to within ~25 km of shore (Gregr et al. 2000). At least in the whaling era, females did not travel north of Vancouver Island whereas males were observed in deep water off Haida Gwaii (Gregr et al. 2000). After the whaling era, sperm whales have been sighted and detected acoustically in B.C. waters throughout the year, with a peak during summer (Ford 2014). Acoustic detections at La Pérouse Bank off southwestern Vancouver Island have been recorded during spring and summer (Ford et al. 2010b). Sightings west of Vancouver Island and Haida Gwaii indicate that this species still occurs in B.C. in small numbers (Ford et al. 1994; Ford 2014). A single sperm whale was sighted during the 2009 ETOMO survey, west of the proposed survey area (Holst 2017). Based on whaling data, Gregr and Trites (2001) proposed that the area off northwestern Vancouver Island and the continental slope may be critical habitat for male sperm whales because of favorable feeding conditions; however, no critical habitat has been designated (Parks Canada 2016). Sperm whales are likely to be encountered in the proposed survey area.

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

Dwarf and pygmy sperm whales are distributed throughout tropical and temperate waters of the Atlantic, Pacific and Indian oceans, but their precise distributions are unknown because much of what we know of the species comes from strandings (McAlpine 2018). They are difficult to sight at sea, because of their dive behavior and perhaps because of their avoidance reactions to ships and behavior changes in relation to survey aircraft (Würsig et al. 1998). The two species are often difficult to distinguish from one another when sighted (McAlpine 2018).

Both *Kogia* species are sighted primarily along the continental shelf edge and slope and over deeper waters off the shelf (Hansen et al. 1994; Davis et al. 1998; Jefferson et al. 2015). Stomach content analyses from stranded whales further support this distribution (McAlpine 2018). Recent data indicate that both *Kogia* species feed in the water column and on/near the seabed, likely using echolocation to search for prey (McAlpine 2018). Several studies have suggested that pygmy sperm whales live and feed mostly beyond the continental shelf edge, whereas dwarf sperm whales tend to occur closer to shore, often over the continental shelf and slope (Rice 1998; Wang et al. 2002; MacLeod et al. 2004; McAlpine 2018). It has also been suggested that the pygmy sperm whale is more temperate and the dwarf sperm whale more tropical, based at least partially on live sightings at sea from a large database from the eastern tropical Pacific (Wade and Gerrodette 1993; McAlpine 2018).

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. 2019a). 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. There are several unconfirmed sighting reports of the pygmy sperm whale from the Canadian west coast (Baird et al. 1996). There is a stranding record of a pygmy sperm whale for northeastern Vancouver Island (Ford 2014), and there is a single dwarf sperm whale stranding record for southwestern Vancouver Island in September 1981 (Ford 2014). Willis and Baird (1998) state that the dwarf sperm whale is likely found in B.C. waters more frequently than recognized, but Ford (2014) suggested that the presence of *Kogia* spp. in B.C. waters is extralimital. Despite the limited number of sightings, 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 and common of the beaked whales, although it is not found in high-latitude polar waters (Heyning 1989; Baird 2018a). It is rarely observed at sea and is known mostly from strandings; it strands more commonly than any other beaked whale (Heyning 1989). Cuvier's beaked whale is found in deep water in the open ocean and over and near the continental slope (Gannier and Epinat 2008; Baird 2018a). 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 LME seems to be declining (Moore and Barlow 2013). Nonetheless, 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 1991–1995 (Barlow 1997). One Cuvier's beaked whale sighting during surveys in 2014 (Barlow 2016). Acoustic monitoring in Washington offshore waters detected Cuvier's beaked whale calls between January and November 2011 (Ŝirović et al. 2012b *in* USN 2015). Cuvier's beaked whales were detected acoustically in waters off Oregon and Washington in August 2016 during the SWFSC PASCAL study using drifting acoustic recorders (Keating et al. 2018). Records of Cuvier's beaked whale in B.C. are scarce, although 20 strandings, one incidental catch, and five sightings have been reported, including off western Vancouver Island (Ford 2014). Most strandings have been reported in summer (Ford 2014). Cuvier's beaked whales could be encountered during the proposed survey.

Baird's Beaked Whale (*Berardius bairdii*)

Baird's beaked whale has a fairly extensive range across the North Pacific north of 30°N, and strandings have occurred as far north as the Pribilof Islands (Rice 1986). Two forms of Baird's beaked whales have been recognized – the common slate-gray form and a smaller, rare black form (Morin et al. 2017). The gray form is seen off Japan, in the Aleutians, and on the west coast of North America, whereas the black from has been reported for northern Japan and the Aleutians (Morin et al. 2017). Recent genetic studies suggest that the black form could be a separate species (Morin et al. 2017). Baird's beaked whale is currently divided into three distinct stocks: Sea of Japan, Okhotsk Sea, and Bering Sea/eastern North Pacific (Balcomb 1989; Reyes 1991). Baird's beaked whales sometimes are seen close to shore, but their primary habitat is over or near the continental slope and oceanic seamounts in waters 1000–3000 m deep (Jefferson et al. 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. 2019a) 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 in the waters off Oregon and Washington in August 2016 during the SWFSC PASCAL study using drifting acoustic recorders (Keating et al. 2018).

There are whaler's reports of Baird's beaked whales off the west coast of Vancouver Island throughout the whaling season (May–September), especially in July and August (Reeves and Mitchell 1993). From 1908–1967, there was a recorded catch of 41 Baird's beaked whales, which were not favored because of their small size and low commercial value (Gregr et al. 2000). Twenty-four sightings have been made in B.C. since the whaling era, including off the west coast of Vancouver Island (Ford 2014). Three strandings have also been reported, including one on northeastern Haida Gwaii and two on the west coast of Vancouver Island. Baird's beaked whales could be encountered in the proposed survey area.

Blainville's Beaked Whale (*Mesoplodon densirostris*)

Blainville's beaked whale is found in tropical and warm temperate waters of all oceans (Pitman 2018). It has the widest distribution throughout the world of all *Mesoplodon* species (Pitman 2018). 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 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 off Washington or Oregon during the August 2016 SWFSC PASCAL study using drifting acoustic recorders (Keating et al. 2018). No sightings have been made off B.C. (Ford 2014). 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.

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 are from California, but at least seven strandings have been recorded along the B.C. coast as far north as Prince Rupert (Mead 1989; Houston 1990a; Willis and Baird 1998; Ford 2014). Two strandings are known from Washington/Oregon (Norman et al. 2004). In addition, at least two sightings off Oregon/Washington, but outside the U.S. EEZ, were reported by Carretta et al. (2019a). During the 2016 SWFSC PASCAL study using drifting acoustic recorders, detections were made of beaked whale sounds presumed to be from Hubbs' beaked whales off Washington and Oregon during August (Griffiths et al. submitted manuscript cited *in* Keating et al. 2018). There have been no confirmed sightings of Hubbs' beaked whales in B.C. 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.

Stejneger's Beaked Whale (*Mesoplodon stejnegeri*)

Stejneger's beaked whale occurs in subarctic and cool temperate waters of the North Pacific (Mead 1989). Most records are from Alaskan waters, and the Aleutian Islands appear to be its center of distribution (Mead 1989; Wade et al. 2003). 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–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 off Oregon and Washington in August 2016 during the SWFSC PASCAL study using drifting acoustic recorders (Keating et al. 2018).

At least five stranding records exist for B.C. (Houston 1990b; Willis and Baird 1998; Ford 2014), including two strandings on the west coast of Haida Gwaii and two strandings on the west coast of Vancouver Island (Ford 2014). A possible sighting was made on the east coast of Vancouver Island (Ford 2014). Stejneger's beaked whales could be encountered during the proposed survey.

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 and Washington (Carretta et al. 2019a). 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. 2019a). Adams et al. (2014) made one sighting off Washington during September 2012. There are no confirmed records of bottlenose dolphins for B.C., although an unconfirmed record exists for offshore waters (Baird et al. 1993). It is possible, although unlikely, that bottlenose 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 The striped dolphin has a cosmopolitan distribution in tropical to warm temperate waters from ~50°N to 40°S (Perrin et al. 1994; Jefferson et al. 2015). It occurs primarily in pelagic waters, but has been observed approaching shore where there is deep water close to the coast (Jefferson et al. 2015). The striped dolphin is typically found in waters outside the continental shelf and is often associated with convergence zones and areas of upwelling; 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), including as far offshore as ~300 n.mi. during the NOAA Fisheries vessel surveys (Carretta et al. 2019a). However, few sightings have been made off Oregon, and no sightings have been reported for Washington (Carretta et al. 2019a). 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 Oregon/Washington. The abundance estimates for 2001, 2005, and 2008 were zero (Barlow 2016).

Striped dolphins are rare in the waters of B.C. and are considered extralimital there (Ford 2014). There are a total of 14 confirmed records of stranded individuals or remains for Vancouver Island (Ford 2014). A single confirmed sighting was made in September 2019 in the Strait of Juan de Fuca (Pacific Whale Watch Association 2019). One bycatch record exists in waters far offshore from Vancouver Island (Ford 2014). It is possible, although unlikely, that striped 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 (Jefferson et al. 2015), ranging from ~60ºN to ~50ºS (Jefferson et al. 2015). It is the most abundant dolphin species in offshore areas of warm-temperate regions in the Atlantic and Pacific (Perrin 2018). It can be found in oceanic and coastal habitats; it is common in coastal waters 200–300 m deep and is also associated with prominent underwater topography, such as seamounts (Evans 1994). 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. 2019a). 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 estuary during summer, with lower densities off southern Oregon (Becker et al. 2014). There are three stranding records for B.C., including one for northwestern Vancouver Island, one for the Strait of Juan de Fuca, and one for Hecate Strait (Ford 2014). Common 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, 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 (RPS 2012b). There were fifteen Pacific white-sided dolphin sightings (462 animals) made during the July 2012 L-DEO seismic surveys off southern Washington (RPS 2012a). This species was not sighted during the July 2012 L-DEO seismic survey off Oregon (RPS 2012c). One group of 10 Pacific white-sided dolphins was sighted during the 2009 ETOMO survey west of the proposed survey area (Holst 2017).

Pacific white-sided dolphins are common throughout the waters of B.C., including Dixon Entrance, Hecate Strait, Queen Charlotte Sound, the west coast of Haida Gwaii, as well as western Vancouver Island, and the mainland coast (Ford 2014). Stacey and Baird (1991a) compiled 156 published and unpublished records to 1988 of the Pacific white-sided dolphin within the Canadian 320-km extended EEZ. These dolphins move inshore and offshore seasonally (Stacey and Baird 1991a). There were inshore records for all months except July, and offshore records from all months except December. Offshore sightings were much more common than inshore sightings, especially in June–October; the mean water depth was ~1100 m. Ford et al. (2011b) reported that most sightings occur in water depths <500 m and within 20 km from shore. Williams and Thomas (2007) estimated an abundance of 25,900 Pacific white-sided dolphins in inshore coastal B.C. waters based on surveys conducted in 2004 and 2005. Best et al. (2015) provided an estimate of 22,160 individuals based on surveys during 2004–2008. 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, 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).

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).

There are 47 records for B.C., mostly in deep water off the west coast of Vancouver Island; however, sightings have also been made in deep water off Haida Gwaii (Ford 2014). Most sightings have occurred in water depths >900 m (Baird and Stacey 1991a). One group of six northern right whale dolphins was seen west of Vancouver Island in water deeper than 2500 m during a survey from Oregon to Alaska (Hauser and Holst 2009). 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 mid-temperate and tropical oceans (Kruse et al. 1999). although it shows a preference for mid-temperate waters of the shelf and slope between 30° and 45° (Jefferson et al. 2014). Although it occurs from coastal to deep water (~200–1000 m depth), it shows a strong preference for mid-temperate waters of upper continental slopes and steep shelf-edge areas (Hartman 2018).

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. 2019a). 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).

Risso's dolphin was once considered rare in B.C., but there have been numerous sightings since the 1970s (Ford 2014). In B.C., most sightings have been made in Gwaii Haanas National Park Reserve, Haida Gwaii, but there have also been sightings in Dixon Entrance, off the west coast of Haida Gwaii, Queen Charlotte Sound, as well as to the west of Vancouver Island (Ford 2014). Strandings have mainly been reported for the Strait of Georgia (Ford 2014). Risso's dolphins could be encountered in the proposed survey area.

False Killer Whale (*Pseudorca crassidens*)

The false killer whale is found worldwide in tropical and temperate waters, generally between 50ºN and 50ºS (Odell and McClune 1999). It is widely distributed, but not abundant anywhere (Carwardine 1995). The false killer whale generally inhabits deep, offshore waters, but sometimes is found over the continental shelf and occasionally moves into very shallow (Jefferson et al. 2015; Baird 2018b). It is gregarious and forms strong social bonds, as is evident from its propensity to strand en masse (Baird 2018b). 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 1986–2001 (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 false killer whales were reported stranded along the Washington coast during 1930–2002, both in El Niño years (Norman et al. 2004).

Stacey and Baird (1991b) suggested that false killer whales are at the limit of their distribution in Canada and have always been rare. Sightings have been made along the northern and central mainland B.C. coast, as well as in Queen Charlotte Strait, Strait of Georgia, and along the west coast of Vancouver Island; there are no records for deeper water in the proposed survey area (Ford 2014). 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 2018). It is very common in temperate waters and also frequents tropical waters, at least seasonally (Heyning and Dahlheim 1988). Killer whales are segregated socially, genetically, and ecologically into three distinct ecotypes: residents, transients, and offshore animals. Killer whales occur in inshore inlets, along the coast, over the continental shelf, and in offshore waters (Ford 2014).

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 B.C. through parts of Southeast Alaska; (3) Southern Residents, mainly in inland waters of Washington State and southern B.C.; (4) Gulf of Alaska, Aleutians, and Bering Sea Transients, from Prince William Sound through to the Aleutians and Bering Sea; (5) AT1 Transients, from Prince William Sound through the Kenai Fjords; (6) West Coast Transients, from California through Southeast Alaska; (7) Offshore, from California through Alaska; and (8) Hawaiian (Muto et al. 2019a,b; Carretta et al. 2019a,b). Individuals from the Southern

Resident, Northern Resident, West Coast Transient, and Offshore stocks could be encountered in the proposed project area.

Resident killer whales mainly feed on salmon, in particular Chinnok, and their movements coincide with those of their prey (Ford 2014). Southern resident killer whales primarily occur in the southern Strait of Georgia, Strait of Juan de Fuca, Puget Sound, and the southern half of the west coast of Vancouver Island (Ford et al. 1994; Baird 2001; Carretta et al. 2019a,b). These areas have been designated as critical habitat either by the U.S. or Canada. Critical habitat in the U.S. currently includes three specific marine areas of Puget Sound, WA: the Summer Core Area, Puget Sound, and the Strait of Juan de Fuca (Fig. 1; NMFS 2006). In the fall, this population is known to occur in Puget Sound, and during the winter, it occurs along the outer coast and does not spend a lot of time in critical habitat areas (Ford 2014).

The U.S. critical habitat includes all waters relative to a contiguous shoreline delimited by the line at a depth of 6.1 m relative to extreme high water. The western boundary of the Strait of Juan de Fuca Area is Cape Flattery, WA (48.38°N; 124.72°W), which is ~18 km from the closest seismic transect line (Fig. 1). In January 2014, NMFS received a petition requesting an expansion to the Southern Resident killer whale critical habitat to include Pacific Ocean marine waters along the U.S. west coast from Cape Flattery, WA, to Point Reyes, CA, extending ~76 km offshore; NMFS released a 12-month finding in February 2015 accepting the validity of a critical habitat expansion (NMFS 2015). Although no revisions have yet been made to the critical habitat, NMFS recently issued a proposed rule for the expansion of critical habitat to include U.S. coastal waters between the 6.1-m and 200-m isobath from the border with Canada south to Point Sur, CA (NMFS 2019a).

In Canada, critical habitat for southern resident killer whales has been designated in the trans-boundary waters in southern B.C., including the southern Strait of Georgia, Haro Strait, and Strait of Juan de Fuca (DFO 2018). The continental shelf waters off southwestern Vancouver Island, including Swiftsure and La Pérouse Banks have also been designated as critical habitat (DFO 2018). The critical habitat has features such as prey availability (specifically chinook and chum salmon), appropriate acoustic environment, water quality, and physical space, and suitable physical habitat that provide areas for feeding, foraging, reproduction, socializing, and resting (DFO 2018). Two of the proposed transect lines intersect the critical habitat on Swiftsure and La Pérouse Banks.

In B.C., the northern residents inhabit the central and northern Strait of Georgia, Johnstone Strait, Queen Charlotte Strait, the west coast of Vancouver Island, and the entire central and north coast of mainland B.C. (Muto et al. 2019a,b). Many sightings have been made in Dixon Entrance and eastern Hecate Strait, which is also considered important habitat (Ford 2014). Critical habitat for the northern resident killer whale has been designated in Jonstone Strait, southeastern Queen Charlotte Strait, western Dixon Entrance along the north coast of Graham Island, Haida Gwaii, and Swiftsure and La Pérouse Banks off southwestern Vancouver Island (DFO 2018). Both northern and southern resident killer whales often forage at Swiftsure and La Pérouse Banks in the summer (Ford 2014).

The main diet of transient killer whales consists of marine mammals, in particular porpoises and seals. West coast transient whales (also known as Bigg's killer whales) range from Southeast Alaska to California (Muto et al. 2019a). The seasonal movements of transients are largely unpredictable, although there is a tendency to investigate harbor seal haulouts off Vancouver Island more frequently during the pupping season in August and September (Baird 1994; Ford 2014). Transients have been sighted throughout B.C. waters, including the waters around Vancouver Island (Ford 2014). 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. Two of 17 killer whales that stranded in Oregon were confirmed as transient (Stevens et al. 1989 *in* Norman et al. 2004).

Little is known about offshore killer whales, but they occur primarily over shelf waters and feed on fish, especially sharks (Ford 2014). Dahlheim et al. (2008) reported sightings in Southeast Alaska during spring and summer. Relatively few sightings have been reported in the waters of B.C.; there have been 103 records since 1988 (Ford 2014). The number of sightings are likely influenced by the fact that these whales prefer deeper waters near the slope, where little sighting effort has taken place (Ford 2014). Most sightings are from Haida Gwaii and 15 km or more off the west coast of Vancouver Island near the continental slope (Ford et al. 1994). Offshore killer whales are mainly seen off B.C. during summer and off California during winter, but they can occur in B.C. waters year-round (Ford 2014). Based on surveys conducted during 2004–2008, Best et al. (2015) estimated that 371 killer whales (all ecotypes) occur in coastal waters of B.C.

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) analyzed 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).

Killer whales could be encountered during the proposed surveys, including northern and southern resident killer whales in their critical habitat in Canada. However, most sightings within the critical habitat off southwestern Vancouver Island have occurred closer to shore than the proposed seismic transects.

Short-finned Pilot Whale (*Globicephala macrorhynchus*)

The short-finned pilot whale is found in tropical and warm temperate waters (Olson 2018); 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 2018). 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. 2019a). Few sightings were made off California/Oregon/ Washington in 1984–1992 (Green et al. 1992; Carretta and Forney 1993; Barlow 1997), but 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). Carretta et al. (2019a) reported one sighting off Oregon during 1991–2014. 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).

Short-finned pilot whales are considered rare in B.C. waters (Baird and Stacey 1993; Ford 2014). There are 10 confirmed records, including three bycatch records in offshore waters, six sightings in offshore waters, and one stranding; the stranding occurred in the Strait of Juan de Fuca (Ford 2014). There are also unconfirmed records for nearshore waters of western Vancouver Island (Baird and Stacey 1993; Ford 2014). Pilot whales are expected to be rare in the proposed survey area.

Harbor Porpoise (*Phocoena phocoena*)

The harbor porpoise inhabits temperate, subarctic, and arctic waters. It is typically found in shallow water (<100 m) nearshore but is occasionally sighted in deeper offshore water (Jefferson et al. 2015); abundance declines linearly as depth increases (Barlow 1988). In the eastern North Pacific, its range extends from Point Barrow, Alaska, to Point Conception, California. Their seasonal movements appear to be inshore-offshore, rather than north-south, as a response to the abundance and distribution of food resources (Dohl et al. 1983; Barlow 1988). Genetic testing has also shown that harbor porpoises along the west coast of North America are not migratory and occupy restricted home ranges (Rosel et al. 1995).

Based on genetic data and density discontinuities, six stocks have been identified in California/ Oregon/Washington: (1) Washington Inland Waters, (2) Northern Oregon/Washington Coast, (3) Northern

California/Southern Oregon, (4) San Francisco-Russian River, (5) Monterey Bay, and (6) Morro Bay (Carretta et al. 2019a). Harbor porpoises from the Northern Oregon/Washington and the Northern California/Southern Oregon stocks could occur in the proposed project area (Carretta et al. 2019a).

Harbor porpoises inhabit coastal Oregon and Washington waters year-round, although there appear to be distinct seasonal changes in abundance there (Barlow 1988; Green et al. 1992). Green et al. (1992) reported that encounter rates were similarly high during fall and winter, intermediate during spring, and low during summer. Encounter rates were highest along the Oregon/Washington coast in the area from Cape Blanco (~43°N) to California, from fall through spring. During summer, the reported encounter rates decreased notably from inner shelf to offshore waters. Green et al. (1992) reported that 96% of harbor porpoise sightings off Oregon/Washington occurred in coastal waters <100 m deep, with a few sightings on the slope near the 200-m isobath. Similarly, predictive density distribution maps show the highest in nearshore waters along the coasts of Oregon/Washington, with very low densities beyond the 500-m isobath (Menza et al. 2016).

Based on surveys conducted during 2004 and 2005, Williams and Thomas (2007) estimated that 9120 harbor porpoises are present in inshore coastal waters of B.C. Best et al. (2015) provided an estimate of 8091 based on surveys during 2004–2008. Harbor porpoises are found along the coast year-round, primarily in coastal shallow waters, harbors, bays, and river mouths of B.C. (Osborne et al. 1988), but can also be found in deep water over the continental shelf and over offshore banks that are no deeper than 150 m (Ford 2014; COSEWIC 2016). Many sightings exist for nearshore waters of Vancouver Island (Ford 2014), including within the proposed survey area. Occasional sightings have also been made in shallow water of Swiftsure and La Pérouse banks off southwestern Vancouver Island (Ford 2014). Harbor porpoises could be encountered in shallower water in the eastern portions of the proposed project area.

Dall's Porpoise (*Phocoenoides dalli*)

Dall's porpoise is found in temperate to subarctic 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; Fleming et al. 2018; Carretta et al. 2019a). 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 (RPS 2012b). There were 16 Dall's porpoise sightings (54 animals) made during the July 2012 L-DEO seismic surveys off southern Washington (RPS 2012a). This species was not sighted during the July 2012 L-DEO seismic survey off Oregon (RPS 2012c).

Dall's porpoise is found all along the B.C. coast and is common inshore and offshore throughout the year (Jefferson 1990; Ford 2014). It is most common over the continental shelf and slope, but also occurs >2400 km from the coast (Pike and MacAskie 1969 *in* Jefferson 1990), and sightings have been made throughout the proposed survey area (Ford 2014). There appears to be a distributional shift inshore during the summer and offshore in winter (Ford 2014). Based on surveys conducted in 2004 and 2005, Williams and Thomas (2007) estimated that there are 4910 Dall's porpoises in inshore coastal waters of B.C. Best et al. (2015) provided an estimate of 5303 individuals based on surveys during 2004–2008. During a survey from Oregon to Alaska, Dall's porpoises were sighted west of Vancouver Island and Haida Gwaii in early October during the southbound transit, but none were sighted in mid-September during the northward transit; all sightings were made in water deeper than 2000 m (Hauser and Holst 2009). Dall's porpoise was the most frequently sighted marine mammal species (5 sightings or 28 animals) during the 2009 ETOMO survey west of the proposed survey area (Holst 2017). Dall's porpoise is likely to be encountered during the proposed seismic survey.

Pinnipeds

Guadalupe Fur Seal (*Arctocephalus townsendi*)

Most breeding and births occur at Isla Guadalupe, Mexico; a secondary rookery exists at Isla Benito del Este (Maravilla-Chavez and Lowry 1999; Aurioles-Gamboa et al. 2010). A few Guadalupe fur seals are known to occur at California sea lion rookeries in the Channel Islands, primarily San Nicolas and San Miguel islands, and sightings have also been made at Santa Barbara and San Clemente islands (Stewart et al. 1987; Carretta et al. 2019a,b). Guadalupe fur seals prefer rocky habitat for breeding and hauling out. They generally haul out at the base of towering cliffs on shores characterized by solid rock and large lava blocks (Peterson et al. 1968), although they can also inhabit caves and recesses (Belcher and Lee 2002). While at sea, this species usually is solitary but typically gathers in the hundreds to thousands at breeding sites.

During the summer breeding season, most adults occur at rookeries in Mexico (Carretta et al. 2019a,b; Norris 2017 *in* USN 2019a,b). Following the breeding season, adult males tend to move northward to forage. Females have been observed feeding south of Guadalupe Island, making an average round trip of 2375 km (Ronald and Gots 2003). Several rehabilitated Guadalupe fur seals that were satellite tagged and released in central California traveled as far north as B.C. (Norris et al. 2015; Norris 2017 *in* USN 2019a,b). Fur seals younger than two years old are more likely to travel to more northerly, offshore areas than older fur seals (Norris 2017 *in* USN 2019a,b). Stranding data also indicates that fur seals younger than 2 years are more likely to occur in the proposed survey area, as this age class was most frequently reported (Lambourn et al. 2012 *in* USN 2019a,b). In 2015–2016, 175 Guadalupe fur seals stranded on the coast of California; NMFS declared this an unusual mortality event (Carretta et al. 2019a,b). Guadalupe fur seals could be encountered during the proposed seismic survey, but most animals are likely to occur at their breeding sites further south at the time of the survey.

Northern Fur Seal (*Callorhinus ursinus*)

The northern fur seal is endemic to the North Pacific Ocean and occurs from southern California to the Bering Sea, Okhotsk Sea, and Honshu Island, Japan (Muto et al. 2019a,b). During the breeding season, most of the worldwide population of northern fur seals inhabits the Pribilof Islands in the southern Bering Sea (NMFS 2007; Lee et al. 2014; Muto et al. 2019a,b). The rest of the population occurs at rookeries on Bogoslof Island in the Bering Sea, in Russia (Commander Islands, Robben Island, Kuril Islands), on San Miguel Island in southern California (NMFS 1993; Lee et al. 2014), and on the Farallon Islands off central California (Muto et al. 2019a,b). In the U.S., two stocks are recognized—the Eastern Pacific and the California stocks (Muto et al. 2019a,b). The Eastern Pacific stock ranges from the Pribilof Islands and Bogoslof Island in the Bering Sea during summer to California during winter (Muto et al. 2019a,b).

When not on rookery islands, northern fur seals are primarily pelagic but occasionally haul out on rocky shorelines (Muto et al. 2019a,b). During the breeding season, adult males usually come ashore in May–August and may sometimes be present until November; adult females are found ashore from June–November (Carretta et al. 2019a; Muto et al. 2019a,b). After reproduction, northern fur seals spend the next 7–8 months feeding at sea (Roppel 1984). Immature seals can remain in southern foraging areas year-round until they are old enough to mate (NMFS 2007). In November, females and pups leave the Pribilof Islands and migrate through the Gulf of Alaska to feeding areas primarily off the coasts of B.C., Washington, Oregon, and California before migrating north again to the rookeries in spring (Ream et al. 2005; Pelland et al. 2014). Males usually migrate only as far south as the Gulf of Alaska (Kajimura 1984). Ream et al. (2005) showed that migrating females moved over the continental shelf as they migrated southeasterly. Instead of following depth contours, their travel corresponded with movements of the Alaska Gyre and the North Pacific Current (Ream et al. 2005). Their foraging areas were associated with eddies, the subarctic-subtropical transition region, and coastal mixing (Ream et al. 2005; Alford et al. 2005). Some juveniles and non-pregnant females may remain in the Gulf of Alaska throughout the summer (Calkins 1986). 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. Pups from the California stock also migrate to Washington, Oregon, and northern California after weaning (Lea et al. 2009).

Northern fur seals were seen throughout the North Pacific during surveys conducted during 1987–1990, including off Vancouver Island and in the western Gulf of Alaska (Buckland et al. 1993). 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). Tracked adult male fur seals that were tagged on St. Paul Island in the Bering Sea in October 2009, wintered in the Bering Sea or northern North Pacific Ocean; females migrated to the Gulf of Alaska and the California Current, including off the west coasts of Haida Gwaii and Vancouver Island (Sterling et al. 2014). Some individuals reach California by December, after which time numbers increase off the west coast of North America (Ford 2014). The peak density shift over the course of the winter and spring, with peak densities occurring in California in February, April off Oregon and Washington, and May off B.C. and Southeast Alaska (Ford 2014). The use of continental shelf and slope waters of B.C. and the northwestern U.S. by adult females during winter is well documented from pelagic sealing data (Bigg 1990).

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).

Off B.C., females and subadult males are typically found during the winter off the continental shelf (Bigg 1990). They start arriving from Alaska during December and most will leave the B.C. waters by July (Ford 2014). Tagged adult female fur seals were shown to concentrate their habitat utilization within 200 km of the shelf break along the west coast of North America; several traveled through the proposed survey area off western Vancouver Island (Pelland et al. 2014). Ford (2014) also reported the occurrence of northern fur seals throughout B.C. waters, including Dixon Entrance, Hecate Strait, Queen Charlotte Sound, and off the west coasts of Haida Gwaii and Vancouver Island, with concentrations over the shelf and slope, especially on La Pérouse Bank, southwestern Vancouver Island. A few animals are seen in inshore waters in B.C., and individuals occasionally come ashore, usually at sea lion haulouts (e.g., Race Rocks, off southern Vancouver Island) during winter and spring (Baird and Hanson 1997). Approximately 125,000 fur seals occur in B.C. over the winter and spring (Ford 2014). Although fur seals sometimes haul out in B.C., there are no breeding rookeries.

Northern fur seals could be observed in the proposed survey area, in particular females and juveniles. However, adult males are generally ashore during the reproductive season from May–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). 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–March (Stewart and Huber 1993). Females arrive in late December or January and give birth within ~1 week of their arrival. 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. Adult females and juveniles forage in the California current off California to B.C. (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). 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. Most elephant seal sightings at sea off Washington were made during June, July, and September; off Oregon, sightings were recorded from November through May (Bonnell et al. 1992). Northern elephant seal pups have been sighted at haulouts in the inland waters of Washington State (Jeffries et al. 2000), and at least three re reported to have been born there (Hayward 2003). 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).

Race Rocks Ecological Reserve, located off southern Vancouver Island, is one of the few spots in B.C. where elephant seals regularly haul out. Based on their size and general appearance, most animals using Race Rocks are adult females or subadults, although a few adult males also haul out there. Use of Race Rocks by northern elephant seals has increased substantially in recent years, most likely as a result of the species' dramatic recovery from near extinction in the early 20th century and its tendency to be highly migratory. A peak number (22) of adults and subadults were observed in spring 2003 (Demarchi and Bentley 2004); pups have also been born there primarily during December and January (Ford 2014). Haul outs can also be found on the western and northeastern coasts of Haida Gwaii, and along the coasts of Vancouver Island (Ford 2014). Juveniles are sometimes seen molting on beaches along the coast of B.C. from December–May, but sometimes also in summer and autumn (Ford 2014). One northern elephant seal was sighted during the 2009 ETOMO survey west of the proposed survey area (Holst 2017). This species could be encountered during the proposed seismic survey.

Harbor Seal (*Phoca vitulina richardsi*)

Two subspecies of harbor seal occur in the Pacific: *P.v. stejnegeri* in the northwest Pacific Ocean and *P.v. richardsi* in the eastern Pacific Ocean. *P.v. richardsi* occurs in nearshore, coastal, and estuarine areas ranging from Baja California, Mexico, north to the Pribilof Islands in Alaska (Carretta et al. 2019a). Five stocks of harbor seals are recognized along the U.S. west coast: (1) Southern Puget Sound, (2) Washington Northern Inland Waters Stock, (3) Hood Canal, (4) Oregon/Washington Coast, and (5) California (Carretta et al. 2019a). The Oregon/Washington stock occurs in the proposed survey area.

Harbor seals inhabit estuarine and coastal waters, hauling out on rocks, reefs, beaches, and glacial ice flows. They are generally non-migratory, but move locally with the tides, weather, season, food availability, and reproduction (Scheffer and Slipp 1944; Fisher 1952; Bigg 1969, 1981). Female harbor seals give birth to a single pup while hauled out on shore or on glacial ice flows; pups are born from May to mid-July. When molting, which occurs primarily in late August, seals spend the majority of the time hauled out on shore, glacial ice, or other substrates. Juvenile harbor seals can travel significant distances (525 km) to forage or disperse (Lowry et al. 2001). The smaller home range used by adults is suggestive of a strong site fidelity (Pitcher and Calkins 1979; Pitcher and McAllister 1981; Lowry et al. 2001).

Harbor seals haul out on rocks, reefs, and beaches along the U.S. west coast (Carretta et al. 2019a). Jeffries et al. (2000) documented several harbor seal rookeries and haulouts along the Washington coastline; it is the only pinniped species that breeds in Washington. Pupping in Oregon and Washington occurs from April–July (Brown 1988). Bonnell et al. (1992) noted that most harbor seals sighted off Oregon and Washington were ≤20 km from shore, with the farthest sighting 92 km from the coast. Menza et al. (2016) also showed the highest predicted densities nearshore. During surveys off the Oregon and Washington coasts, 88% of at-sea harbor seals occurred over shelf waters <200 m deep, with a few sightings near the 2000-m contour, and only one sighting over deeper water (Bonnell et al. 1992). Most (68%) at-sea sightings were recorded in September and November (Bonnell et al. 1992). Harbor seals were only seen in nearshore areas during surveys on the shelf and slope in 2011 and 2012 (Adams et al. 2014). Twelve sightings occurred in nearshore waters from R/V *Northern Light* during a survey off southern Washington during July 2012 (RPS 2012a). Harbor seals were also taken as bycatch east of southern Oregon in the west coast groundfish fishery during 2002–2009 (Jannot et al. 2011).

Williams and Thomas (2007) noted an abundance estimate of 19,400 harbor seals for the inshore coastal waters of B.C. based on surveys in 2004 and 2005. Best et al. (2015) provided an abundance estimate of 24,916 seals based on coastal surveys during 2004–2008. The total population in B.C. was estimated at ~105,000 in 2008 (Ford 2014). Harbor seals occur along all coastal areas of B.C., including the western coast of Vancouver Island, with the highest concentration in the Strait of Georgia (13.1 seals per kilometre of coast); average densities elsewhere are 2.6 seals per kilometre (Ford 2014). Almost 1400 haul outs have been reported for B.C., many of them in the Strait of Georgia (Ford 2014). Given their preference for coastal waters, harbor seals could be encountered in the easternmost parts of the proposed project area.

Steller Sea Lion (*Eumetopias jubatus*)

The Steller sea lion occurs along the North Pacific Rim from northern Japan to California (Loughlin et al. 1984). It is distributed around the coasts to the outer shelf from northern Japan through the Kuril Islands and Okhotsk Sea, through the Aleutian Islands, central Bering Sea, southern Alaska, and south to California (NOAA 2019d). There are two stocks, or DPSs, of Steller sea lions – the Western and Eastern DPSs, which are divided at 144°W longitude (Muto et al. 2019a,b). The Western DPS is listed as *endangered* and includes animals that occur in Japan and Russia (Muto et al. 2019a,b); the Eastern DPS was delisted from *threatened* in 2013 (NMFS 2013a). Only individuals from the Eastern DPS could occur in the proposed survey area.

Steller sea lions typically inhabit waters from the coast to the outer continental shelf and slope throughout their range; they are not considered migratory, although foraging animals can travel long distances (Loughlin et al. 2003; Raum-Suryan et al. 2002). Rookeries of Steller sea lions from the Eastern DPS are located in southeast Alaska, B.C., Oregon, and California; there are no rookeries in Washington (NMFS 2013a; Muto et al. 2019a,b). Breeding adults occupy rookeries from late-May to early-July (NMFS 2008). Federally designated critical habitat for Steller sea lions in Oregon and California includes all rookeries (NMFS 1993). Although the Eastern DPS was delisted from the ESA in 2013, the designated critical habitat remains valid (NOAA 2019e). The critical habitat in Oregon is located along the coast at Rogue Reef (Pyramid Rock) and Orford Reef (Long Brown Rock and Seal Rock). The critical habitat area includes aquatic zones that extend 0.9 km seaward and air zones extending 0.9 km above these terrestrial and aquatic zones (NMFS 1993). The Orford Reef and Rogue Reef critical habitats are located 7 km and 9 km from the nearest proposed seismic transect line, respectively (Fig. 1).

Non-breeding adults use haulouts or occupy sites at the periphery of rookeries during the breeding season (NMFS 2008). Pupping occurs from mid-May to mid-July (Pitcher and Calkins 1981) and peaks in June (Pitcher et al. 2002). Territorial males fast and remain on land during the breeding season (NMFS 2008). Females with pups generally stay within 30 km of the rookeries in shallow (30–120 m) water when feeding (NMFS 2008). Tagged juvenile sea lions showed localized movements near shore (Briggs et al. 2005). Loughlin et al. (2003) reported that most (88%) at-sea movements of juvenile Steller sea lions in the Aleutian Islands were short (<15 km) foraging trips. The mean distance of juvenile sea lion trips at sea was 16.6 km, and the maximum trip distance recorded was 447 km. Long-range trips represented 6% of all trips at sea, and trip distance and duration increase with age (Loughlin et al. 2003; Call et al. 2007). Although Steller sea lions are not considered migratory, foraging animals can travel long distances outside of the breeding season (Loughlin et al. 2003; Raum-Suryan et al. 2002). During the summer, they mostly forage within 60 km from the coast; during winter, they can range up to 200 km from shore (Ford 2014).

During surveys off the coasts of Oregon and Washington, Bonnell et al. (1992) noted that 89% of sea lions occurred over the shelf at a mean distance of 21 km from the coast and near or in waters <200 m deep; the farthest sighting occurred ~40 km from shore, and the deepest sighting location was 1611 m deep. Sightings were made along the 200-m depth contour throughout the year (Bonnell et al. 1992). During aerial surveys over the shelf and slope off Oregon and Washington, one Steller sea lion was seen on the Oregon shelf during January 2011, and two sightings totaling eight individuals were made on September 2012 off southern Oregon (Adams et al. 2014). During a survey off Washington/Oregon June–July 2012, two Steller sea lions were seen from R/V *Langseth* (RPS 2012b) off southern Oregon. Eight sightings of 11 individuals were made from R//V *Northern Light* during a survey off southern Washington during July 2012 (RPS 2012a). Steller sea lions were also taken as bycatch off southern Oregon in the west coast groundfish fishery during 2002–2009 (Jannot et al. 2011).

In B.C., there are six main rookeries, which are situated at the Scott Islands off northwestern Vancouver Island, the Kerouard Islands near Cape St. James at the southern end of Haida Gwaii, North Danger Rocks in eastern Hecate Strait, Virgin Rocks in eastern Queen Charlotte Sound, Garcin Rocks off southeastern Moresby Island in Haida Gwaii, and Gosling Rocks on the central mainland coast (Ford 2014). The Scott Islands and Cape St. James rookeries are the two largest breeding sites with 4000 and 850 pups born in 2010, respectively (Ford 2014). Some adults and juveniles are also found on sites known as year-round haulouts during the breeding season. Haul outs are located along the coasts of Haida Gwaii, the central and northern mainland coast, the west coast of Vancouver Island, and the Strait of Georgia; some are year-round sites whereas others are only winter haul outs (Ford 2014). Pitcher et al. (2007) reported 24 major haulout sites (>50 sea lions) in B.C., but there are currently around 30 (Ford 2014). The total pup and non-pup count of Steller sea lions in B.C. in 2002 was 15,438; this represents a minimum population estimate (Pitcher et al. 2007). The highest pup counts in B.C. occur in July (Bigg 1988). Steller sea lions could be encountered in the proposed project areas, especially in the waters closer to shore.

California Sea Lion (*Zalophus californianus*)

The primary range of the California sea lion includes the coastal areas and offshore islands of the eastern North Pacific Ocean from B.C. to central Mexico, including the Gulf of California (Jefferson et al. 2015). However, its distribution is expanding (Jefferson et al. 2015), and its secondary range extends into the Gulf of Alaska (Maniscalco et al. 2004) and southern Mexico (Gallo-Reynoso and Solórzano-Velasco 1991), where it is occasionally recorded.

California sea lion rookeries are on islands located in southern California, western Baja California, and the Gulf of California (Carretta et al. 2019a). Five genetically distinct geographic populations have been identified: (1) Pacific Temperate (includes rookeries in U.S. waters and the Coronados Islands to the south), (2) Pacific Subtropical, (3) Southern Gulf of California, (4) Central Gulf of California, and (5) Northern Gulf of California (Schramm et al. 2009). Animals from the Pacific Temperate population occur in the proposed project area.

In California and Baja California, births occur on land from mid-May to late-June. During August and September, after the mating season, the adult males migrate northward to feeding areas as far north as Washington (Puget Sound) and B.C. (Lowry et al. 1992). They remain there until spring (March–May), when they migrate back to the breeding colonies (Lowry et al. 1992; Weise et al. 2006). The distribution of immature California sea lions is less well known but some make northward migrations that are shorter in length than the migrations of adult males (Huber 1991). However, most immature seals are presumed to remain near the rookeries for most of the year, as are females and pups (Lowry et al. 1992).

California sea lions are coastal animals that often haul out on shore throughout the year, but peak numbers off Oregon and Washington occur during the fall (Bonnell et al. 1992). During aerial surveys off the coasts of Oregon and Washington during 1989–1990, California sea lions were sighted at sea during the fall and winter, but no sightings were made during June–August (Bonnell et al. 1992). Numbers off Oregon decrease during winter, as animals travel further north (Mate 1975 *in* Bonnell et al. 1992).

King (1983) noted that sea lions are rarely found more than 16 km offshore. During fall and winter surveys off Oregon and Washington, mean distance from shore was ~13 km and most were observed in water <200 m deep; however, sightings were made in water as deep as 356 m (Bonnell et al. 1992). Weise et al. (2006) reported that males normally forage almost exclusively over the continental shelf, but during anomalous climatic conditions they can forage farther out to sea (up to 450 km offshore).

During aerial surveys over the shelf and slope off Oregon and Washington (Adams et al. 2014), California sea lions were seen during all survey months (January–February, June–July, September–October). Although most sightings occurred on the shelf, during February 2012, one sighting was made near the 2000-m depth contour, and during June 2011 and July 2012, sightings were made along the 200-m isobath off southern Oregon (Adams et al. 2014). During October 2011, sightings were made off the Columbia River estuary near the 200-m isopleth and on the southern Oregon shelf; during September 2012, sightings occurred in nearshore waters off Washington and in shelf waters along the coast of Oregon (Adams et al. 2014). Adams et al. (2014) reported sightings more than 60 km off the coast of Oregon. California sea lions were also taken as bycatch off Washington and Oregon in the west coast groundfish fishery during 2002–2009 (Jannot et al. 2011).

California sea lions used to be rare in B.C., but their numbers have increased substantially during the 1970s and 1980s (Ford 2014). Wintering California sea lion numbers have increased off southern Vancouver Island since the 1970s, likely as a result of the increasing California breeding population (Olesiuk and Bigg 1984). Several thousand occur in the waters of B.C. from fall to spring (Ford 2014). Adult and subadult male California sea lions are mainly seen in B.C. during the winter (Olesiuk and Bigg 1984). They are mostly seen off the west coast of Vancouver Island and in the Strait of Georgia, but they are also known to haul out along the coasts of Haida Gwaii, including Dixon Entrance, and the mainland (Ford 2014). California sea lions could be encountered in the proposed project area.

Fissipeds

Northern Sea Otter (*Enhydra lutris kenyoni*)

The northern sea otter can be found along the coast of North America from Alaska to Washington. Sea otters generally occur in shallow (<35 m), nearshore waters in areas with sandy or rocky bottoms, where they feed on a wide variety of sessile and slow-moving benthic invertebrates (Rotterman and Simon-Jackson 1988). Sea otters are generally not migratory and do not disperse over long distances; however, individual sea otters are capable of travelling in excess of 100 km (Garshelis and Garshelis 1984), although movements are likely limited by geographic barriers, high energy requirements of animals, and social behavior. Before commercial exploitation, the worldwide population of sea otters was estimated to be between 150,000 (Kenyon 1969) and 300,000 (Johnson 1982). Commercial exploitation reduced the total sea otter population to as low as 2000 in 13 locations (Kenyon 1969). In 1911, sea otters received protection under the North Pacific Fur Seal Convention, and populations recovered quickly (Kenyon 1969). The world sea otter population is currently estimated at ~150,000 (Davis et al. 2019).

Sea otters were translocated from Alaska to shallow coastal waters off the Olympic Peninsula of Washington; the population has increased from 59 reintroduced individuals in 1969–1970 to ~2058 in 2017 (Sato et al. 2018). The current population is 2785 (Jeffries et al. 2019). The population ranges from Pillar Point in the Strait of Juan de Fuca to Cape Flattery, and south to Point Grenville (USFWS 2018). Although sea otters were also reintroduced to Oregon in the 1970s, the reintroduction was not successful (McAllister 2018). Nonetheless, sometimes sea otters are reported as far south as Newport, Oregon (USFWS 2018). Sea otters occur in coastal areas of Washington typically in shallow (<30 m depth) water less than 4 km from shore (Laidre et al. 2009).

Sea otters were also translocated from Alaska to B.C. (Bigg and MacAskie 1978). In 2013, the B.C. population was estimated to number at least 6754 individuals (DFO 2015; Nichol et al. 2015). In B.C., sea otters regularly occur off northern and western Vancouver Island, and along the central mainland coast (Ford 2014; DFO 2015; Nichol et al. 2015). Although most individuals occur north of Clayoquot Sound (Nichol et al. 2015), some animals occur in Barkley Sound and in the Strait of Juan de Fuca to Victoria (Ford 2014). There is some limited interchange between sea otter populations in Washington and B.C. (USWFS 2018). Given that the survey is proposed to occur in water >60 m, sea otters are expected to be rare during the proposed survey. However, some sea otters could occur within the area that is ensonified by airgun sounds.

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 late spring/summer 2020. 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). Physical damage to a mammal's hearing apparatus can occur if it is exposed to sound impulses that have very high peak pressures, especially if the impulses have very short rise times (e.g., Morell et al. 2017). However, the impulsive nature of sound is range-dependent, becoming less harmful over distance from the source (Hastie et al. 2019). 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. Kyhn et al. (2019) reported that baleen whales and seals were likely masked over an extended period of time during four concurrent seismic surveys in Baffin Bay, Greenland. Nieukirk et al. (2012), Blackwell et al. (2013), and Dunlop (2018) also 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, 2018). If a marine mammal does react briefly to an underwater sound by changing its behavior or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or population (e.g., New et al. 2013a). However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on individuals and populations could be significant (Lusseau and Bejder 2007; Weilgart 2007; New et al. 2013b; Nowacek et al. 2015; Forney et al. 2017). Some studies have attempted modeling to assess consequences of effects from underwater noise at the population level (e.g., New et al. 2013b; King et al. 2015; Costa et al. 2016a,b; Ellison et al. 2016; Harwood et al. 2016; Nowacek et al. 2016; Farmer et al. 2017).

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

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

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

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

Dunlop et al. (2015) reported that migrating humpback whales in Australia responded to a vessel operating a 20 in^3 airgun by decreasing their dive time and speed of southward migration; however, the same responses were obtained during control trials without an active airgun, suggesting that humpbacks responded to the source vessel rather than the airgun. A ramp up was not superior to triggering humpbacks to move away from the vessel compared with a constant source at a higher level of 140 in^3, although an increase in distance from the airgun(s) was noted for both sources (Dunlop et al. 2016a). Avoidance was also shown when no airguns were operational, indicating that the presence of the vessel itself had an effect on the response (Dunlop et al. 2016a,b). Overall, the results showed that humpbacks were more likely to avoid active small airgun sources (20 and 140 in^3) within 3 km and received levels of at least 140 dB re 1 $\mu Pa^2 \cdot s$ (Dunlop et al. 2017a). Responses to ramp up and use of a large 3130 in^3 array elicited greater behavioral changes in humpbacks when compared with small arrays (Dunlop et al. 2016c). Humpbacks deviated from their southbound migration when they were within 4 km of the active large airgun source, where received levels were >130 dB re 1 $\mu Pa^2 \cdot s$ (Dunlop et al. 2017b, 2018). These results are consistent with earlier studies (e.g., McCauley et al. 2000).

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 $\mu Pa^2 \cdot s$, decreased at $CSEL_{10\text{-min}}$ >127 dB re 1 $\mu Pa^2 \cdot s$, and whales were nearly silent at $CSEL_{10\text{-min}}$ >160 dB re 1 $\mu Pa^2 \cdot s$. Thus, bowhead whales in the Beaufort Sea apparently decreased their calling rates in response to seismic operations, although movement out of the area could also have contributed to the lower call detection rate (Blackwell et al. 2013, 2015).

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

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

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

Various species of *Balaenoptera* (blue, sei, fin, and minke whales) have occasionally been seen in areas ensonified by airgun pulses. Sightings by observers on seismic vessels using large arrays off the U.K. from 1994 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 $\mu Pa^2 \cdot s$). For the same survey, Pirotta et al. (2014) reported that the probability of recording a porpoise buzz decreased by 15% in the ensonified area, and that the probability was positively related to the distance from the seismic ship; the decreased buzzing occurrence may indicate reduced foraging efficiency. Nonetheless, animals returned to the area within a few hours (Thompson et al. 2013). In a captive facility, harbor porpoise showed avoidance of a pool with elevated sound levels, but search time for prey within that pool was no different than in a quieter pool (Kok et al. 2017).

Kastelein et al. (2013a) reported that a harbor porpoise showed no response to an impulse sound with an SEL below 65 dB, but a 50% brief response rate was noted at an SEL of 92 dB and an SPL of 122 dB re 1 $\mu Pa_{0\text{-peak}}$. However, Kastelein et al. (2012c) reported a 50% detection threshold at a SEL of 60 dB to a similar impulse sound; this difference is likely attributable to the different transducers used during the two studies (Kastelein et al. 2013c). Van Beest et al. (2018) exposed five harbor porpoise to a single 10 in^3 airgun for 1 min at 2–3 s intervals at ranges of 420–690 m and levels of 135–147 dB $\mu Pa^2 \cdot s$. One porpoise moved away from the sound source but returned to natural 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 developing new guidance for predicting behavioral effects (Scholik-Schlomer 2015). As behavioral responses are not consistently associated with received levels, some authors have made recommendations on different approaches to assess behavioral reactions (e.g., Gomez et al. 2016; Harris et al. 2017; Tyack and Thomas 2019).

Pinnipeds.—Pinnipeds are not likely to show a strong avoidance reaction to an airgun array. Visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds and only slight (if any) changes in behavior. However, telemetry work has suggested that avoidance and other behavioral reactions may be stronger than evident to date from visual studies (Thompson et al. 1998). Observations from seismic vessels operating large arrays off the U.K. from 1994 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, 2018, 2019a,b; 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).

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; Nachtigall et al. 2018)

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. Harbor seals may be able to decrease their exposure to underwater sound by swimming just below the surface where sound levels are typically lower than at depth (Kastelein et al. 2018).

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

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

The new noise exposure criteria for marine mammals that were recently released by NMFS (2016a, 2018a) account for the newly-available scientific data on TTS, the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors. For impulsive sounds, such 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, MF cetaceans, HF cetaceans, phocids, and otariids.

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 70 Marine Mammal Unusual Mortality Events (UME) in the U.S. (NOAA 2019f). 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 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 nearly no available information on marine mammal behavioral responses to MBES sounds (Southall et al. 2013) or sea turtle responses to MBES systems. Much of the literature on marine mammal response to sonars relates to the types of sonars used in naval operations, including low-frequency, mid-frequency, and high-frequency active sonars (see review by Southall et al. 2016). However, the MBES sounds are quite different from naval sonars. Ping duration of the MBES is very short relative to naval sonars. Also, at any given location, an individual marine mammal would be in the beam of the MBES for much less time given the generally downward orientation of the beam and its narrow fore-aft beamwidth; naval sonars often use near-horizontally-directed sound. In addition, naval sonars have higher duty cycles. These factors would all reduce the sound energy received from the MBES relative to that from naval sonars.

During a recent study, group vocal periods (GVP) were used as proxies to assess foraging behavior of Cuvier's beaked whales during multibeam mapping in southern California (Varghese et al. 2019). The study found that there was no significant difference between GVP during multibeam mapping and non-exposure periods, but the number of GVP was significantly greater after MBES exposure than before MBES exposure. During an analogous study assessing Naval sonar (McCarthy et al. 2011), significantly fewer GVPs were recorded during sonar transmission (McCarthy et al. 2011; Varghese et al. 2019).

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. 2017), and significantly fewer beaked whale vocalizations were detected while an EK60 echosounder was active vs. passive (Cholewiak et al. 2017).

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

Other Possible Effects of Seismic Surveys

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

Vessel noise from 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; Cholewiak et al. 2018). In addition to the frequency and duration of the masking sound, the strength, temporal pattern, and location of the introduced sound also play a role in the extent of the masking (Branstetter et al. 2013, 2016; Finneran and Branstetter 2013; Sills et al. 2017). Branstetter et al. (2013) reported that time-domain metrics are also important in describing and predicting masking. In order to compensate for increased ambient noise, some cetaceans are known to increase the source levels of their calls in the presence of elevated noise levels from shipping, shift their peak frequencies, or otherwise change their vocal behavior (e.g., Parks et al. 2011, 2012, 2016a,b; Castellote et al. 2012; Melcón et al. 2012; Azzara et al. 2013; Tyack and Janik 2013; Luís et al. 2014; Sairanen 2014; Papale et al. 2015; Bittencourt et al. 2016; Dahlheim and Castellote 2016; Gospić and Picciulin 2016; Gridley et al. 2016; Heiler et al. 2016; Martins et al. 2016; O'Brien et al. 2016; Tenessen and Parks 2016; Fornet et al. 2018). Similarly, harbor seals increased the minimum frequency and amplitude of their calls in response to vessel noise (Matthews 2017); however, harp seals did not increase their call frequencies in environments with increased low-frequency sounds (Terhune and Bosker 2016).

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

Baleen whales are thought to be more sensitive to sound at these low frequencies than are toothed whales (e.g., MacGillivray et al. 2014), possibly causing localized avoidance of the proposed survey 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. Similarly, Currie et al. (2017) found a significant decrease in close encounters with humpback whales in the Hawaiian Islands, and therefore reduced likelihood of ship strike, when vessels speeds were below 12.5 kt. However, McKenna et al. (2015) noted the potential absence of lateral avoidance demonstrated by blue whales and perhaps other large whale species to vessels. The PEIS concluded that the risk of collision of seismic vessels or towed/deployed equipment with marine mammals or sea turtles 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. (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 survey area (outside of Canadian Territorial Waters) in the absence of a seismic survey. To the extent that marine mammals tend to move away from seismic sources before the sound level reaches the criterion level and tend not to approach an operating airgun array, these estimates likely overestimate the numbers actually exposed to the specified level of sound. The overestimation is expected to be particularly large when dealing with the higher sound level criteria, i.e., the PTS thresholds (Level A), as animals are more likely to move away when received levels are higher. Thus, they are less likely to approach within the PTS threshold radii than they are to approach within the considerably larger ≥160 dB (Level B) radius.

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; Barlow and Forney 2007; Forney 2007; Barlow 2010). Ship surveys for cetaceans in slope and offshore waters of Oregon and Washington were conducted by NMFS/SWFSC in 1991, 1993, 1996, 2001, 2005, 2008, and 2014 and synthesized by Barlow (2016); these surveys were conducted up to ~556 km from shore from June or August to November or December. These data were used by SWFSC to develop spatial models of cetacean densities for the CCE. 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. In B.C., several systematic surveys have been conducted in coastal waters (e.g., Williams and Thomas 2007; Ford et al. 2010a; Best et al. 2015; Harvey et al. 2017). Surveys in coastal as well as offshore waters were conducted by DFO during 2002 to 2008; however, little effort occurred off the west coast of Vancouver island during late spring/summer (Ford et al. 2010).

The U.S. Navy primarily used SWFSC spatial models to develop a marine species density database for the Northwest Training and Testing Study Area (USN 2019a), which encompasses the U.S. portion of the proposed survey area; if no density spatial modeling was available, other data sources were used (USN 2019a). The USN marine species density database is at this time the most comprehensive density data set available for the CCE. However, GIS data layers are currently unavailable for the database; thus, in this analysis the USN data were used only for species for which density data were not available from an alternative spatially-explicit model (e.g., minke, sei, gray, false killer, killer, and short-finned pilot whales, *Kogia* spp., and pinnipeds). As recommended by NMFS, spatially-explicit density data from the NOAA CetSound website (NOAA 2019l) were used for most other species (i.e., humpback, blue, fin, sperm, Baird's beaked, and other small beaked whales; bottlenose, striped, short-beaked common, Pacific white-sided, Risso's, and northern right whale dolphins; and Dall's porpoise). CetMap (https://cetsound.noaa.gov/cda) provides output habitat-based density models for cetaceans in the CCE. As CetMap provides output from habitat-based density models for cetaceans in the CCE (Becker et al. 2016) in the form of GIS layers; these were used to calculate takes in the survey area. As CetMap did not have a spatially-explicit GIS density layer for the harbor porpoise, densities from Forney et al. (2014) were used for that species. Densities for sea otters were calculated based on the number of otters occurring within the habitat area within the 40-m isobath. The methods used to determine species densities are detailed in Appendix B.

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. However, the approach used here is based on the best available data.

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 4 shows 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). When seasonal densities were available, the calculated exposures were based on late spring/ summer densities, which were deemed to be most representative of the proposed survey timing. It should be noted that the exposure estimates assume that the proposed surveys would be completed in entirety. Thus, the following estimates of the numbers of marine mammals potentially exposed to sounds ≥160 dB re 1 μPa_{rms} are precautionary and probably overestimate the actual numbers of marine mammals that could be involved.

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

The number of marine mammals that could be exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} (Level B) for marine mammals on one or more occasions have been calculating based on 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. The area expected to be ensonified 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 (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 4. 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

TABLE 4. 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 late spring/summer 2020. Species in italics are listed under the ESA as *endangered* or *threatened*.

	Calculated Take		Regional Population	Level B + Level A as	Requested Take
Species	Level B[1]	Level A[2]	Size	% of Pop.[3]	Authorization[4]
LF Cetaceans					
North Pacific right whale	*0*	*0*	*400*	*0*	*0*
Humpback whale	*203*	*10*	*10,103*	*2.1*	*213*
Blue whale	*73*	*4*	*1,496*	*5.2*	*77*
Fin whale	*94*	*6*	*18,680*	*0.5*	*100*
Sei whale	*35*	*2*	*27,197*	*0.1*	*37*
Minke whale	115	7	20,000	0.6	122
Gray whale	132	2	26,960	0.5	134
MF Cetaceans					
Sperm whale	*72*	*0*	*26,300*	*0.3*	*72*
Baird's beaked whale	86	0	2,697	3.2	86
Small beaked whale[5]	253	1	6,318	4.0	254
Bottlenose dolphin[6]	1	0	1,924	0	13
Striped dolphin[6]	7	0	29,211	0	46
Short-beaked common dolphin	121	0	969,861	0	121
Pacific white-sided dolphin	6,994	13	48,974	14.3	7,007
Northern right-whale dolphin	4,559	9	26,556	17.2	4,568
Risso's dolphin	2,120	4	6,336	33.5	2,124
False killer whale[7]	N.A.	N.A.	N.A.	N.A.	5
Killer whale[8]	86	0	920	9.4	86
Short-finned pilot whale	24	0	836	2.8	24
HF Cetaceans					
Pygmy/dwarf sperm whale	147	6	4,111	3.7	153
Dall's porpoise	11,986	452	31,053	40.1	12,438
Harbor porpoise	16,230	449	65,347	25.5	16,679
Otariid Seals					
Northern fur seal	5,326	8	620,660	0.9	5,334
Guadalupe fur seal	2,383	4	34,187	7.0	*2,387*
California sea lion	1,280	2	257,606	0.5	1,282
Steller sea lion	9,178	10	77,149	11.9	9,188
Phocid Seal					
Northern elephant seal	3,233	20	179,000	1.8	3,253
Harbor seal	7,608	37	129,732	5.9	7,645
Marine Fissiped					
Northern Sea Otter	263	0	2,785	9.4	263
Sea Turtle					
Leatherback turtle	*4*	*0*	*N.A.*	*N.A.*	*4*

N.A. means not applicable or not available. Note: Takes in Canadian Territorial Waters are excluded.
1 Level B takes, based on the 160-dB criterion, excluding exposures to sound levels equivalent to PTS thresholds.
2 Level A takes if there were no mitigation measures.
3 Requested take authorization is Level A plus Level B calculated takes, used by NMFS as proxy for number of individuals exposed.
4 Requested take authorization (Level A + Level B) expressed as % of population off California/Oregon/Washington, Eastern North Pacific, or U.S. stock (see Table 3).
5 Requested take includes 7 Blainville's beaked whales, 86 Stejneger's beaked whales, 86 Cuvier's beaked whales, and 74 Hubbs' beaked whales (see Appendix B for more information).
6 Requested take increased to mean group size (Barlow 2016).
7 Requested take increased to mean group size (Mobley et al. 2000).
8 Includes individuals from all stocks, including up to 7 killer whales from the southern resident stock.

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 44,303 cetaceans and 29,089 pinnipeds (Table 4). That total includes 507 ESA-listed cetaceans: 213 humpback whales, 100 fin whales, 77 blue whales, 38 sei whales, 72 sperm whales, and 7 southern resident killer whales representing 2.1%, 0.5%, 5.2%, 0.1%, 0.3%, and 8.2% of the regional populations, respectively. In addition, 2387 ***threatened*** Guadalupe fur seals could be exposed or 7% of their regional population. In addition, 340 beaked whales could be exposed.

Although the % of the population estimated to be ensonified during the surveys are large for Risso's dolphin (33.5%) and Dall's porpoise (~40%), these are likely overestimates, in particular because the population sizes do not include animals from the entire survey area. As noted above, densities derived from past surveys may not be representative of the densities that would be encountered during the proposed seismic surveys because of considerable year-to-year variability in oceanographic conditions. If densities from Barlow (2016) are used, the calculations result in takes of 17.5% of the population for Risso's dolphin, and 21.3% of the Dall's porpoise population; depending on the oceanographic conditions during the survey, these estimates may be more representative. In addition, the individuals are wide-ranging, and it is likely that some individuals would be ensonified multiple times instead of many different individuals being exposed during the survey. Only two sightings of 10 Risso's dolphins were seen during the L-DEO surveys off Washington/Oregon in late spring/summer 2012 (RPS 2012a,b,c).

Conclusions

The proposed seismic surveys would involve towing a 36-airgun array, which introduces pulsed sounds into the ocean. Routine vessel operations, other than the proposed seismic operations, are conventionally assumed not to affect marine mammals sufficiently to constitute "taking". In §3.6.7, §3.7.7, §3.8.7, and §3.9.7, the PEIS concluded that airgun operations with implementation of the proposed monitoring and mitigation measures could result in a small number of Level B behavioral effects in some mysticetes, odontocetes, pinniped, and sea otters 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 (e.g., NMFS 2019c,d).

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 limited whaling and sealing by indigenous groups in the Pacific Northwest. In the U.S., the Makah tribe has historically hunted gray whales; in recent times, a gray whale was successfully hunted on 17 May 1999 (NOAA 2015). NOAA has recently released a proposed rule to allow a limited hunt for gray whales by the Makah tribe (NOAA 2019h). In Canada, various First Nations harvest seals and sea lions. Given the temporary nature of the proposed activities and the fact that most operations would occur at least 5 km from shore, 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 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. However, the scientific objectives for the proposed surveys could not be met using a smaller source. The full R/V *Langseth* source array is needed to reach the deep imaging targets of the megathrust and oceanic Moho under the continental margin (up to ~20 km bsl). This large source is also needed to ensure recording of refracted arrivals at large ranges of up to 200 km on the planned OBS array as well as an array of land stations that may be deployed.
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*. Although marine mammals, including baleen whales, are expected to occur regularly in the proposed survey area during the spring and summer, the peak migration period for gray whales is expected to occur before the start of the surveys. Late spring/summer is the most practical season for the proposed surveys based on operational requirements.
3. *Mitigation Zones*—The proposed surveys would acquire data with the 36-airgun array at a tow depth of 12 m. L-DEO model results are used to determine the 160-dB_{rms} radius for the 36-airgun array and 40-in^3 (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 1μPa_{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 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 LF cetaceans, MF cetaceans, HF, phocids, and otariids (including sea otters). 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 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.

Shut-down/Power-down Procedures

The operating airgun(s) would be shut down if a marine mammal or turtle is seen within or approaching the EZ. For designated animals for which shut down has been waived (e.g., bow-riding dolphins), power-down procedures would be followed if designated species enter the EZ. The operating airgun(s) would also be powered down in the event an ESA-listed seabird were observed diving or foraging within the designated EZ. In a power-down scenario, a shut down would be implemented if (1) an animal enters the EZ of the single airgun after a power down has been initiated, or (2) 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) a power down has exceeded 30 min.

A power down involves decreasing the operating airguns in use down to a single 40-in^3 airgun such that the radius of the threshold zone is decreased to the extent that marine mammals, seabirds, or turtles are no longer in or about to enter the EZ. 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.

Following a shut down or 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 and turtles, or
- it has not been seen within the zone for 30 min in the case of mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, and beaked whales.

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.

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 harassment, which must be reported to NMFS;

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

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

XIV. Coordinating Research to Reduce and Evaluate Incidental Take

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

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

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Appendix A: Determination of Mitigation Zones

APPENDIX A: DETERMINATION OF MITIGATION ZONES

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

For deep and intermediate-water cases, the field measurements cannot be used readily to derive mitigation radii, as at those sites the calibration hydrophone was located at a roughly constant depth of 350–500 m, which may not intersect all the sound pressure level (SPL) isopleths at their widest point from the sea surface down to the maximum relevant water depth for marine mammals of ~2000 m (Costa and Williams 1999). Figures 2 and 3 in Appendix H of the PEIS show how the values along the maximum SPL line that connects the points where the isopleths attain their maximum width (providing the maximum distance associated with each sound level) may differ from values obtained along a constant depth line. At short ranges, where the direct arrivals dominate and the effects of seafloor interactions are minimal, the data recorded at the deep and slope sites are suitable for comparison with modeled levels at the depth of the calibration hydrophone. At longer ranges, the comparison with the mitigation model—constructed from the maximum SPL through the entire water column at varying distances from the airgun array—is the most relevant. The results are summarized below.

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

The proposed surveys would acquire data with the 36-airgun array at a maximum tow depth of 12 m. For deep water (>1000 m), we use the deep-water radii obtained from L-DEO model results down to a maximum water depth of 2000 m. The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor (multiplication) of 1.5, such that observed levels at very near offsets fall below the corrected mitigation curve (Fig. 16 in Appendix H of the PEIS). The shallow-water radii are obtained by scaling the empirically derived measurements from the GoM calibration survey to account for the differences in tow depth between the calibration survey (6 m) and the proposed survey (12 m); whereas the shallow water in the GoM may not exactly replicate the shallow water environment at the proposed survey site, it has been shown to serve as a good and very conservative proxy (Crone et al. 2014). A simple scaling factor is calculated from the ratios of the isopleths determined by the deep-water L-DEO model, which are essentially a measure of the energy radiated by the source array.

For the 36-airgun array, the 150-dB Sound Exposure Level (SEL)[1] corresponds to deep-water maximum radii of 10,553 m for 12-m tow depth (Fig. A-1) and 7244 m for a 6-m tow depth (Fig. A-2), yielding a scaling factor of 1.4568 to be applied to the shallow-water 6-m tow depth results. Similarly, the 165 dB SEL corresponds to deep-water maximum radii of 1864 m for 12-m tow depth (Fig. A-1) and 1284 m for for 6-m tow depth (Fig. A-2), yielding a scaling factor of 1.4517. The 185 SEL corresponds to deep-water maximum radii of 181 m for 12-m tow depth (Fig. A-1) and 126 m for 6-m tow depth (Fig. A-2), yielding a scaling factor of 1.4331. Measured 160- and 175-dB re 1µPa_{rms} distances in shallow water for the 36-airgun array towed at 6 m depth were 17.5 k and 2.84 km, respectively, based on a 95th percentile fit (Tolstoy et al. 2009). Multiplying by the scaling factors to account for the tow depth difference between 6 and 12 m yields distances of 25,494 m and 4123 m, for the 160- and 175-dB sound levels, respectively.

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

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

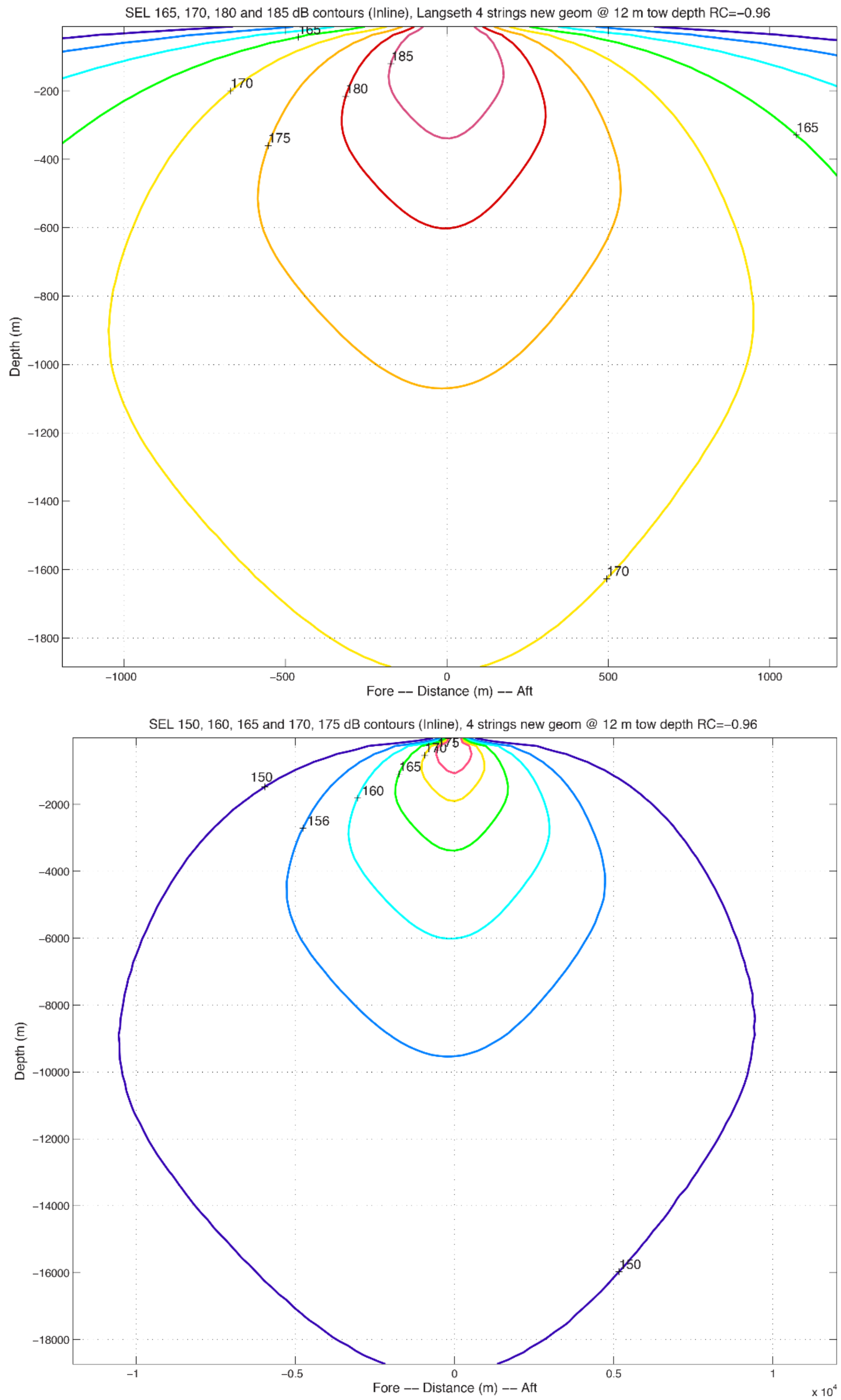

FIGURE A-1. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array at a 12-m tow depth planned for use during the proposed surveys in the Northeast Pacific Ocean. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB SEL isopleth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

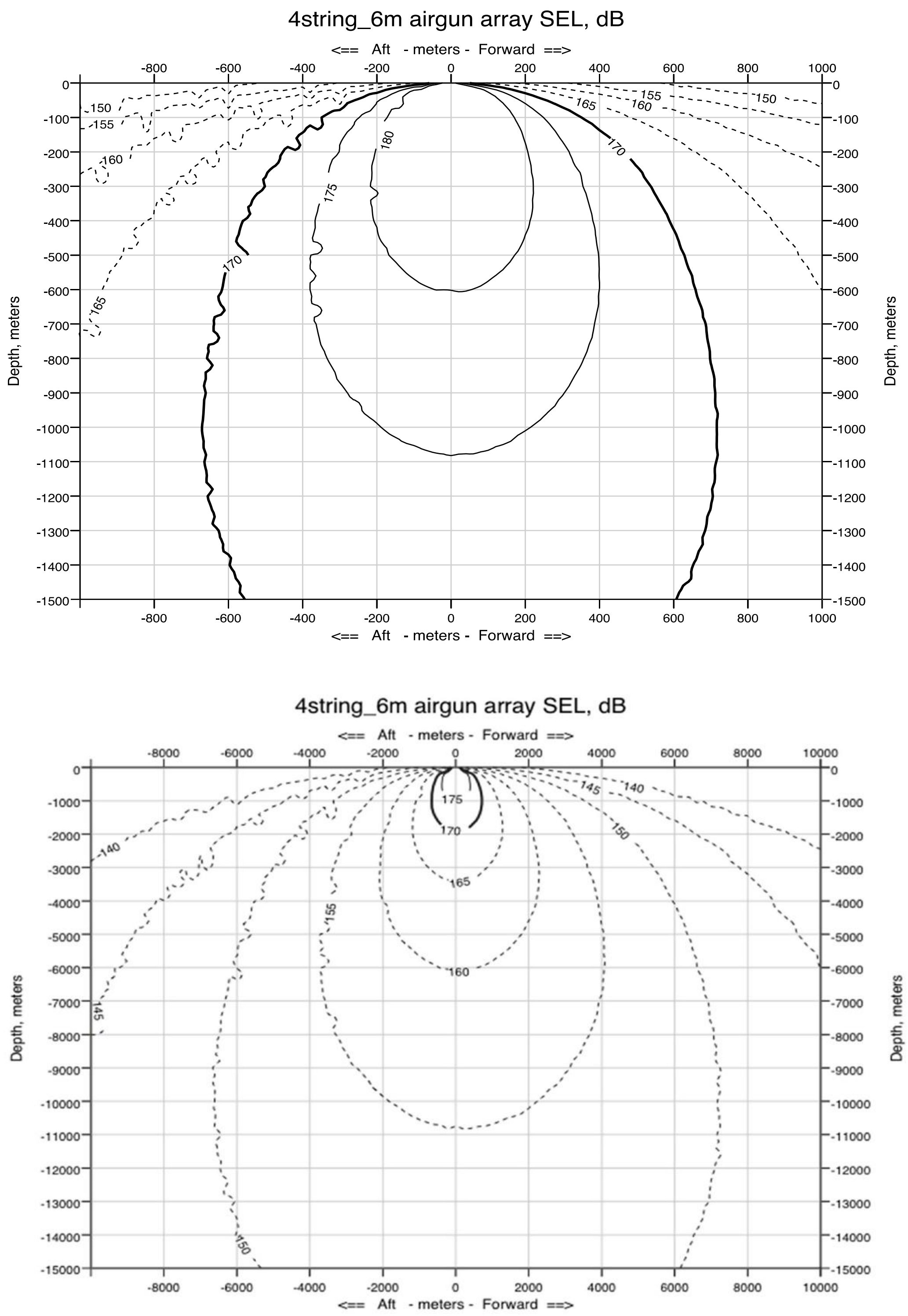

Figure A-2. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array at a 6-m tow depth used during the GoM calibration survey. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150 dB SEL isopleth is a proxy for the 160-dB rms isopleth.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

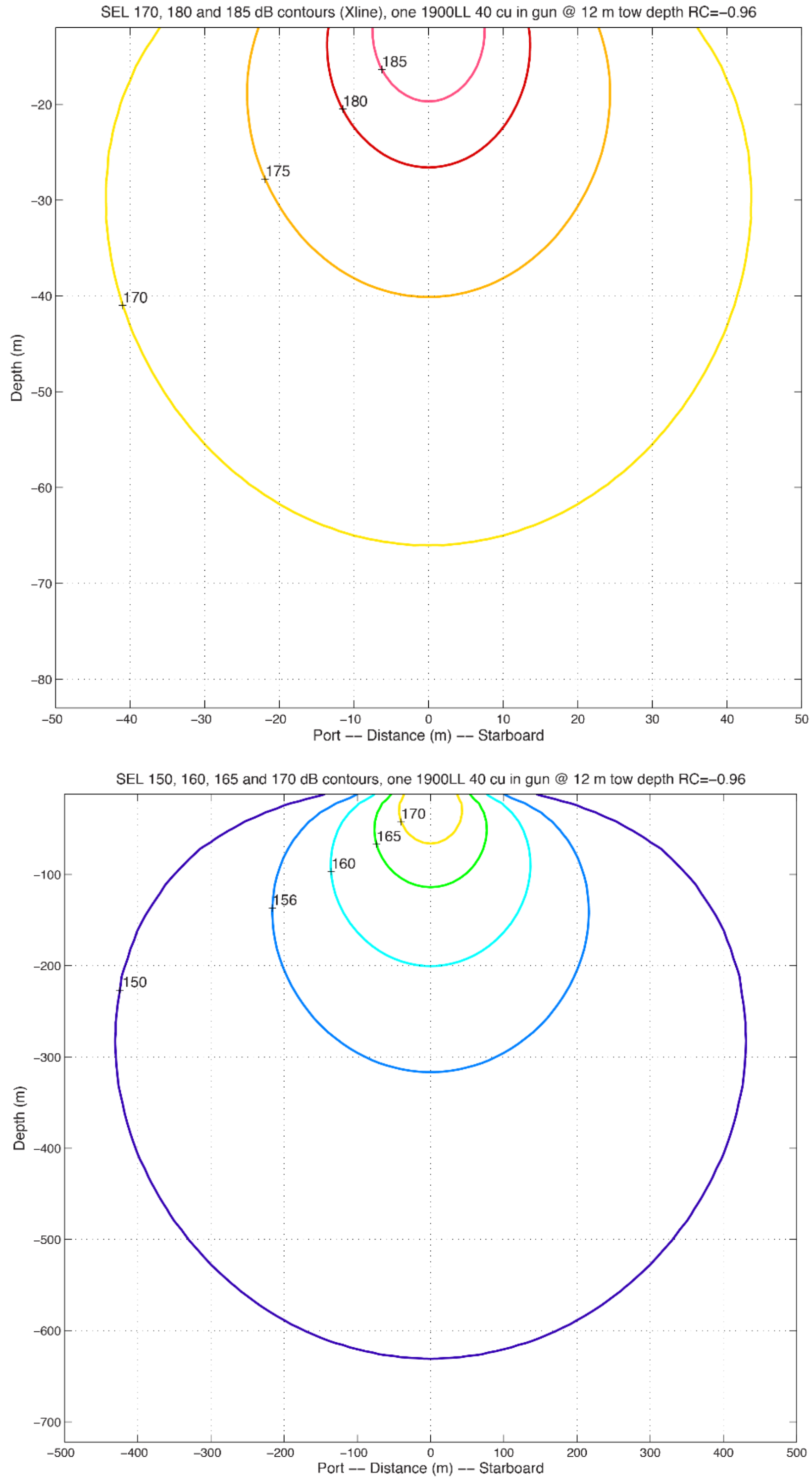

FIGURE A-3. Modeled deep-water received SELs from a single 40-in^3 airgun towed at a 12-m depth, which is planned for use as a mitigation airgun during the proposed surveys in the Northeast Pacific Ocean. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB 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 and 175-dB re 1µPa_{rms} sound levels are expected to be received for the 36-airgun array and the single (mitigation) airgun. The 160-dB level is the behavioral disturbance criteria (Level B) that is used by NMFS to estimate anticipated takes for marine mammal. The 175-dB level is used by NMFS, based on data from the USN (2017), to determine behavioral disturbance for turtles. A recent retrospective analysis of acoustic propagation of *Langseth* sources in a coastal/shelf environment from the Cascadia Margin off Washington suggests that predicted (modeled) radii (using an approach similar to that used here) for *Langseth* sources were 2–3 times larger than measured in shallow water, so in fact, as expected, were very conservative (Crone et al. 2014). Similarly, data collected by Crone et al. (2017) during a survey off New Jersey in 2014 and 2015 confirmed that *in situ* measurements and estimates of the 160- and 180-dB distances collected by the *Langseth* hydrophone streamer were 2–3 times smaller than the predicted operational mitigation radii. In fact, five separate comparisons conducted of the L-DEO model with *in situ* received levels[2] have confirmed that the L-DEO model generated conservative EZs, resulting in significantly larger EZs than required by National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS).

In July 2016, NMFS released new technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (NMFS 2016, 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; including sea otters). 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 dual criteria for sea turtles (USN 2017) were also used here. The new NMFS guidance did not alter the current threshold, 160 dB re 1µPa_{rms}, for Level B harassment (behavior). Southall et al. (2019) provided updated scientific recommendations regarding noise exposure criteria which are similar to those presented by NMFS (2016, 2018), but include all marine mammals (including sirenians), s re-classification of hearing groups, and alternative frequency-weighting functions.

The SEL_{cum} for the *Langseth* array is derived from calculating the modified farfield signature. The farfield signature is often used as a theoretical representation of the source level. To compute the farfield signature, the source level is estimated at a large distance directly below the array (e.g., 9 km), and this level is back projected mathematically to a notional distance of 1 m from the array's geometrical center. However, it has been recognized that the source level from the theoretical farfield signature is never physically achieved at the source when the source is an array of multiple airguns separated in space

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

TABLE A-1. Level B. Predicted distances to which sound levels ≥160-dB and ≥175-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 and the 175-dB criterion applies to sea turtles.

Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted distances (in m) to the 160-dB Received Sound Level	Predicted distances (in m) to the 175-dB Received Sound Level
Single Bolt airgun, 40 in^3	12	>1000 m	431[1]	77[1*]
		100–1000 m	647[2]	116[2]
		<100 m	1,041[3]	170[3]
4 strings, 36 airguns, 6600 in^3	12	>1000 m	6,733[1]	1,864[1]
		100–1000 m	10,100[2]	2,796[2]
		<100 m	25,494[3]	4,123[3]

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

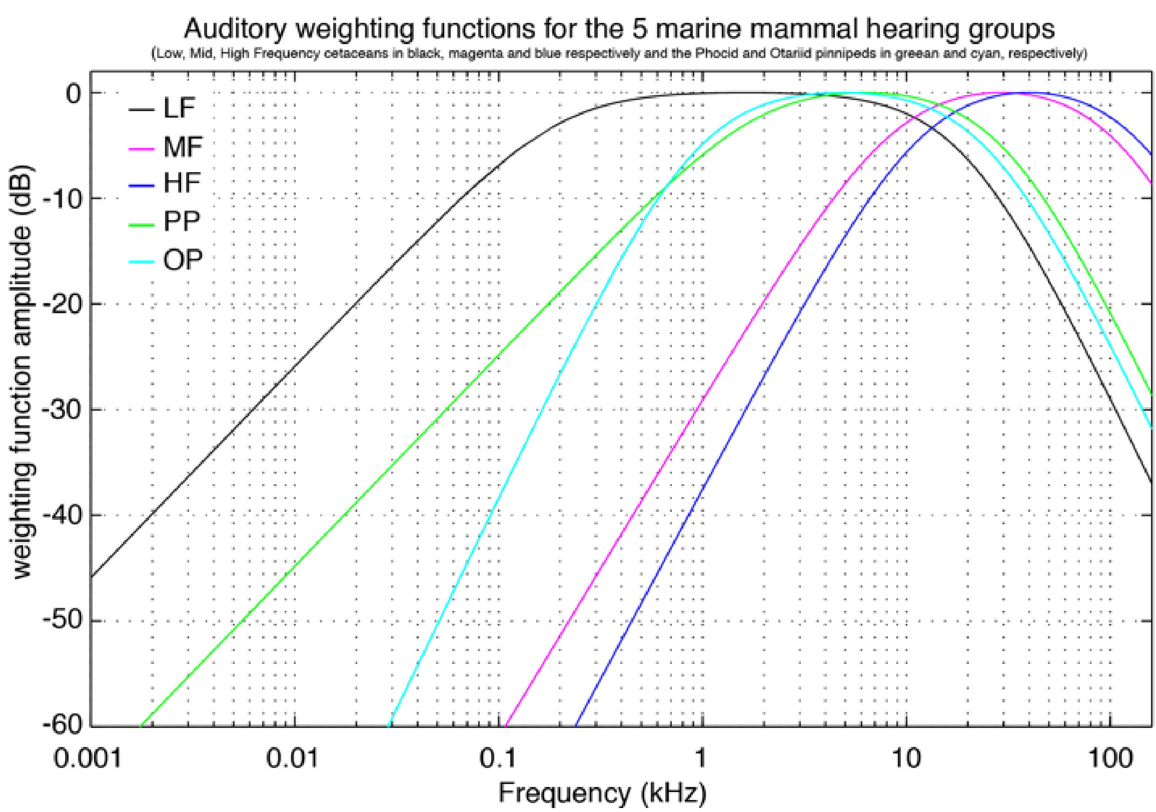

FIGURE A-4. Auditory weighting functions for five marine mammal hearing groups from the NMFS Technical Guidance Spreadsheet.

(Tolstoy et al. 2009). Near the source (at short ranges, distances <1 km), the pulses of sound pressure from each individual airgun in the source array do not stack constructively as they do for the theoretical farfield signature. The pulses from the different airguns spread out in time such that the source levels observed or modeled are the result of the summation of pulses from a few airguns, not the full array (Tolstoy et al. 2009). At larger distances, away from the source array center, sound pressure of all the airguns in the array stack coherently, but not within one time sample, resulting in smaller source levels (a few dB) than the source level derived from the farfield signature. Because the farfield signature does not take into account the 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 2.2 m/s and a 1/Repetition rate of 17.3 s were used as inputs to the NMFS User Spreadsheet for calculating the distances to the SEL_{cum} PTS thresholds (Level A) for the 36-airgun array and the single 40-in^3 mitigation airgun.

For the LF cetaceans, 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. The weighting function calculations, thresholds for SEL_{cum}, and the distances to the PTS thresholds for the 36-airgun array are shown in Table A-3. Figure A-5 shows the impact of weighting functions by hearing group. Figures A-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.

TABLE A-2. Results for single SEL source level modeling for the 36-airgun array with and without applying weighting functions to the five marine mammal hearing groups and sea turtles. The modified farfield signature is estimated using the distance from the source array geometrical center to where the SEL_{cum} threshold is the largest.

SEL_{cum} Threshold	183	185	155	185	203	204
Radial Distance (m) (no weighting	315.5691	246.4678	8033.2	246.4678	28.4413	25.1030
Modified Farfield SEL	232.9819	232.8352	233.0978	232.8352	232.0790	231.9945
Radial Distance (m) (with weighting function)	71.3752	N.A.	N.A.	N.A.	N.A.	N.A.
Adjustment (dB)	-12.91	N.A.	N.A.	N.A.	N.A.	N.A.

* Propagation of 20 $\log_{10}$ (Radial distance) is used to estimate the modified farfield SEL. N.A. means not applicable or not available.

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 hearing groups.

STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	
PROJECT/SOURCE INFORMATION (Please include any assumptions)	Source : 4 string 36 element 6600 cu.in of the R/V Langseth at a 12 m 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)	17.35573	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	231.9945
Source Factor	1.14485E+22	1.10682E+22	1.17581E+22	1.10682E+22	9.29945E+21	9.12026E+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	Sea Turtles
SEL_{cum} Threshold	183	185	155	185	203	204
PTS SEL_{cum} Isopleth to threshold (meters)	**426.9**	**0.0**	**1.3**	**13.9**	**0.0**	**20.5**

WEIGHTING FUNCTION CALCULATIONS

Weighting Function Parameters	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	Sea Turtles	
a	1	1.6	1.8	1	2	1.4	
b	2	2	2	2	2	2	
f_1	0.2	8.8	12	1.9	0.94	0.077	
f_2	19	110	140	30	25	0.44	
C	0.13	1.2	1.36	0.75	0.64	2.35	
Adjustment (dB)†	-12.91	-56.70	-66.07	-25.65	-32.62	-4.11	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, pinnipeds, and sea turtles, the difference between weighted–unweighted spectral source levels at each frequency was integrated to calculate adjustment factors (see spectrum levels in Figure A-5).

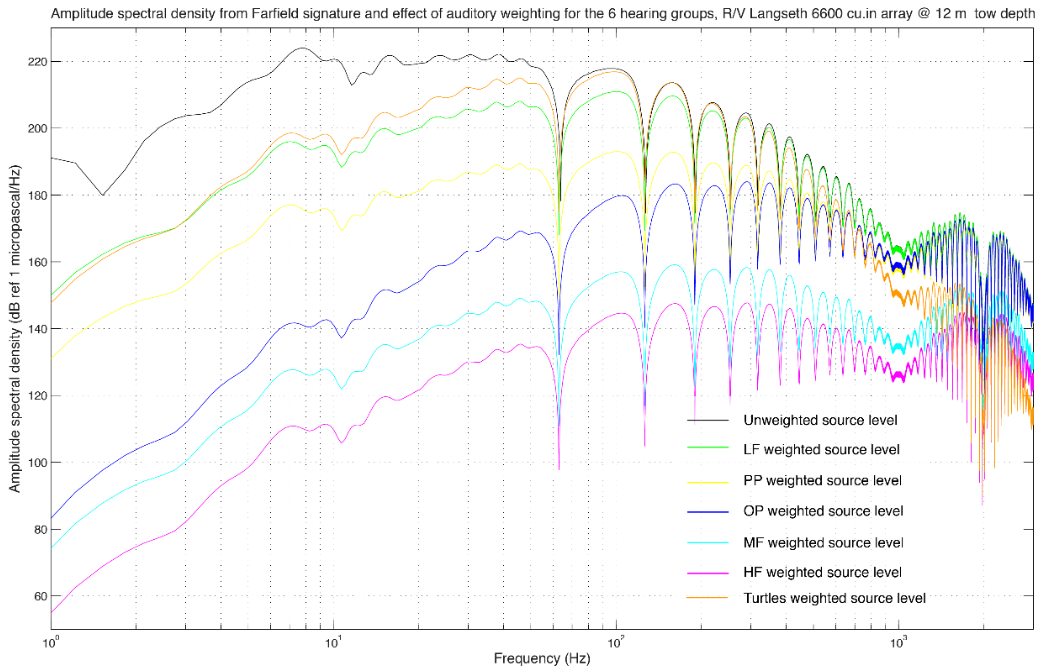

FIGURE A-5. Modeled amplitude spectral density of the 36-airgun array farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), Otariid Pinnipeds (OP), and Sea Turtles. Modeled spectral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

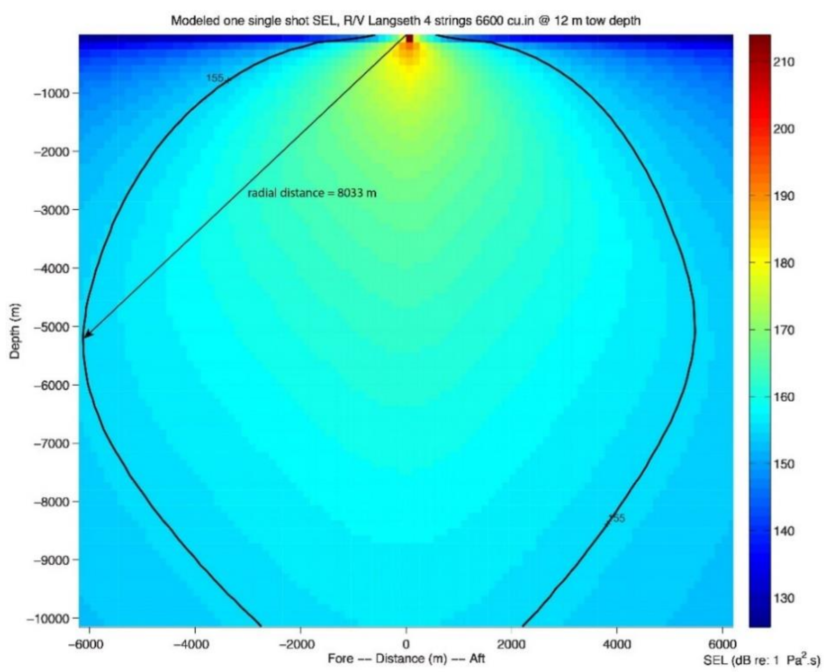

FIGURE A-6. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 155-dB SEL isopleth (8033 m). Radial distance allows us to determine the modified farfield SEL using a propagation of $20\log_{10}$(radial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

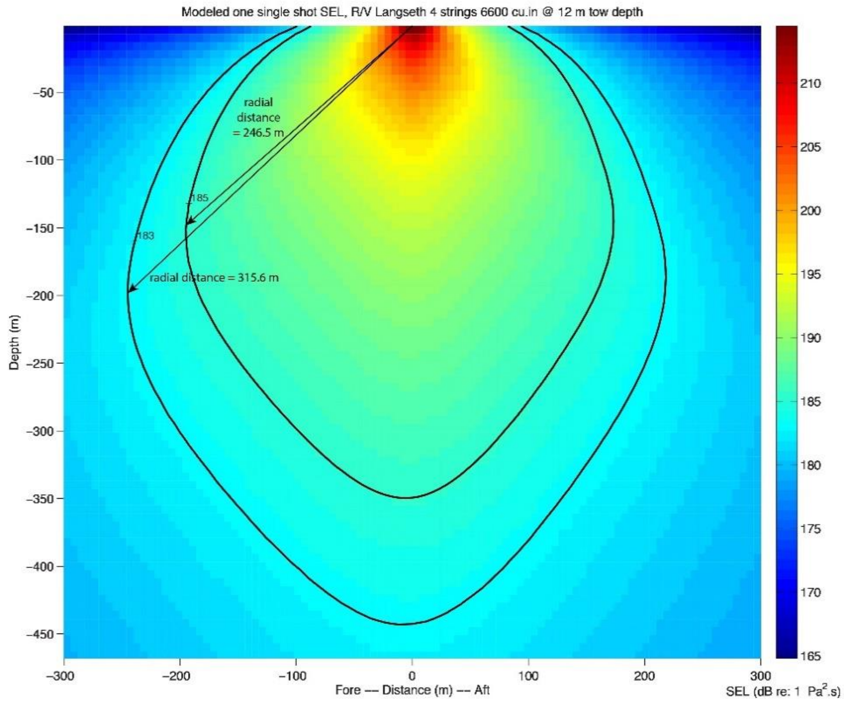

FIGURE A-7. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 183–185-dB SEL isopleths (315.6 and 246.5 m, respectively).

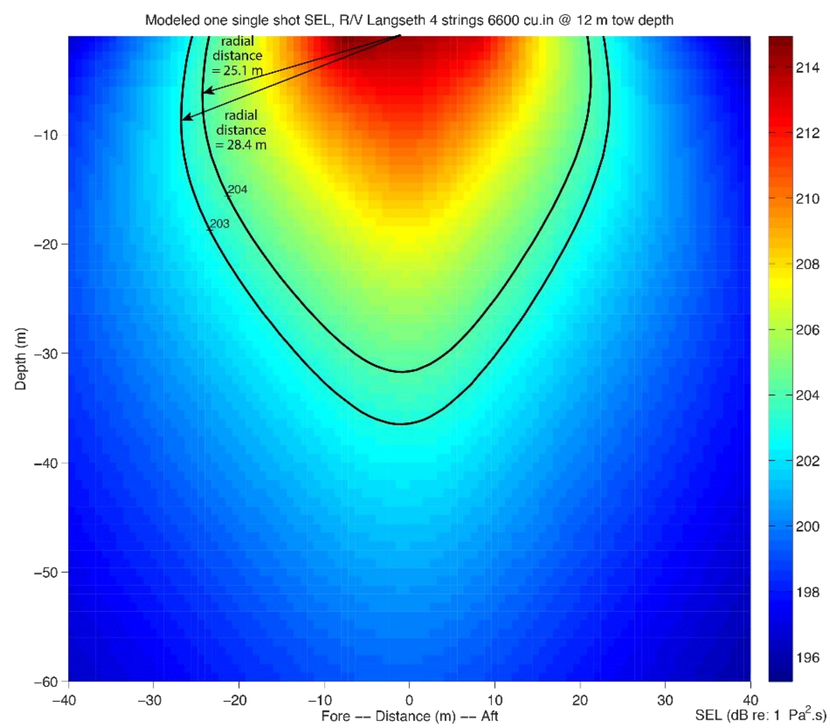

FIGURE A-8. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 203-dB and 204-dB SEL isopleth (28.4 m and 25.1 m, respectively).

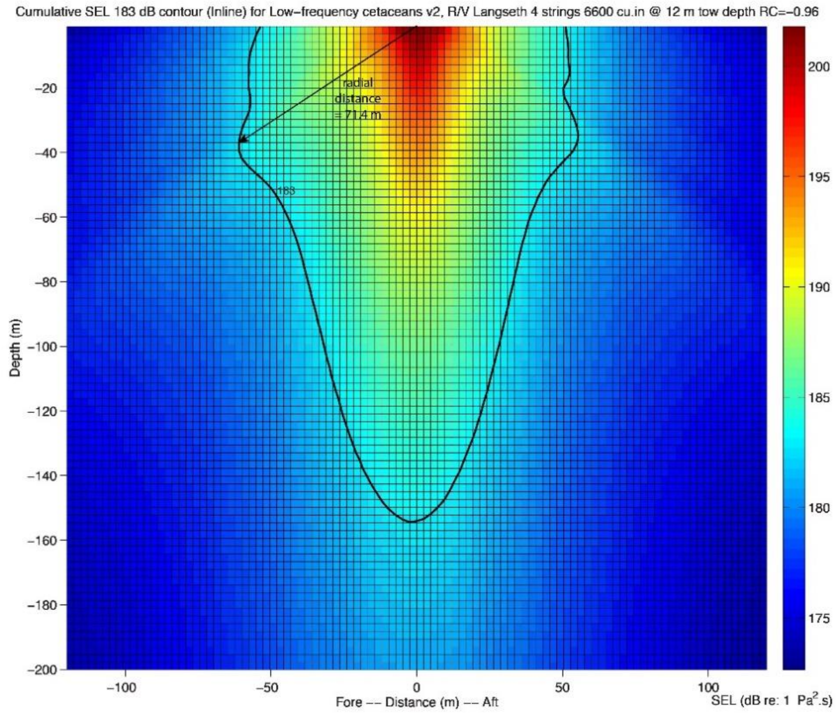

FIGURE A-9. Modeled received sound exposure levels (SELs) from the 36-airgun array at a 12-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one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

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

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

TABLE A-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 surveys in the Northeast Pacific Ocean.

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

N.A. means not applicable or not available.

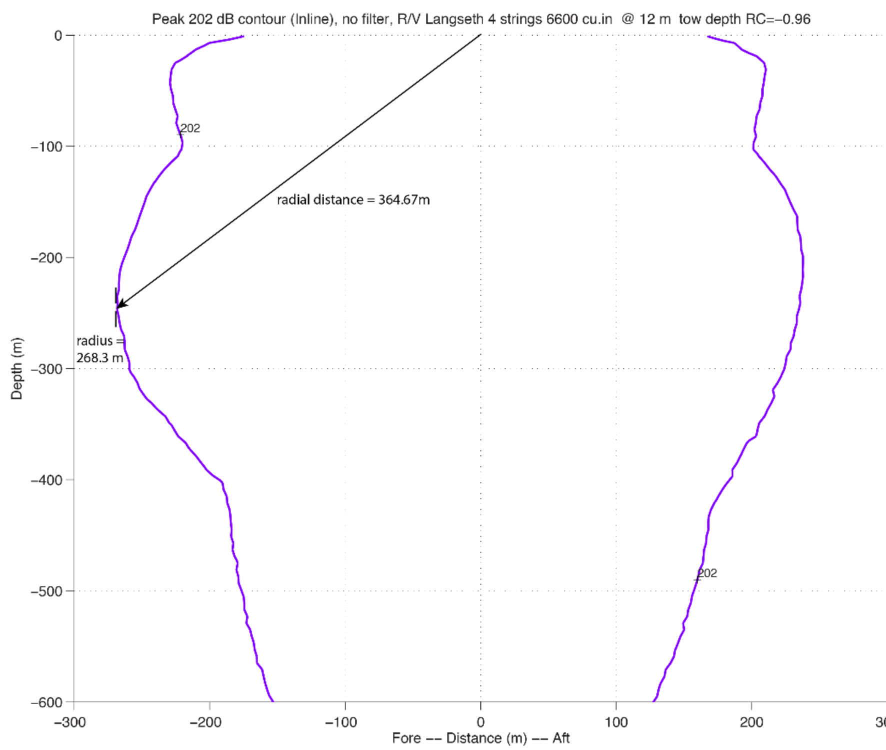

FIGURE A-10. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distance to the 202-dB Peak isopleth.

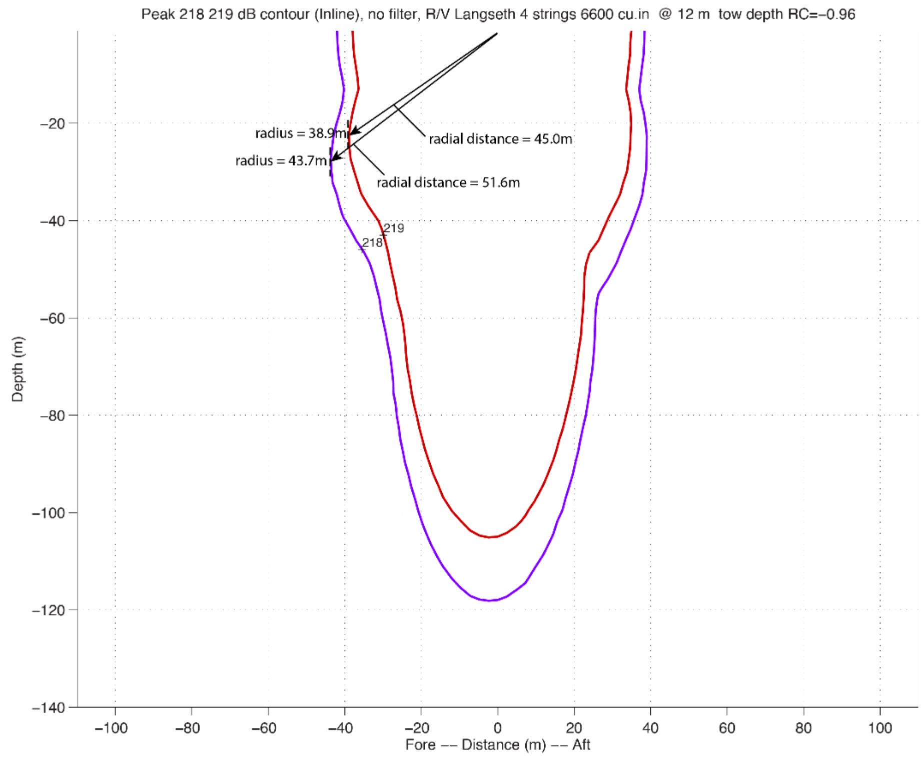

FIGURE A-11. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distances to the 218- and 219-dB Peak isopleths.

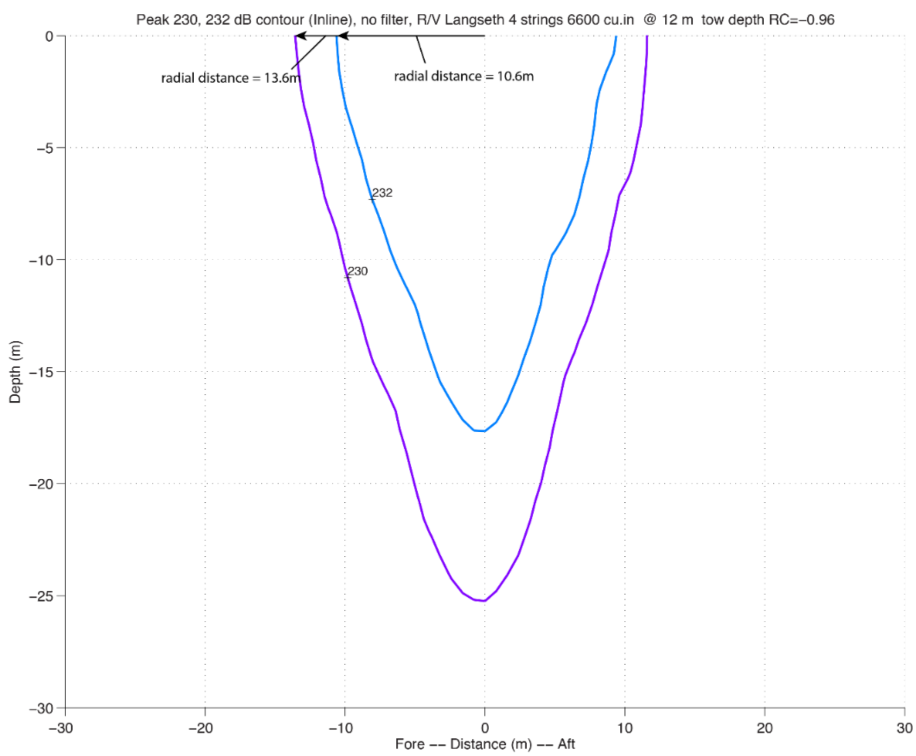

FIGURE A-12. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distances to the 230- and 232-dB Peak isopleths.

TABLE A-5. Level A threshold distances for different marine mammal hearing groups and sea turtles for the 36-airgun array. 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 Level A takes and threshold distances.

	Level A Threshold Distances (m) for Various Hearing Groups					
	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds and Sea Otters	Sea Turtles
PTS SEL_{cum}	**426.9**	0	1.3	13.9	0	**20.5**
PTS Peak	38.9	**13.6**	**268.3**	**43.7**	**10.6**	10.6

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

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 $\log_{10}$ (Radian distance) is used to estimate the modified farfield SEL. N.A. means not applicable or not available.

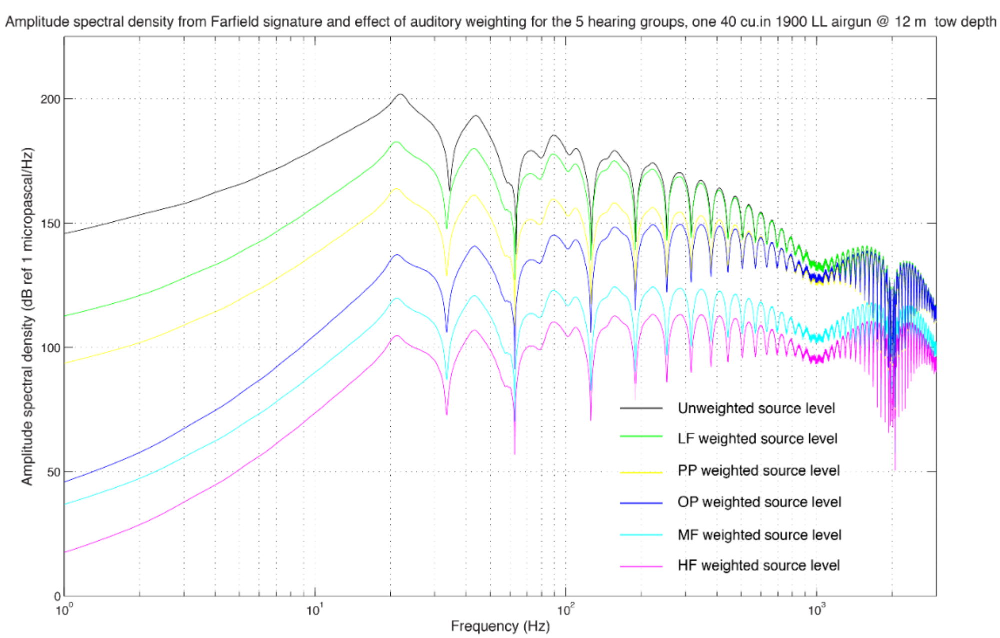

FIGURE A-13. Modeled amplitude spectral density of the 40-in^3 airgun farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral levels are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

TABLE A-7. Results for single shot SEL source level modeling for the single 40-in^3 mitigation airgun with weighting function calculations for the SEL_{cum} criteria, as well as resulting isopleths to thresholds for various marine mammal hearing groups.

STEP 1: GENERAL PROJECT INFORMATION

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

STEP 2: WEIGHTING FACTOR ADJUSTMENT

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

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

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

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

STEP 3: SOURCE-SPECIFIC INFORMATION

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

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

SEL_{cum}

Source Velocity (meters/second)	2.16067	4.2 knots
1/Repetition rate^ (seconds)	17.35572762	37.5/2.16067

†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	1.14717E+19	1.12211E+19	1.57528E+19	1.12211E+19	9.89617E+18

RESULTANT ISOPLETHS*

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

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
SEL_{cum} Threshold	183	185	155	185	203
PTS SEL_{cum} Isopleth to threshold (meters)	0.5	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-13).

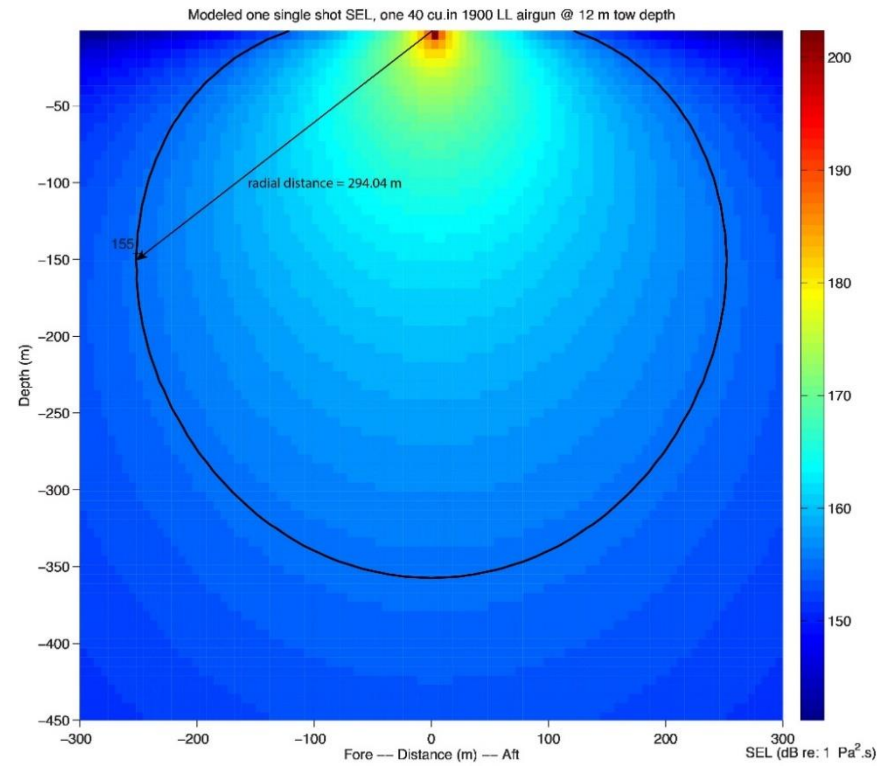

FIGURE A-14. Modeled received sound levels (SELs) in deep water from one 40-in³ airgun at a 12-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (294.04 m).

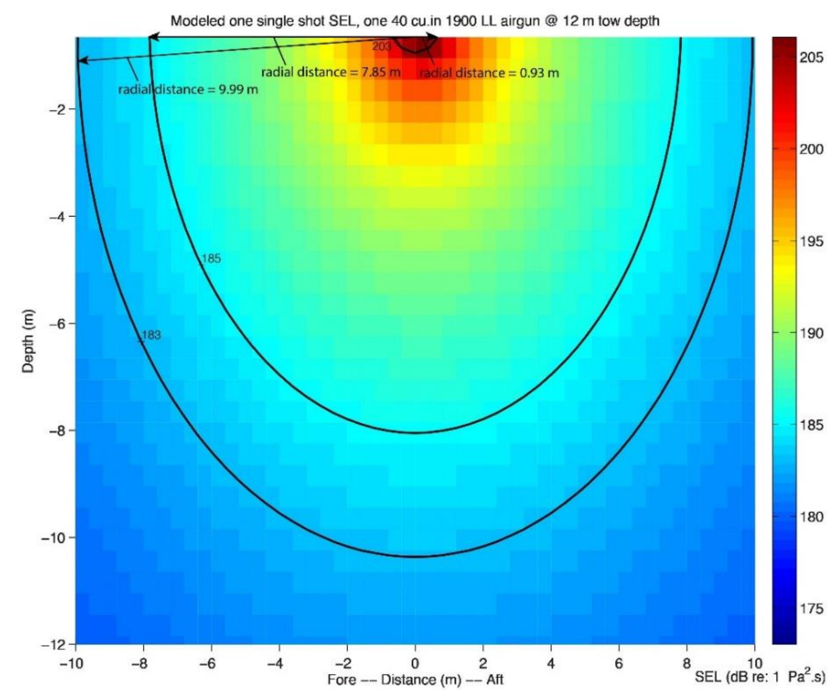

FIGURE A-15. Modeled received sound levels (SELs) in deep water from one 40-in³ airgun at a 12-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183–185 dB and 203 dB SEL isopleths.

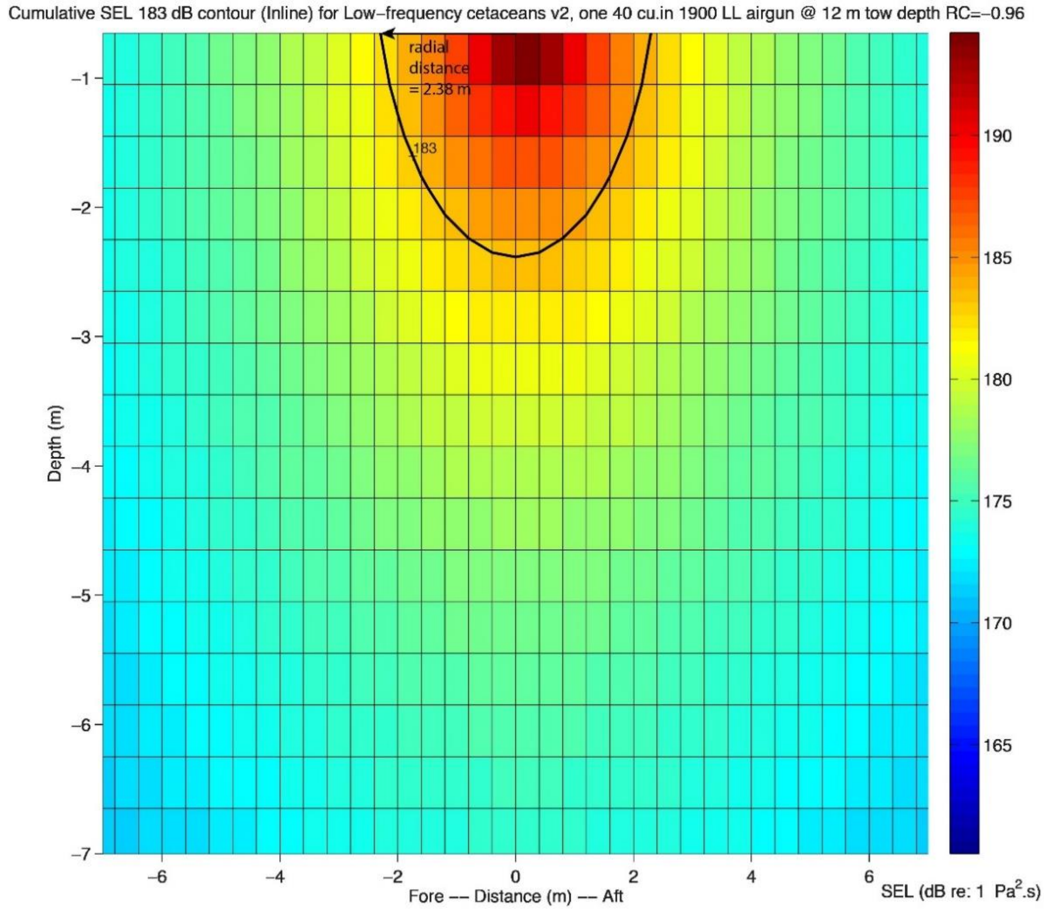

FIGURE A-16. Modeled received sound exposure levels (SELs) from one 40-in^3 mitigation at a 12-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one shot. The difference in radial distances between Fig. A-15 and this figure allows us to estimate the adjustment in dB.

TABLE A-8. NMFS Level A acoustic thresholds (Peak SPL_{flat}) for impulsive sources for marine mammals and predicted distances to Level A thresholds for various marine mammal hearing groups that could be received from the 40-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 and Sea Otters
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.

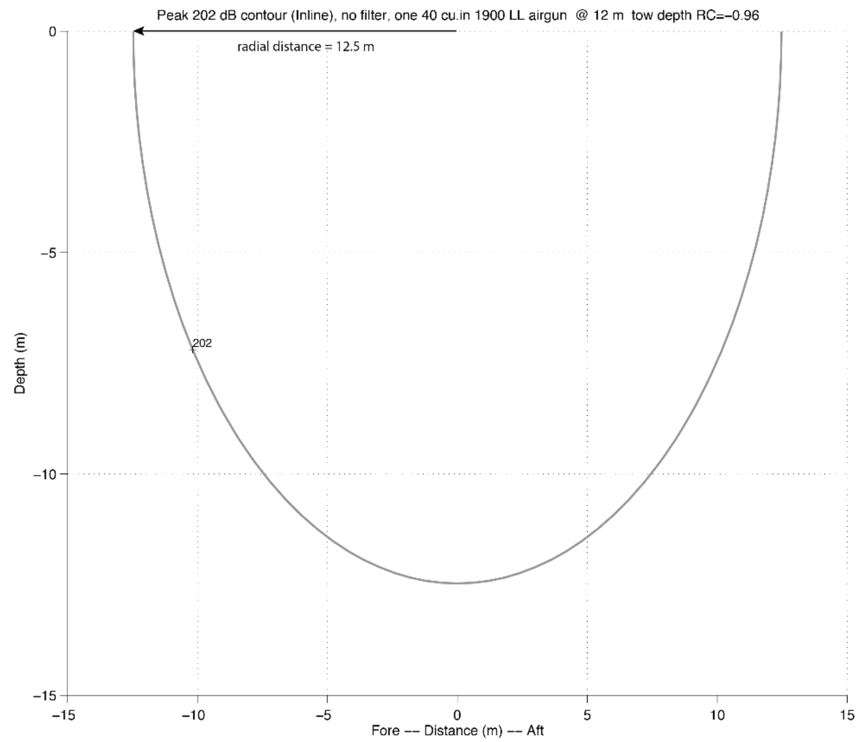

FIGURE A-17. Modeled deep-water received Peak SPL from one 40 in³ airgun at a 12-m tow depth. The plot provides the radial distance from the source geometrical center to the 202-dB Peak isopleth.

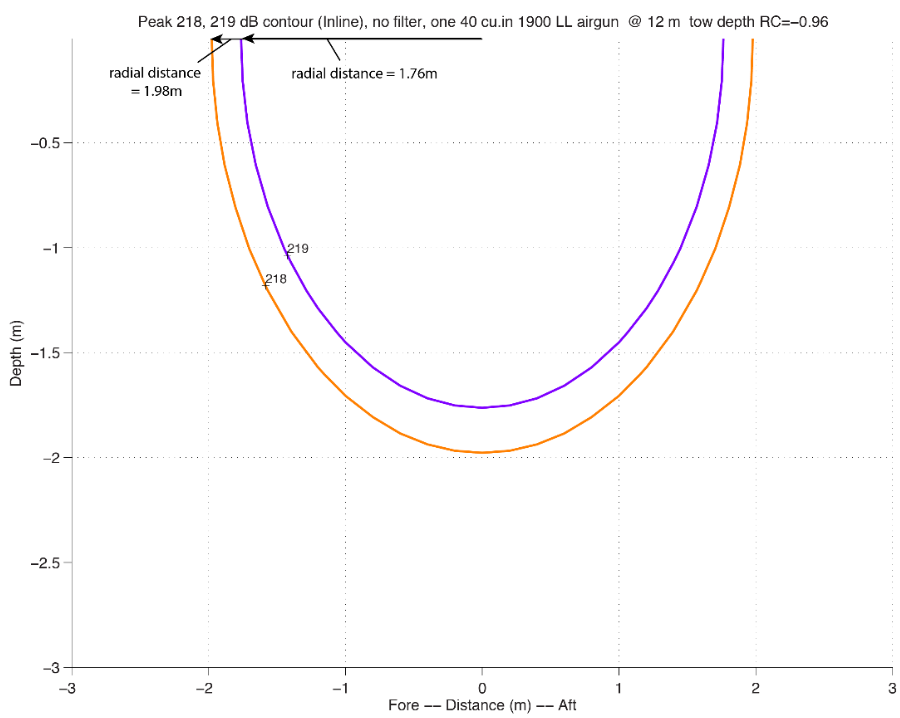

FIGURE A-18. Modeled deep-water received Peak SPL from one 40 in³ airgun at a 12-m tow depth. The plot provides the radial distances from the source geometrical center to the 218 and 219-dB Peak isopleths.

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APPENDIX B: METHODS FOR MARINE MAMMAL DENSITIES AND TAKE CALCULATIONS

APPENDIX B: METHODS FOR MARINE MAMMAL DENSITIES AND TAKE CALCULATIONS

The U.S. Navy primarily used SWFSC spatial models to develop a marine species density database for the Northwest Training and Testing Study Area (USN 2019a), which encompasses the U.S. portion of the proposed survey area; if no density spatial modeling was available, other data sources were used (USN 2019a). The USN marine species density database is currently the most comprehensive density data set available for the CCE. However, GIS data layers are currently unavailable for the database; thus, in this analysis the USN data were used only for species for which density data were not available from an alternative spatially-explicit model (e.g., minke, sei, gray, false killer, killer, and short-finned pilot whales, *Kogia* spp., pinnipeds, and leatherback sea turtle). For these species, GIS was used to determine the areas expected to be ensonified in each density category. The densities (Table B-1) were then multiplied by the ensonified areas to determine Level A and Level B takes (Table B-2).

As recommended by NMFS, spatially-explicit density data from the NOAA CetSound website (NOAA 2019l) were used for most other species (i.e., humpback, blue, fin, sperm, Baird's beaked, and other small beaked whales; bottlenose, striped, short-beaked common, Pacific white-sided, Risso's, and northern right whale dolphins; and Dall's porpoise). CetMap (https://cetsound.noaa.gov/cda) provides output habitat-based density models for cetaceans in the CCE. As CetMap provides output from habitat-based density models for cetaceans in the CCE (Becker et al. 2016) in the form of GIS layers; these were used to calculate takes in the survey area. The density estimates were available in the form of a GIS grid with each cell in the grid measuring ~7 km east-west by 10 km north-south. This grid was intersected with a GIS layer of the areas expected to be ensonified to >160 dB SPL within the three water depth categories (<100 m, 100–1000 m, >1000 m). The densities from all grid cells overlapping the ensonified areas within each water depth category were averaged to calculate a zone-specific density for each species (Table B-1). These densities were then multiplied by the total area (for the U.S. and non-territorial waters of Canada) within each water depth category expected to be ensonified above the relevant threshold levels to estimate Level A and Level B takes (Table B-3).

As CetMap did not have a spatially-explicit GIS density layer for the harbor porpoise, densities from Forney et al. (2014) were used for that species for the portions of the survey area that occurred within the 200-m isobath (Table B-1). Densities for sea otters (Table B-1) were calculated based on the number of otters in Washington (Jeffries et al. 2017) and B.C. (Nichol et al. 2015) occurring within the 40-m isobath of their respective habitats in the U.S. (USFWS 2018) and Canada (Nichol et al. 2015; Province of B.C. 2019). As sea otters spend a substantial amount of time each day at the surface, the densities were corrected for their daily activity budget and time spent underwater. According to Yeates et al. (2007), sea otters spend 40.2% of time resting, 36.3% foraging, 9.1% grooming, and 8.5% swimming; 7.3% of time is spent doing other activities. If 36.3% of a day is spent foraging, and dives are on average 55 s long and surface bouts between dives are 45 s long (Laidre and Jameson 2006), then a total of 20% each day is spent underwater while foraging. Combining the portion of time spent underwater during swimming (8.5%) and foraging (20%) resulted in a correction factor of 0.285. As all sea otter habitat in B.C. that was estimated to be ensonified occurred within Canadian Territorial Waters, no takes were calculated for B.C.

The requested take for false killer whales was increased to mean group size provided by Mobley et al. (2000), as no density information was available for Oregon, Washington, or B.C. The requested takes for small beaked whales were assigned to various species as follows: assuming that Cuvier's beaked whale and Stejneger's beaked whale are expected to occur in similar numbers in the survey area as Baird's beaked whale, the same take as determined for Baird's beaked whale was assigned to the other two beaked whale species (i.e., 83 individuals each). As Blainville's beaked whale is unlikely to occur in the survey area, it was allotted a take of 7 individuals or the maximum group size as reported by Jefferson et al. (2015). The remaining takes (70) were assigned to Hubbs' beaked whale, which is expected to be rare in the survey area. For killer whales, the density for all stocks occurring offshore were used from USN (2019b).

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TABLE B-1. Marine mammal densities expected to occur in the proposed survey area in the Northeast Pacific Ocean.

		Estimated Density (#/km^2)					
Species	Category	Density (not by water depth)	Shallow water <100 m	Intermediate water 100-1000 m	Deep water >1000 m	Source	Comments
LF Cetaceans							
North Pacific right whale			*0*	*0*	*0*		Not provided but near zero
Humpback whale			*0.005240*	*0.004020*	*0.000483*	Becker et al. (2016)	Summer/fall
Blue whale			0.002023	0.001052	0.000358	Becker et al. (2016)	Annual densities
Fin whale			*0.000202*	*0.000931*	*0.001381*	Becker et al. (2016)	Annual densities
Sei whale			*0.000400*	*0.000400*	*0.000400*	USN (2019a)	Annual densities
Minke whale			*0.001300*	*0.001300*	*0.001300*	USN (2019a)	Annual densities
Gray whale							
	1: 0-10 km from shore	0.015500				USN (2019a)	Density for summer (July-November)
	2: 10-47 km from shore	0.001000				USN (2019a)	Density for summer (July-November)
MF Cetaceans							
Sperm whale			*0.0000586*	*0.0001560*	*0.0013023*	Becker et al. (2016)	Annual densities
Baird's beaked whale			0.000114	0.000300	0.001468	Becker et al. (2016)	Annual densities
Small beaked whale			0.000788	0.001356	0.003952	Becker et al. (2016)	Annual densities
Bottlenose dolphin			0.000001	0.000001	0.000011	Becker et al. (2016)	Annual densities
Striped dolphin			0.000000	0.000002	0.000133	Becker et al. (2016)	Annual densities
Short-beaked common dolphin			0.000508	0.001029	0.001644	Becker et al. (2016)	Annual densities
Pacific white-sided dolphin			0.051523	0.094836	0.070060	Becker et al. (2016)	Annual densities
Northern right-whale dolphin			0.010178	0.043535	0.062124	Becker et al. (2016)	Annual densities
Risso's dolphin			0.030614	0.030843	0.015885	Becker et al. (2016)	Annual densities
False killer whale							
Killer whale (Offshore waters)			0.000920	0.000920	0.000920	USN (2019b)	Annual densities
Short-finned pilot whale			0.000250	0.000250	0.000250	USN (2019a)	Annual densities
HF Cetaceans							
Pygmy/dwarf sperm whale			0.001630	0.001630	0.001630	USN (2019a)	Annual densities
Dall's porpoise			0.145077	0.161061	0.113183	Becker et al. (2016)	Summer/fall
Harbor porpoise							
	1: North of 45N	0.624000				Forney et al. (2014)	Annual density north of 45N, within 200-m isobath
	2: South of 45N	0.467000				Forney et al. (2014)	Annual density south of 45N, within 200-m isobath
Otariid Seals							
Northern fur seal							
	1: up to 70 km from shore	0.011325				USN (2019a)	Density for June (summer densities are lower), adjusted for most recent population size
	2: 70-130 km from shore	0.134644				USN (2019a)	Density for June (summer densities are lower), adjusted for most recent population size
	3: >130 km from shore	0.010342				USN (2019a)	Density for June (summer densities are lower), adjusted for most recent population size
Guadalupe fur seal							
	1: within 200-m isobath	*0.023477*				USN (2019a)	Density for summer (other densities lower), adjusted for most recent population size
	2: 200-m isobath to 300 km	*0.026260*				USN (2019a)	Density for summer (other densities lower), adjusted for most recent population size
California sea lion							
	1: 0-40 km from shore	0.028800				USN (2019a)	Density for August (density zero during June and July)
	2: 40-70 km from shore	0.003700				USN (2019a)	Density for August (density zero during June and July)
	3: 70-450 km from shore	0.006500				USN (2019a)	Density for August (density zero during June and July)
Steller sea lion							
	1: within 200-m isobath	0.308886				USN (2019a)	Average densities for OR/WA for summer; adjusted for most recent population size
	2: 200-m isobath to 300 km	0.002222				USN (2019a)	Average densities for OR/WA for summer; adjusted for most recent population size
Phocid Seals							
Northern elephant seal			0.034600	0.034600	0.034600	USN (2019a)	Density for summer; revised to account for 2020 population size
Harbor seal							
	1: within 30 km from shore	0.342400				USN (2019a)	Annual density within 30 km from WA/OR shore

TABLE B-2. Take estimates for the proposed survey area in the Northeast Pacific Ocean for the harbor porpoise and species with densities from USN (2019a,b).

Species	Estimated Density (#/km^2) Category 1	Category 2	Category 3	Regional Population Size	Level B 160 dB Ensonified Area (km^2) Category 1	Category 2	Category 3	Level A Ensonified Area (km^2) Category 1	Category 2	Category 3	Level B Takes Category 1	Category 2	Category 3	Level B Takes (All)	Level A Takes	Level A Takes	% of Pop. (Total Takes)	A+B Take Authorization
LF Cetaceans																		
North Pacific right whale	*0*	*0*	*0*	400	11,434	24,201	50,925	541	1,358	3,707	0	0	0	0	0	0	0.00	0
Sei whale	*0.0004000*	*0.0004000*	*0.0004000*	27,197	11,434	24,201	50,925	541	1,358	3,707	5	10	20	35	32	2	0.13	35
Minke whale	0.0013000	0.0013000	0.0013000	20,000	11,434	24,201	50,925	541	1,358	3,707	15	31	66	113	105	7	0.56	113
Gray whale	0.0155000	0.0010000		26,960	4,189	27,019		45	1,722		65	27	0	92	90	2	0.34	92
MF Cetaceans																		
False killer whale	N.A.	N.A.	N.A.	N.A.	11,434	24,201	50,925	17	44	119	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	**5**
Killer whale	0.0009200	0.0009200	0.0009200	918	11,434	24,201	50,925	17	44	119	11	22	47	80	79	0	8.67	80
Short-finned pilot whale	0.0002500	0.0002500	0.0002500	836	11,434	24,201	50,925	17	44	119	3	6	13	22	24	0	2.59	**29**
HF Cetaceans																		
Pygmy/dwarf sperm whale	0.0016300	0.0016300	0.0016300	4,111	11,434	24,201	50,925	340	857	2,336	19	39	83	141	135	6	3.43	141
Harbor porpoise	0.6240000	0.4670000		65,347	14,068	9,054		495	301		8,778	4,228	0	13,007	12,557	449	19.90	13,007
Otariid Seals																		
Northern fur seal	0.0113247	0.1346441	0.0103424	620,660	40,062	29,518	16,979	57	54	29	454	3,974	176	4,604	4,596	8	0.74	4,604
Guadalupe fur seal	*0.0234772*	*0.0262595*		34,187	23,122	62,719		32	109		543	1,647	0	2,190	2,383	4	6.41	2,190
California sea lion	0.0288000	0.0037000	0.0065000	257,606	27,476	12,587	46,497	40	17	83	791	47	302	1,140	1,138	2	0.44	1,140
Steller sea lion	0.3088864	0.0022224		77,149	23,122	62,719		32	109		7,142	139	0	7,281	7,271	10	9.44	7,281
Phocid Seal																		
Northern elephant seal	0.0345997	0.0345997	0.0345997	179,000	11,434	24,201	50,925	55	140	382	396	837	1,762	2,995	2,975	20	1.67	2,995
Harbor seal	0.3424000			129,732	19,091			107			6,537	0	0	6,537	6,500	37	5.04	6,537

N.A. means not available. Requested take for the false killer whale is based on mean group size (Mobley et al. 2000) and that for short-finned pilot whales is based on mean group size from Barlow (2016). For different categories, see density table (Table B-1).

TABLE B-3. Take estimates for the proposed survey area in the Northeast Pacific Ocean for the species with densities from Becker et al. (2016).

Species	Estimated Density (#/km^2)			Regional Population Size	Level B 160 dB Ensonified Area (km^2)			Level A Ensonified Area (km^2)			Level B Takes			Level B Takes (All)	Level B-Level A Takes	Level A Takes	% of Pop. (Total Takes)	Requested Level A+B Take Authorization
	Category 1	Category 2	Category 3		Category 1	Category 2	Category 3	Category 1	Category 2	Category 3	Category 1	Category 2	Category 3					
LF Cetaceans																		
North Pacific right whale	*0*	*0*	*0*	400	11,434	24,201	50,925	541	1,358	3,707	0	0	0	0	0	0	0.00	0
Sei whale	*0.0004000*	*0.0004000*	*0.0004000*	27,197	11,434	24,201	50,925	541	1,358	3,707	5	10	20	35	32	2	0.13	35
Minke whale	0.0013000	0.0013000	0.0013000	20,000	11,434	24,201	50,925	541	1,358	3,707	15	31	66	113	105	7	0.56	113
Gray whale	0.0155000	0.0010000		26,960	4,189	27,019		45	1,722		65	27	0	92	90	2	0.34	92
MF Cetaceans																		
False killer whale	N.A.	N.A.	N.A.	N.A.	11,434	24,201	50,925	17	44	119	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	**5**
Killer whale	0.0009200	0.0009200	0.0009200	918	11,434	24,201	50,925	17	44	119	11	22	47	80	79	0	8.67	80
Short-finned pilot whale	0.0002500	0.0002500	0.0002500	836	11,434	24,201	50,925	17	44	119	3	6	13	22	22	0	2.59	**29**
HF Cetaceans																		
Pygmy/dwarf sperm whale	0.0016300	0.0016300	0.0016300	4,111	11,434	24,201	50,925	340	857	2,336	19	39	83	141	135	6	3.43	141
Harbor porpoise	0.6240000	0.4670000		65,347	14,068	9,054		495	301		8,778	4,228	0	13,007	12,557	449	19.90	13,007
Otariid Seals																		
Northern fur seal	0.0113247	0.1346441	0.0103424	620,660	40,062	29,518	16,979	57	54	29	454	3,974	176	4,604	4,596	8	0.74	4,604
Guadalupe fur seal	*0.0234772*	*0.0262595*		34,187	23,122	62,719		32	109		543	1,647	0	2,190	2,186	4	6.41	2,190
California sea lion	0.0288000	0.0037000	0.0065000	257,606	27,476	12,587	46,497	40	17	83	791	47	302	1,140	1,138	2	0.44	1,140
Steller sea lion	0.3088864	0.0022224		77,149	23,122	62,719		32	109		7,142	139	0	7,281	7,271	10	9.44	7,281
Phocid Seal																		
Northern elephant seal	0.0345997	0.0345997	0.0345997	179,000	11,434	24,201	50,925	55	140	382	396	837	1,762	2,995	2,975	20	1.67	2,995
Harbor seal	0.3424000			129,732	19,091			107			6,537	0	0	6,537	6,500	37	5.04	6,537

Requested takes for bottlenose dolphin, striped dolphin, and short-beaked common dolphin were increased to mean group size from Barlow (2016).

TAKE SUMMARY

TABLE 1. 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 late spring/summer 2020. Takes for Canadian Territorial Waters are not included here. Species in italics are listed under the ESA as *endangered* or *threatened*.

Species	Calculated Take: Level B[1]	Calculated Take: Level A[2]	Regional Population Size	Level B + Level A as % of Pop.[3]	Requested Take Authorization[4]
LF Cetaceans					
North Pacific right whale	*0*	*0*	*400*	*0*	*0*
Humpback whale	*172*	*10*	*10,103*	*1.8*	*182*
Blue whale	*63*	*4*	*1,496*	*4.5*	*67*
Fin whale	*89*	*6*	*18,680*	*0.5*	*95*
Sei whale	*32*	*2*	*27,197*	*0.1*	*35*
Minke whale	105	7	20,000	0.6	113
Gray whale	90	2	26,960	0.3	92
MF Cetaceans					
Sperm whale	*71*	*0*	*26,300*	*0.3*	*71*
Baird's beaked whale	83	0	2,697	3.1	83
Small beaked whale[5]	243	1	6,318	3.8	243
Bottlenose dolphin[6]	1	0	1,924	0	**13**
Striped dolphin[6]	7	0	29,211	0	**46**
Short-beaked common dolphin	114	0	969,861	0	**179**
Pacific white-sided dolphin	6,439	13	48,974	13.2	6,452
Northern right-whale dolphin	4,324	9	26,556	16.3	4,334
Risso's dolphin	1,902	4	6,336	30.1	1,905
False killer whale[7]	N.A.	N.A.	N.A.	N.A.	**5**
Killer whale[8]	79	0	918	8.7	80
Short-finned pilot whale	24	0	836	2.6	**29**
HF Cetaceans					
Pygmy/dwarf sperm whale	135	6	4,111	3.4	141
Dall's porpoise	10,869	452	31,053	36.5	11,320
Harbor porpoise	12,557	449	65,347	19.9	13,007
Otariid Seals					
Northern fur seal	4,596	8	620,660	0.7	4,604
Guadalupe fur seal	2,383	4	34,187	6.4	*2,190*
California sea lion	1,138	2	257,606	0.4	1,140
Steller sea lion	7,271	10	77,149	9.4	7,281
Phocid Seal					
Northern elephant seal	2,975	20	179,000	1.7	2,995
Harbor seal	6,500	37	129,732	5.0	6,537

N.A. means not applicable or not available.

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

2 Level A takes if there were no mitigation measures.

3 Requested take authorization is Level A plus Level B calculated takes.

4 Requested take authorization (Level A + Level B) expressed as % of population off California/Oregon/ Washington, Eastern North Pacific, or U.S. stock.

5 Requested take includes 7 Blainville's beaked whales, 83 Stejneger's beaked whales, 83 Cuvier's beaked whales, and 70 Hubbs' beaked whales (see Appendix B for more information).

6 Requested take increased to mean group size (Mobley et al. 2000). 7 Includes individuals from all stocks.

APPENDIX C: ENSONIFIED AREAS FOR MARINE MAMMAL TAKE CALCULATIONS

Survey Zone		Criteria	Daily Ensonified Area (km^2)	Total Survey Days	Total Ensonified Area (km^2)	Relevant Isopleth (m)
Shallow <100 m		160 dB	309.0	37	11,433.8	12650
Intermediate 100-1000 m		160 dB	654.1	37	24,200.7	9468
Deep >1000 m		160 dB	1376.3	37	50,924.6	6733
	Overall	**160 dB**	**2339.4**	**37**	**86,559.1**	
All zones		LF Cetacean	151.5	37	5,605.3	426.9
All zones		MF Cetacean	4.9	37	179.9	13.6
All zones		HF Cetacean	95.5	37	3,532.9	268.3
All zones		Otariid	3.8	37	140.2	10.6
All zones		Phocid	15.6	37	577.6	43.7
All zones		Sea Turtle	7.3	37	271.1	20.5

APPENDIX D: USING EMPIRICAL DATA FOR ESTIMATION OF LEVEL B RADII

Based on Crone et al.'s 2014 paper ("*Estimating shallow water sound power levels and mitigation radii for the R/V Marcus G. Langseth using an 8 km long MCS streamer*" [Timothy J. Crone, Maya Tolstoy, and Helene Carton], empirical data collected on the Cascadia Margin in 2012 during the COAST Survey support the use of the multichannel seismic (MCS) streamer data and the use of Sound Exposure Level (SEL) as the appropriate measure to use for the prediction of mitigation radii for the proposed 2020 Cascadia Survey. In addition, this peer-reviewed paper showed that the method developed for this purpose is most appropriate for shallow water depths, up to approximately (~) 200m.

To estimate Level B (behavioral disturbance for cetaceans) radii in shallow and intermediate water depths, we used the received levels from MCS data collected by the research vessel (R/V) *Marcus G. Langseth (Langseth)* during the COAST survey (Crone et al., 2014), which occurred in the same area as the proposed 2020 Cascadia Survey. Streamer data in shallow water collected in 2012 have the advantage of including the effects of local and complex subsurface geology, seafloor topography and water column properties and thus allow us to establish mitigation radii more confidently than by using the data from calibration experiments in the Gulf of Mexico [Tolstoy et al., 2004, 2009; Diebold et al., 2010].

As shown by Madsen et al., 2005, Southall et al., 2007 and Crone et al., 2014, the use of the root mean square (RMS) pressure levels to calculate received levels of an impulsive source leads to undesirable variability in levels due to the effects of signal length, potentially without significant changes in exposure level. All these studies recommend the use of SEL to establish impulsive source thresholds used for mitigation.

Here we provide both the actual measured 160 decibel $(dB)_{RMS}$ and $160dB_{SEL}$ to demonstrate that for determining mitigation radii in shallow water and intermediate, both would be significantly less than the modeled data for this region.

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Extracted from Crone et al. 2014 – Section 4.1

4. Discussion

4.1. RMS Versus SEL In his paper, Madsen [2005] makes a compelling argument against the use of RMS (equation (3)) for the determination of safe exposure levels and mitigation radii for marine protected species, partially on the grounds that this measure does not take into account the total acoustic energy that an animal's auditory system would experience. Madsen [2005] recommended the use of SEL as well as measures of peak pressure to establish impulsive source thresholds used for mitigation. Southall et al. [2007] came to similar conclusions.

Our work should provide further motivation for a regulatory move away from RMS power levels for marine protected species mitigation purposes. In shallow waters especially, interactions between direct, reflected, and refracted arrivals of acoustic energy from the array can result in large variations in signal length (T_{90}), and commensurate large variations in RMS without necessarily significant changes in exposure level. The use of SEL, which accounts for signal length, should be preferred for mitigation purposes in shallow water.

****

The proposed surveys would acquire data with a 4 string 6600 in^3 airgun array at a tow depth of 12 m while the data collected in 2012 were acquired with a 4 string 6600 in^3 airgun array at a tow depth of 9 m. To account for the differences in tow depth between the COAST survey (6600 in^3 at 9 m tow depth) and the proposed survey (6600 in^3 at 12 m tow depth), we calculated a scaling factor using the deepwater modeling. The 150 dB_{SEL} corresponds to deep-water maximum radii of 10,533 m for the 6600 in^3 airguns at 12 m tow depth, and 9,149 m for the 6600 in^3 at 9m tow depth yielding scaling factors of 1.15 to be applied to the shallow-water 9m tow depth results.

As the 6600 cu.in source is 18m wide (across-line direction) and 16m long (along-line direction), this quasi-symmetric source is also able to capture azimuthal variations.

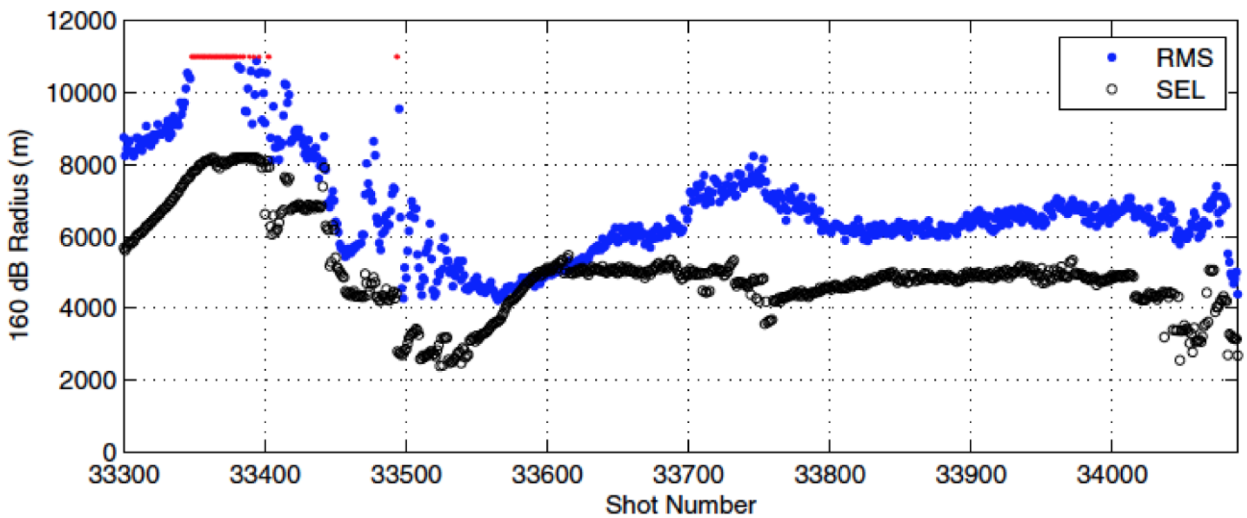

Figure 1: Measured radius distances to the 160 dB radii for both SEL and RMS along line A/T collected in 2012 in Cascadia with the Langseth 6600 in^3 airgun array towed at a depth of 9m (Fig. 12 from Crone et al., 2014). This line extends across the shelf from ~50m water depth (Shot 33,300), 100m water depth (Shot # 33,675) out ~to the shelf break at 200m water depth (~Shot # 34000).

The entire $160dB_{SEL}$ level data are within the length of the streamer and are well behaved throughout this depth profile. The measured sound level data in this area suggest that the $160dB_{SEL}$ mitigation radius distance would be well defined at a maximum of 8,192 km but that the $160dB_{RMS}$ would be close to ~11 km (Figure 1). For a few shots along this profile, the 160 dB_{RMS} is just beyond the end of the R/V *Langseth* streamer (8 km). For these shots, extrapolation was necessary. Crone et al., 2014 could only extrapolate the $160dB_{RMS}$ levels up to a distance of ~11 km (~133% of the length of the streamer). However, the stable $160dB_{SEL}$ levels across this interval would support an extrapolated value of not much more than 11 km for the $160dB_{RMS}$ level given that the $160dB_{RMS}$ and $160dB_{SEL}$ levels track consistently along the profile (Figure 1).

As noted in Table 2 of Crone et al., 2014, the full range of $160dB_{RMS}$ measured radii for intermediate waters is 4,291 m to 8,233m. The maximum $160dB_{RMS}$ measured radii, 8,233 m (represented by a single shot at ~33750 from Figure 1), was selected for the $160dB_{RMS}$ measured radii in Table 1. Only 2 shots in water depths greater than 100 m had radii that exceeded 8000 m and there were over 1,100 individual shots analyzed in the data, thus use of 8,233 m is conservative.

TABLE 1: Comparison of Modeled Mitigation Radii with Empirically-derived Radii from the Cascadia Margin during the 2012 COAST Survey. Radii for both measured $160dB_{RMS}$ and $160dB_{SEL}$ are shown with (in Red for$160dB_{RMS}$) and without conversion factor for source tow depth.

Array	Water Depth (m)	Proposed CASCADIA PROJECT RADII (using LDEO Modeling)	COAST PROJECT RADII (using LDEO Modeling)	Predicted Cascadia Project Radii using Empircal Data (Crone et al.2014). 160dB RMS Measured distances w/source depth conversion factor are shown in RED			
		Predicted distances (in m) to the 160-dB RMS Received Sound Level Langseth 6600 cu.in @12m	Predicted distances (in m) to the 160-dB RMS Received Sound Level Langseth 6600 cu.in @9m (COAST CRUISE)	Measured Distance (m) @ 160dB SEL from Figure 1 (Figure 12 - Crone et al., 2014)	Measured Distances (m) @160dB SEL w/Conversion Factor (1.15) from 9m to 12m Source Tow Depth	Measured Distance (m) @ 160dB RMS from Figure 1 (Figure 12 -Crone et al., 2014)	Measured Distances (m) @160dB RMS w/Conversion Factor (1.15) from 9m to 12m Tow Depth
4 strings, 36 airguns, 6600 in3	<100 m	25,494	20,550	8,192	9,421	11000*	12,650
	100 - 1000m	10,100	12,200	5478	6300	8233	9468
					*Note: This value is extrapolated from end of 8km streamer. Based on stable SEL values at same shot values, RMS extrapolated value is reasonable approximation		

Summary:

The empirical data collected during the COAST Survey on Cascadia Margin and measured $160dB_{RMS}$ and $160dB_{SEL}$ values demonstrate that the modeled predictions are quite conservative by a factor of up to ~2 to 2.5 times less than modeled predictions for the proposed Cascadia project. While we have sought to err on the conservative side for our activities, being overly conservative can dramatically overestimate potential and perceived impacts of a given activity. We understand that the $160dB_{RMS}$ and have been highlighted here as the the standard metric to be used but evidence from multiple publications including Crone et al. (2014) have argued that SEL is a more appropriate metric for mitigation radii calculations. However, its important to note that use of either measured SEL or RMS metrics yields significantly smaller radii in shallow water than model predictions. Overall, there is strong scientific basis justifying revising the mitigation radii and re-considering potential impacts of this activity.

When evaluating the empirical and modeled distances, all the other considerations and aspects of the airgun array still apply including:

- the airgun array is actually a distributed source and the predicted farfield level is never actually fully achieved
- the downward directionality of the airguns means that the majority of energy is directed downwards and not horizontally
- animals observed at the surface benefit from Lloyds mirror effect
- there is only one source vessel and the entire survey area is not ensonified all at one time, but rather the much smaller area around the vessel.

For these reasons, we believe the more scientifically appropriate approach for the proposed survey is to use Level B threshold distances based on the empirical data adjusted for tow depth.