Draft Environmental Assessment/Analysis of a Marine Geophysical Survey by R/V *Marcus G. Langseth* of the Cascadia Subduction Zone in the Northeast Pacific Ocean, Late Spring/Summer 2020

Prepared for

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ABSTRACT

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 and Nodes 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. The surveys would use a 36-airgun towed array with a total discharge volume of ~6600 in^3 and would occur in water depths ranging from 60–4400 m.

NSF, as the research funding and action agency, has a mission to "promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense…". The proposed seismic surveys would collect data in support of two research proposals that have been reviewed under the NSF merit review process and identified as an NSF program priority. They would serve 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.

This Draft Environmental Assessment/Analysis (EA) addresses NSF's requirements under the *National Environmental Policy Act* (NEPA) for the proposed NSF federal action within the U.S. EEZ and Executive Order 12114, "Environmental Effects Abroad of Major Federal Actions", for the proposed NSF federal action within the Canadian EEZ. Due to their involvement with the Proposed Action, the U.S. Geological Survey (USGS) has agreed to be a Cooperating Agency. As operator of R/V *Langseth*, L-DEO, on behalf of itself, NSF, WHOI, and UTIG, will request an Incidental Harassment Authorization (IHA) from the U.S. National Marine Fisheries Service (NMFS) to authorize the incidental (i.e., not intentional) harassment of small numbers of marine mammals should this occur during the seismic surveys. The analysis in this document supports the IHA application process and provides additional information on marine species that are not addressed by the IHA application, including sea turtles, seabirds, fish, and invertebrates that are listed under the U.S. *Endangered Species Act* (ESA), including candidate species. As analysis on endangered and threatened species was included, this document will also be used to support ESA Section 7 consultations with NMFS and the U.S. Fish and Wildlife Service (USFWS). Alternatives addressed in this EA consist of the Proposed Action with issuance of an associated IHA and the No Action alternative, with no IHA and no seismic surveys. This document tiers to the Programmatic Environmental Impact Statement/Overseas Environmental Impact Statement for Marine Seismic Research Funded by the National Science Foundation or Conducted by the U.S. Geological Survey (June 2011) and Record of Decision (June 2012), referred to herein as PEIS. This document also tiers to the Environmental Assessment of Marine Geophysical Surveys by the R/V *Marcus G. Langseth* in the Northeastern Pacific Ocean, June–July 2012 and issued Finding of No Significant Impact for similar seismic surveys conducted in 2012 in, or near, the proposed survey area.

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.

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*.

Potential impacts of the proposed seismic surveys on the environment would be primarily a result of the operation of the airgun array. A multibeam echosounder and sub-bottom profiler would also be operated during the surveys. Impacts from the Proposed Action would be associated with increased underwater anthropogenic sounds, which could result in avoidance behavior by marine mammals, sea turtles, seabirds, and fish, and other forms of disturbance. An integral part of the planned surveys is a monitoring and mitigation program designed to minimize potential impacts of the proposed activities on marine animals present during the proposed surveys, and to document, as much as possible, the nature and extent of any effects. Injurious impacts to marine mammals, sea turtles, and seabirds have not been proven to occur near airgun arrays or the other types of sound sources to be used. However, a precautionary approach would still be taken; the planned monitoring and mitigation measures would reduce the possibility of any effects.

Protection measures designed to mitigate the potential environmental impacts to marine mammals, sea turtles, and seabirds would include the following: ramp ups; typically two (but a minimum of one) dedicated observers maintaining a visual watch during all daytime airgun operations; two observers before and during ramp ups during the day; no start-ups during poor visibility or at night unless the exclusion zone (EZ) and passive acoustic monitoring (PAM) have been monitored for 30 min with no detections; PAM via towed hydrophones during both day and night to complement visual monitoring; and power downs (or if necessary shut downs) when marine mammals or sea turtles are detected in or about to enter the designated EZ. The acoustic source would also be powered or shut down in the event an ESA-listed seabird would be observed diving or foraging within the designated EZ. Observers would also watch for any impacts the acoustic sources may have on fish. L-DEO and its contractors are committed to applying these measures in order to minimize effects on marine mammals, sea turtles, seabirds, and fish, and other potential

environmental impacts. Ultimately, survey operations would be conducted in accordance with all applicable international, U.S. federal, and state regulations, including IHA and Incidental Take Statement (ITS) requirements.

With the planned monitoring and mitigation measures, unavoidable impacts to each species of marine mammal and sea turtle that could be encountered would be expected to be limited to short-term, localized changes in behavior and distribution near the seismic vessel. At most, effects on marine mammals would be anticipated as falling within the Marine Mammal Protection Act (MMPA) definition of "Level B Harassment" for those species managed by NMFS. No long-term or significant effects would be expected on individual marine mammals, sea turtles, seabirds, fish, the populations to which they belong, or their habitats. However, NSF is required to request, and NMFS may issue, Level A takes for some marine mammal species although Level A takes are very unlikely. No significant impacts would be expected on the populations of those species for which a Level A take is permitted.

LIST OF ACRONYMS

~	approximately
2-D	two-dimensional
ADCP	Acoustic Doppler Current Profiler
AEP	Auditory Evoked Potential
AMVER	Automated Mutual-Assistance Vessel Rescue
B.C.	British Columbia, Canada
BIA	Biologically Important Area
CA	California
CBD	Convention on Biological Diversity
CCE	California Current Ecosystem
CITES	Convention on International Trade in Endangered Species
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
DAA	Detailed Analysis Area
dB	decibel
DFO	(Canada) Department of Fisheries and Oceans
DPS	Distinct Population Segment
EA	Environmental Assessment/Analysis
EBSA	Ecologically or Biologically Significant Marine Areas
EFH	Essential Fish Habitat
EHV	Endeavour Hydrothermal Vents
EIS	Environmental Impact Statement
EO	Executive Order
ESA	(U.S.) *Endangered Species Act*
ETOMO	Endeavour Tomography
ETP	Eastern Tropical Pacific
EZ	Exclusion Zone
FM	Frequency Modulated
FONSI	Finding of no significant impact
GIS	Geographic Information System
GoM	Gulf of Mexico
h	hour
HAPC	Habitat Area of Particular Concern
hp	horsepower
Hz	Hertz
IHA	Incidental Harassment Authorization (under MMPA)
in	inch
ITS	Incidental Take Statement
IUCN	International Union for the Conservation of Nature
IWC	International Whaling Commission
kHz	kilohertz
km	kilometer
kt	knot
L-DEO	Lamont-Doherty Earth Observatory
LFA	Low-frequency Active (sonar)
LME	Large Marine Ecosystem
m	meter
MBES	Multibeam Echosounder
MCS	Multi-Channel Seismic
MFA	Mid-frequency Active (sonar)

min	minute
MMPA	(U.S.) *Marine Mammal Protection Act*
MPA	Marine Protected Area
ms	millisecond
NMFS	(U.S.) National Marine Fisheries Service
nmi	nautical mile
NOAA	National Oceanic and Atmospheric Administration
NPC	The North Pacific Current
NRC	(U.S.) National Research Council
NSF	National Science Foundation
OBN	Ocean Bottom Node
OBS	Ocean Bottom Seismometer
OBSIC	Ocean Bottom Seismometer Instrument Center
ODFW	Oregon Department of Fish and Wildlife
OEIS	Overseas Environmental Impact Statement
OOI	Ocean Observatories Initiative
p or pk	peak
PDO	Pacific Decadal Oscillation
PEIS	Programmatic Environmental Impact Statement
PI	Principal Investigator
PTS	Permanent Threshold Shift
PSO	Protected Species Observer
QAA	Qualitative Analysis Area
rms	root-mean-square
ROV	remotely operated vehicle
R/V	research vessel
s	second
SARA	(Canada) *Species at Risk Act*
SBP	Sub-bottom Profiler
SEL	Sound Exposure Level (a measure of acoustic energy)
SFU	Simon Fraser University
SIO	Scripps Institution of Oceanography
SPL	Sound Pressure Level
SOSUS	(U.S. Navy) Sound Surveillance System
SWFSC	Southwest Fisheries Science Center
t	tonnes
TTS	Temporary Threshold Shift
U.K.	United Kingdom
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
U.S.	United States of America
USCG	U.S. Coast Guard
USGS	U.S. Geological Survey
USFWS	U.S. Fish and Wildlife Service
UTIG	University of Texas at Austin, Institute of Geophysics
μPa	microPascal
vs.	versus
WCMC	World Conservation Monitoring Centre
WHOI	Woods Hole Oceanographic Institution
y	year

I PURPOSE AND NEED

This Draft Environmental Assessment/Analysis (EA) addresses NSF's requirements under the *National Environmental Policy Act* (NEPA) and Executive Order 12114, "Environmental Effects Abroad of Major Federal Actions". The Draft EA tiers to 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. This document also tiers to the EA of Marine Geophysical Surveys by R/V *Marcus G. Langseth* in the Northeastern Pacific Ocean, June–July 2012 and associated Finding of No Significant Impact (FONSI) for similar seismic surveys conducted in 2012 in, or near, the proposed survey area.[1] The purpose of this Draft EA is to provide the information needed to assess the potential environmental impacts associated with the Proposed Action, including the use of an airgun array during the proposed seismic surveys. Due to their involvement with the Proposed Action, the U.S. Geological Survey (USGS) has agreed to be a Cooperating Agency.

The Draft EA provides details of the Proposed Action at the site-specific level and addresses potential impacts of the proposed seismic surveys on marine mammals, sea turtles, seabirds, fish, and invertebrates. The Draft EA will also be used in support of other regulatory processes, including an application for an Incidental Harassment Authorization (IHA) and Section 7 consultations under the *Endangered Species Act* (ESA) with the National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS). The IHA would allow the non-intentional, non-injurious "take by harassment" of small numbers of marine mammals[2] during the proposed seismic surveys by Columbia University's Lamont-Doherty Earth Observatory (L-DEO) in the Northeast Pacific Ocean during late spring/summer (June–July) 2020. Per NMFS requirement, small numbers of Level A takes will be requested for the remote possibility of low-level physiological effects; however, because of the characteristics of the Proposed Action and proposed monitoring and mitigation measures, in addition to the general avoidance by marine mammals of loud sounds, Level A takes are considered highly unlikely.

1.1 Mission of NSF

The National Science Foundation (NSF) was established by Congress with the *National Science Foundation Act* of 1950 (Public Law 810507, as amended) and is the only federal agency dedicated to the support of fundamental research and education in all scientific and engineering disciplines. Further details on the mission of NSF are described in § 1.2 of the PEIS.

1.2 Purpose of and Need for the Proposed Action

As noted in the PEIS, § 1.3, NSF has a continuing need to fund seismic surveys that enable scientists to collect data essential to understanding the complex Earth processes beneath the ocean floor. The purpose of the proposed study is to use two-dimensional (2-D) seismic surveying and Ocean Bottom Seismometers (OBS) and Ocean Bottom Nodes (OBN) to investigate the Cascadia Subduction Zone and provide data

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[1] EA and FONSI available on the NSF website (https://www.nsf.gov/geo/oce/envcomp/index.jsp).

[2] To be eligible for an IHA under the MMPA, the proposed "taking" (with mitigation measures in place) must not cause serious physical injury or death of marine mammals, must have negligible impacts on the species and stocks, must "take" no more than small numbers of those species or stocks, and must not have an unmitigable adverse impact on the availability of the species or stocks for legitimate subsistence uses.

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 new constraints on earthquake and tsunami potential in this heavily populated region of the Pacific Northwest. The proposed activities would collect data in support of two research proposals that were reviewed through the NSF merit review process and were identified as NSF program priorities to meet the agency's critical need to foster an understanding of Earth processes.

1.3 Background of NSF-funded Marine Seismic Research

The background of NSF-funded marine seismic research is described in § 1.5 of the PEIS.

1.4 Regulatory Setting

The regulatory setting of this EA is described in § 1.8 of the PEIS, including the

- Executive Order 12114;
- *National Environmental Protection Act* (NEPA);
- *Marine Mammal Protection Act* (MMPA);
- *Endangered Species Act* (ESA);
- *National Historic Preservation Act* (NHPA);
- *Coastal Zone Management Act* (CZMA); and
- *Magnuson-Stevens Fishery Conservation and Management Act* **-** Essential Fish Habitat (EFH).

II ALTERNATIVES INCLUDING PROPOSED ACTION

In this Draft EA, two alternatives are evaluated: (1) the proposed seismic surveys and associated issuance of an associated IHA and (2) No Action alternative. Additionally, two alternatives were considered but were eliminated from further analysis. A summary of the Proposed Action, the alternative, and alternatives eliminated from further analysis is provided at the end of this section.

2.1 Proposed Action

The Draft EA includes analysis for two separate proposals received by NSF; however, due to their linked and dependent nature, they are considered the Proposed Action and are jointly analyzed herein. The Proposed Action, including project objectives and context, activities, and monitoring/ mitigation measures for the proposed seismic surveys and use of OBSs and OBNs, is described in the following subsections.

2.1.1 Project Objectives and Context

Researchers from L-DEO, Woods Hole Oceanographic Institution (WHOI), and the University of Texas at Austin Institute of Geophysics (UTIG), have proposed to conduct seismic surveys using R/V *Langseth* in the Northeast Pacific Ocean (Fig. 1). Although not funded through NSF, collaborators from the USGS, Drs. M. Nedimovic (Dalhousie University), and A. Calvert (Simon Fraser University; SFU) would work with the PIs to achieve the research goals, providing assistance, such as through logistical support, and data acquisition and exchange.

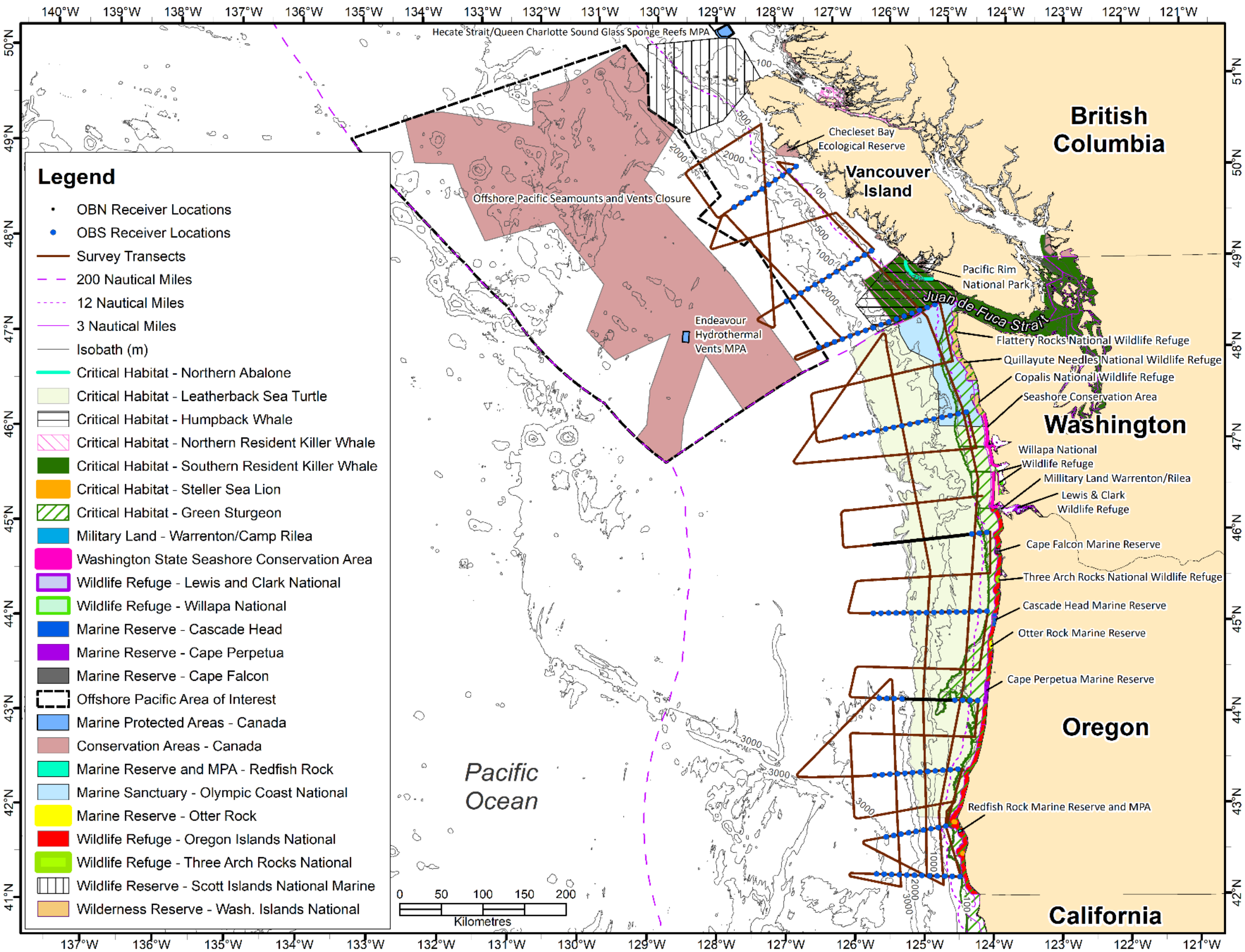

FIGURE 1. Location of the proposed seismic surveys in the Northeast Pacific Ocean and conservation areas near the proposed survey location.

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 and therefore would undergo separate environmental review, the project 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 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 following information provides an overview of the research project objectives associated with the surveys.

At the Cascadia Subduction Zone, the slow ongoing descent of the Juan de Fuca plate beneath the northwestern coast of North America has generated large earthquakes and associated tsunamis in the past. Geologic records suggest that some sections of the subduction zone fault or "megathrust", which extends ~35–90 mi. seaward from the coasts of northern California all the way to southern British Columbia (B.C.), slipped less than other sections during the last earthquake (1700 AD), and that in some prior large earthquakes, only parts of the subduction zone ruptured. The last earthquake is estimated to have been of magnitude 9, similar to that of the Tohoku earthquake in Japan in 2011; an earthquake of similar size is possible at Cascadia within the next century. Whether current inferences of along-margin variations in fault slip during the last earthquake may persist in future ruptures has important implications for quantifying earthquake and tsunami hazards for the population centers of the Pacific Northwest. Geologic structure such as seamounts and other topographic features in the descending Juan de Fuca plate, the structure and properties of the thick folded and faulted package of sediments that forms above the subduction zone fault, or the properties of megathrust fault rocks, could contribute to these along-margin variations. While at most of the World's subduction zones there is abundant present-day seismicity along the megathrust which can be used to constrain first-order properties of the subduction fault including its depth and geometry, the Cascadia Subduction Zone is "eerily" quiet with little seismicity recorded from much of the megathrust. With the paucity of instrumentally-recorded seismicity and the lack of offshore geodetic constraints on the distribution of interseismic locking, little is known of the properties of the subduction zone fault interface within the mega-thrust earthquake zone and how they vary along and across strike. The current observations allow for a wide range of possible future earthquake scenarios.

The acquired data would be designed 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 seismogenic zone at Cascadia. The data would be processed to pre-stack depth migration using state-of-the art seismic processing techniques and would be made openly available to the community, providing a high-quality data set illuminating the regional subsurface architecture all along the Cascadia Subduction Zone.

Aside from localized surveys conducted in 2012 by R/V *Langseth* using an 8-km streamer, no modern multi-channel seismic (MCS) data have been acquired at the Cascadia Subduction Zone. Data acquired prior to these surveys were collected in the 80's and 90's with much shorter streamers (2.6–4 km) and poorer quality sources and provide poor-to-no image of the earthquake fault interface at Cascadia. Long streamer (>8 km) MCS data represent major advances over the previous generation of MCS studies in the region for two primary reasons. (1) Data acquired with long-offset streamers support advanced techniques for noise and multiple suppression that enable imaging with improved clarity and resolution of the plate interface to much greater depths than previously obtained. (2) They enable construction of high-resolution, high-accuracy velocity models, which not only contribute to improved imaging via pre-stack depth migration, but can provide constraints on material properties at the megathrust that affect slip behavior. The proposed 15-km long streamer would provide significantly improved velocity determination from both reflection move-out based analysis and recorded refractions. The proposed study would also provide the first regional-scale characterization of the full length of the Cascadia Subduction Zone, enabling the first study of along-strike segmentation in megathrust properties. It would move the Cascadia megathrust zone from arguably one of the least well characterized heavily populated megathrust regions to one of the best.

Modern long-offset marine seismic reflection imaging techniques provide the best tools available for illuminating a subduction zone to the depths of the earthquake source region and below. They also provide constraints on geologic structure and material properties at the subduction fault that contribute to frictional state and variations in slip behavior along the fault. The overall goal of the seismic program proposed by L-DEO, UTIG, and WHOI is to acquire a regional grid of modern marine seismic reflection data spanning the entire Cascadia Subduction Zone to image how the geologic structure and properties of this subduction zone vary both along and across the margin. 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.

2.1.2 Proposed Activities

2.1.2.1 Location of the Survey Activities

The proposed survey 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, for the surveys, the tracklines could occur anywhere within the coordinates noted above. The surveys are proposed to occur within Exclusive Economic Zones (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.

2.1.2.2 Description of Activities

The procedures to be used for the proposed marine geophysical surveys would be similar to those used during previous surveys by L-DEO and would use conventional seismic methodology. The survey would involve one source vessel, 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 OBS program would leverage the seismic surveys by R/V *Langseth*.

As the airgun arrays are towed along the survey lines, the hydrophone streamer would transfer the data to the on-board processing system; 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.

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.

In addition to the operation of the airgun array, a multibeam echosounder (MBES), sub-bottom profiler (SBP), and 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.

2.1.2.3 Schedule

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. As R/V *Langseth* is a national asset, NSF and L-DEO strive to schedule its operations in the most efficient manner possible; schedule efficiencies are achieved when regionally occurring research projects are scheduled consecutively and non-operational transits are minimized. Because of the nature of the NSF merit review process and the long timeline associated with the ESA Section 7 consultation and IHA processes, not all research projects or vessel logistics are identified at the time the consultation documents are submitted to federal regulators; typically, however, these types of details, such as port arrival/departure locations, are not a substantive component of the consultations. 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.

2.1.2.4 Vessel Specifications

R/V *Langseth* is described in § 2.2.2.1 of the PEIS. The vessel speed during seismic operations would be ~4.2 kt (~7.8 km/h).

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

2.1.2.5 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.

2.1.2.6 OBS and OBN Description

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 from 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. As the OBNs are small, 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 31 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 31 units are deployed, the ROV would be retrieved, the skid would be reloaded with another 31 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.

2.1.2.7 Additional Acoustical Data Acquisition Systems

Along with the airgun operations, two additional acoustical data acquisition systems (an MBES and SBP) would be operated from R/V *Langseth* during the proposed surveys, but not during transits to/from the survey site and port. The ocean floor would be mapped with the Kongsberg EM 122 MBES and a Knudsen Chirp 3260 SBP. These sources are described in § 2.2.3.1 of the PEIS. To retrieve OBSs, an acoustic release transponder (pinger) is used to interrogate the instrument at a frequency of 8–11 kHz, and a response is received at a frequency of 11.5–13 kHz. The burn-wire release assembly is then activated, and the instrument is released to float to the surface from the anchor which is not retrieved. However, OBSs would not be recovered by R/V *Langseth*.

2.1.3 Monitoring and Mitigation Measures

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

Wright 2014; Dolman and Jasny 2015). Some of those recommendations have been taken into account here.

2.1.3.1 Planning Phase

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

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.

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.

Mitigation Zones**.—**During the planning phase, 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 also shows the distances at which the 175-dB re $1\mu Pa_{rms}$ sound level is expected to be received for the 36-airgun array and a single airgun; this level is used by NMFS, as well as the U.S. Navy (USN 2017), to determine behavioral disturbance for turtles.

The thresholds for permanent threshold shift (PTS) onset or Level A Harassment (injury) for marine mammals and sea turtles 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) (NMFS 2016a, 2018a), and sea turtles (USN 2017). 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 turtles and LF cetaceans, and Peak SPL is used for all other marine mammal hearing groups (Table 2).

TABLE 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 in³	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 in³	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.

TABLE 2. Level A threshold distances for different marine mammal hearing groups and sea turtles 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	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

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 shut 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-in³ 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 below.

2.1.3.2 Operational Phase

Marine mammals and sea turtles are known to occur in the proposed survey area. However, the number of individual animals expected to be approached closely during the proposed activities are expected to be relatively small in relation to regional population sizes. To minimize the likelihood that potential impacts could occur to the species and stocks, monitoring and mitigation measures proposed during the operational phase of the proposed activities, which are consistent with the PEIS and past IHA and incidental take statement (ITS) requirements, include:

1. monitoring by PSOs for marine mammals, sea turtles, and ESA-listed seabirds diving near the vessel, and observing for potential impacts of acoustic sources on fish;
2. passive acoustic monitoring (PAM);
3. PSO data and documentation; and
4. mitigation during operations (speed or course alteration; power-down, shut-down, and ramp-up procedures; and special mitigation measures for rare species, species concentrations, and sensitive habitats).

Five independently contracted PSOs would be on board the survey vessel with rotating shifts to allow two observers to monitor for marine species during daylight hours, and one observer to conduct PAM during day- and night-time seismic operations. The proposed operational mitigation measures are standard for all high-energy seismic cruises, per the PEIS, and are described in the IHA application, and therefore are not discussed further here. Special mitigation measures were considered for this cruise. It is unlikely that concentrations of large whales would be encountered within the 160-dB isopleth, but if they were, they would be avoided.

With the proposed monitoring and mitigation provisions, potential effects on most, if not all, individuals would be expected to be limited to minor behavioral disturbance. Those potential effects would be expected to have negligible impacts both on individual marine mammals and on the associated species and stocks. Ultimately, survey operations would be conducted in accordance with all applicable U.S. federal regulations, including IHA and ITS requirements.

2.2 Alternative 1: No Action Alternative

An alternative to conducting the Proposed Action is the "No Action" alternative, i.e., do not issue an IHA and do not conduct the research operations (Table 3). Under the "No Action" alternative, NSF would not support L-DEO to conduct the proposed research operations. From NMFS' perspective, pursuant to its obligation to grant or deny permit applications under the MMPA, the "No Action" alternative entails NMFS denying the application for an IHA. If NMFS were to deny the application, L-DEO would not be authorized to incidentally take marine mammals. If the research was not conducted, the "No Action" alternative would result in no disturbance to marine mammals attributable to the Proposed Action. Although the No-Action Alternative is not considered a reasonable alternative because it does not meet the purpose and need for the Proposed Action, it is included and carried forward for analysis in § 4.3.

2.3 Alternatives Considered but Eliminated from Further Analysis

Table 3 provides a summary of the Proposed Action, alternative, and alternatives eliminated from further analysis.

2.3.1 Alternative E1: Alternative Location

At the Cascadia Subduction Zone, the slow ongoing descent of the Juan de Fuca plate beneath the northwestern coast of North America has generated large earthquakes and associated tsunamis in the past in this heavily populated region of the Pacific Northwest. This would be the first seismic imaging investigation spanning nearly the entire length of the Cascadia Subduction Zone and would move the Cascadia megathrust zone from arguably one of the least well characterized heavily populated megathrust regions to one of the best. The overarching goal of the study is to use modern MCS data to characterize subducting plate and accretionary wedge structure, and properties of the megathrust, along the full length of the Cascadia Subduction Zone. This regional characterization would be used to determine whether there are any systematic relationships among upper and lower plate properties, paleorupture segmentation,

TABLE 3. Summary of Proposed Action, Alternative Considered, and Alternatives Eliminated.

Proposed Action	Description
Proposed Action: Conduct marine geophysical surveys and associated activities in the Northeast Pacific Ocean	Under this action, research activities are proposed to study earth processes and would involve 2-D seismic surveys. Active seismic portions would be expected to take ~39 days, plus 1 day for transit. Additional operational days would be expected for equipment deployment, maintenance, and retrieval; weather; marine mammal activity; and other contingencies. The affected environment, environmental consequences, and cumulative impacts of the proposed activities are described in § III and IV. The standard monitoring and mitigation measures identified in the PEIS would apply, along with any additional requirements identified by regulating agencies in the U.S. and Canada. All necessary permits and authorizations, including an IHA, would be requested from regulatory bodies.
Alternatives	Description
Alternative 1: No Action	Under this Alternative, no proposed activities would be conducted, and seismic data would not be collected. While this alternative would avoid impacts to marine resources, it would not meet the purpose and need for the Proposed Action. Geological data of scientific value and relevance increasing our understanding of Cascadia Subduction Zone, adding to the comprehensive assessment of geohazards for the Pacific Northwest such as earthquakes and tsunamis, and for the development of an earthquake early warning network, would not be collected. The collection of new data, interpretation of these data, and introduction of new results into the greater scientific community and applicability of these data to other similar settings would not be achieved. No permits and authorizations, including an IHA, would be needed from regulatory bodies, as the Proposed Action would not be conducted.
Alternatives Eliminated from Further Analysis	Description
Alternative E1: Alternative Location	At the Cascadia Subduction Zone, the slow ongoing descent of the Juan de Fuca plate beneath the northwestern coast of North America has generated large earthquakes and associated tsunamis in the past in this heavily populated region of the Pacific Northwest. This would be the first seismic imaging investigation spanning nearly the entire length of the Cascadia Subduction Zone and would move the Cascadia megathrust zone from arguably one of the least well characterized heavily populated megathrust regions to one of the best. The acquired data would add to the comprehensive assessment of geohazards for the Northeast Pacific region. The proposed science underwent the NSF merit review process, and the science, including the site location, was determined to be meritorious.
Alternative E2: Use of Alternative Technologies	Under this alternative, L-DEO would use alternative survey techniques, such as marine vibroseis, that could potentially reduce impacts on the marine environment. Alternative technologies were evaluated in the PEIS, § 2.6. At this time, however, these technologies are still not feasible, commercially viable, or appropriate to meet the Purpose and Need.

and along-margin variations in present-day coupling at Cascadia. The data would also be used to characterize down-dip variations along the megathrust that may be linked to transitions in fault properties, from the updip region near the deformation front, which is of most interest for tsunamigenesis, to near shore where the downdip transition in the locked zone may reside.

2.3.2 Alternative E2: Use of Alternative Technologies

As described in § 2.6 of the PEIS, alternative technologies to the use of airguns were investigated to conduct high-energy seismic surveys. At this time, these technologies are still not feasible, commercially viable, or appropriate to meet the Purpose and Need. Additional details about these technologies are given in the Final USGS EA (RPS 2014a).

III AFFECTED ENVIRONMENT

As described in the PEIS, Chapter 3, the description of the affected environment focuses only on those resources potentially subject to impacts from the actions being proposed here; other activities (e.g., land-based component) will be analyzed under separate review. The discussion of the affected environment (and associated analyses) focuses mainly on those related to marine biological resources, as the proposed short-term activity has the potential to impact marine biological resources within the project area. These resources are identified in § III, and the potential impacts to these resources are discussed in § IV. Initial review and analysis of the proposed Project activity determined that the following resource areas did not require further analysis in this EA:

- *Air Quality/Greenhouse Gases*—Project vessel emissions would result from the proposed activity; however, these short-term emissions would not result in any exceedance of Federal Clean Air standards. Emissions would be expected to have a negligible impact on the air quality within the proposed survey area;
- *Land Use*—All activities are proposed to occur in the marine environment. Thus, no changes to current land uses or activities in the proposed survey area would result from the Project;
- *Safety and Hazardous Materials and Management*—No hazardous materials would be generated or used during the proposed activities. All Project-related wastes would be disposed of in accordance with international, U.S. state, and federal requirements;
- *Geological Resources (Topography, Geology and Soil)*—The proposed Project would result in very minor disturbances to seafloor sediments from OBN and OBS deployments during the surveys; small anchors would not be recovered. The proposed activities would not significantly impact geologic resources;
- *Water Resources*—No discharges to the marine environment that would adversely affect marine water quality are expected in the Project area. Therefore, there would be no impacts to water resources resulting from the proposed Project activity;
- *Terrestrial Biological Resources*—All proposed Project activities would occur in the marine environment and would not impact terrestrial biological resources;
- *Visual Resources*—No visual resources would be expected to be negatively impacted as the area of operation is outside of the land and coastal viewshed. Operations would take place at least 8 km from land;
- *Socioeconomic and Environmental Justice*—Implementation of the proposed project would not affect, beneficially or adversely, socioeconomic resources, environmental justice, or the protection of children. No changes in the population or additional need for housing or schools would occur. Although there are a number of shore-accessible SCUBA diving sites along the coasts of Oregon, Washington, and B.C. (see Section 3.9), the proposed activities would occur in water depths >60 m, outside the range for recreational SCUBA diving. Human activities in the area around the survey vessel would be limited to fishing activities, other vessel traffic, and whale watching. However, no significant impacts on fishing, vessel traffic, or whale watching would be anticipated particularly because of the short duration of the proposed activities. Fishing and potential impacts to fishing are

described in further detail in Sections III and IV, respectively. No other socioeconomic impacts would be anticipated as result of the proposed activities.

3.1 Oceanography

The proposed survey area is located in the northeastern Pacific Ocean. The North Pacific Current (NPC) is a warm water current that flows west to east between 40ºN and 50ºN. The NPC forms the northern part of the clockwise-flowing subtropical gyre; to the north of it, the subarctic gyre flows counterclockwise (Escorza-Treviño 2009). The convergence zone of the subarctic and central gyres, known as the Subarctic Boundary, crosses the western and central North Pacific Ocean at 42ºN (Escorza-Treviño 2009). It is in that area that the change in abundance of cold-water vs. warm-water species is the greatest (Escorza-Treviño 2009). In the eastern Pacific, the NPC splits into the northward flowing Alaska Current and the southward flowing California Current (Escorza-Treviño 2009). The California Current system nutrifies offshore waters by mixing with water from the shelf edge (Buchanan et al. 2001).

The northern portion of the proposed survey area (i.e., Vancouver Island) is located within the Gulf of Alaska Large Marine Ecosystem (LME); this LME is classified as a Class II, moderately productive (150–300 $gC/m^2/y$) ecosystem (Aquarone and Adams 2009a). The southern portion of the proposed survey area (Washington and Oregon) is located within the California Current LME. This LME is considered a Class III low productivity ecosystem (<150 $gC/m^2/y$) although seasonal upwelling of cold nutrient-rich water in this region generate localized areas of high productivity supporting fisheries (Aquarone and Adams 2009b). Winds blowing toward the equator cause upwelling during March–November and are strongest over the main flow of the California Current which is 200–400 km offshore (Longhurst 2007). Persistent eddies in the summer in some locations, like the Strait of Juan de Fuca, can transport upwelling waters up to several hundred kilometers offshore (Longhurst 2007). Even in winter, cold upwelled water "tongues" can extend offshore for hundreds of kilometers, increasing nutrient levels offshore (Longhurst 2007). The highest productivity occurs in May–June (Longhurst 2007). Acoustic backscatter surveys within the California Current LME showed that fish and zooplankton are associated with shallow bathymetry in this region; the highest densities were located in water <4000 m deep (Philbrick et al. 2003).

Numerous publications have examined the role of climate shifts as a forcing agent on species and community structure of the North Pacific Ocean (e.g., Francis and Hare 1994; Klyashtorin 1998; McGowan et al. 1998; Hollowed et al. 1998; Hare and Mantua 2000). Regime shifts that might impact productivity in the region include the Pacific Decadal Oscillation (PDO) and the El Niño Southern Oscillation. The PDO is similar to a long-lived El Niño-like pattern of climate variability; it is mainly evident in the North Pacific/North American area, whereas El Niños are typical in the tropics (Mantua 1999). PDO "events" persist for 20–30 years, whereas typical El Niño events persist for 6–18 months (Mantua 1999). In the past century, there have been two PDO cycles: "cool" PDO regimes during 1890–1924 and 1947–1976, and "warm" PDO regimes during 1925–1946 and 1977–the mid-1990s (Mantua et al. 1997; Minobe 1997). The latest "cool" period appears to have occurred during the mid-1990s until 2013 (NOAA 2019a).

A mass of warm water, referred to as "the Blob", formed in the Gulf of Alaska during autumn 2013 and grew and spread across the majority of the North Pacific and Bering Sea during spring and summer 2014, resulting in sea surface temperature anomalies ≥4ºC across the region (Peterson et al. 2016). During autumn 2014, decreased upwelling winds caused a portion of this warm water to travel eastward towards the continental shelf off eastern Alaska and the Pacific Northwest, making the sea surface temperature pattern associated with the Blob resemble a "warm" or "positive" PDO pattern (Peterson et al. 2016). Ongoing effects from "the Blob" were further perturbed by a major El Niño arriving from the south and affecting the region during 2015 and 2016, the combination of which reduced the ecosystem's productivity and altered marine community structure for several years (Brodeur et al. 2018). As of May 2016, sea surface temperature anomalies in the outer shelf waters off Oregon remained 2ºC higher, with indications the trend would likely continue well into 2017 (Peterson et al. 2016). Changes in the eastern North Pacific Ocean marine ecosystem have been correlated with changes in the PDO. Warm PDOs showed increased coastal productivity in Alaska and decreased productivity off the U.S. west coast, whereas the opposite north-south pattern of marine ecosystem productivity was seen during cold PDOs (Mantua 1999).

During late 2018, sustained unseasonably warm conditions likely caused the formation of a new mass of warm water encompassing a large portion of the Pacific Ocean, emulating "the Blob" and dubbed the "Son of the Blob" (Britten 2018). Such warm-water masses are speculated to be linked to climate change and have been correlated with warmer weather on land, deceased whales and extreme mortality events of other higher-trophic level organisms, occurrences of uncommon marine taxa, widespread toxic algal blooms, and poor feeding conditions for many fish species (Britten 2018; Brodeur et al. 2018). A significant shift in prey availability and feeding habits was observed for anchovy, sardine, mackerel, herring, and smelt species in the northern California Current Ecosystem (CCE) off the Washington and Oregon coasts (Brodeur et al. 2018). While the effects of "the Blob" or the "Son of the Blob" are not yet fully understood, the formation of warm water patches are increasingly common in the Pacific Ocean off the western Canadian and American coasts (Britten 2018).

3.2.1 Protected Areas

3.2.1 Critical Habitat in the U.S.

Several habitats near or within the proposed survey area have been specifically identified as important to U.S. ESA-listed species, including critical habitat for marine mammals, sea turtles, seabirds, and fish. Although there is critical habitat adjacent to the survey area for the ***threatened*** Pacific Coast population of western snowy plover and the ***threatened*** marbled murrelet, this habitat is strictly terrestrial and would not be affected by the proposed activities.

Steller Sea Lion Critical Habitat**.—**Federally designated critical habitat for Steller sea lions in Oregon and California includes all rookeries (NMFS 1993). Although the Eastern Distinct Population Segment (DPS) was delisted from the ESA in 2013, the designated critical habitat remains valid (NOAA 2019b). The critical habitat in Oregon is located along the coast at Rogue Reef (Pyramid Rock) and Orford Reef (Long Brown Rock and Seal Rock; see Fig. 1). 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.

Southern Resident Killer Whale Critical Habitat**.—**Critical habitat for the ***endangered*** Eastern North Pacific Southern Resident stock of killer whales is defined in detail in the Code of Federal Regulations (NMFS 2006). Critical habitat currently includes three specific marine areas of Puget Sound, WA: the Summer Core Area, Puget Sound, and the Strait of Juan de Fuca. The 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 2015a). 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).

Humpback Whale Proposed Critical Habitat*.—**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).

Leatherback Sea Turtle Critical Habitat*.—**In January 2012, NMFS designated critical habitat for the ***endangered leatherback sea turtle along the west coast of the U.S. (NMFS 2012). The critical habitat includes marine areas of ~64,760 km^2 from Cape Flattery, WA, to Cape Blanco, OR, and ~43,798 km^2 off California (NMFS 2012). The survey area east of the 2000-m contour is located within critical habitat (see Fig. 1).

Green Sturgeon Critical Habitat*.—**Coastal U.S. marine critical habitat for the ***threatened Southern DPS of North American green sturgeon includes waters within ~109 m (60 fathoms) depth from Monterey Bay, CA, north to Cape Flattery, WA, to its U.S. boundary, encompassing 29,581 km^2 of marine habitat (NMFS 2009). The proposed survey area that is located in water depths less than 109 m occurs within this critical habitat (see Fig. 1).

Rockfish Critical Habitat*.—**Critical habitats have been designated for the ***threatened Puget Sound/Georgia Basin DPS of yelloweye rockfish and for the ***endangered*** Puget Sound/Georgia Basin DPS of bocaccio (NMFS 2014). However, no critical habitat occurs within the proposed survey area.

Pacific Eulachon Critical Habitat*.—**Critical habitat has been designated for the ***threatened Southern DPS of Pacific eulachon/smelt for Washington and Oregon. Most of the critical habitat occurs in freshwater rivers and creeks, but some does include estuarine waters (NMFS 2011a; NOAA 2019b). However, none of the proposed seismic transect lines enter critical habitat.

***Salmonid Critical Habitat*.—**Critical habitat has been designated for a number of ESA-listed salmonid species or evolutionary significant units (ESU) for Washington and Oregon (see Section 3.7.1, Table 6, for list of species). Most of the critical habitat occurs in freshwater rivers and creeks, but some of it includes nearshore marine waters (NOAA 2019b). However, none of the proposed seismic transect enter critical habitat.

3.2.2 Critical Habitat in Canada

Several habitats near or within the proposed survey area have been identified as important under Canada's *Species at Risk Act* (SARA) to listed species, including critical habitat for three populations of marine mammals and northern abalone. Critical habitat for the ***threatened*** marbled murrelet occurs adjacent to the study area, but this habitat is strictly terrestrial and would not be affected by the proposed activities. Critical habitat is defined under SARA as the "habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as such in the recovery strategy or action plan for the species" (DFO 2018a). According to the Canadian Department of Fisheries and Oceans (DFO), critical habitat could include areas used for spawning, rearing young, feeding and migration, depending on the species and may not be destroyed (DFO 2018a).

***Southern Resident Killer Whale Critical Habitat*.—**Critical habitat 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 2018a). The continental shelf waters off southwestern Vancouver Island, including Swiftsure and La Pérouse Banks have also been designated as critical habitat (DFO 2018a). The critical habitat has features such as prey availability (specifically chinook and chum salmon), suitable acoustic environment, water quality, and physical space that provide areas for feeding, foraging, reproduction, socializing, and resting (DFO 2018a). Two of the proposed transect lines intersect the critical habitat on Swiftsure and La Pérouse Banks (see Fig. 1).

***Northern Resident Killer Whale Critical Habitat*.—**Critical habitat has been designated in Jonstone Strait and southeastern Queen Charlotte Strait. The continental shelf waters off southwestern Vancouver Island, including Swiftsure and La Pérouse Banks, have also been designated as critical habitat, as well as western Dixon Entrance along the north coast of Graham Island, Haida Gwaii (DFO 2018a). 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, resting, and beach rubbing (DFO 2018a). Two of the proposed transect lines intersect the critical habitat on Swiftsure and La Pérouse Banks (see Fig. 1).

***Humpback Whale Critical Habitat*.—**Critical habitat for humpbacks has been designated in four locations in B.C., including off southwestern Vancouver Island (see Fig. 1). 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 2013a). 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 2013a). Two of the proposed transect lines intersect the critical habitat on Swiftsure and La Pérouse Banks (see Fig. 1).

***Northern Abalone Critical Habitat*.—**Critical habitat for northern abalone has been identified within four distinct geospatial areas that include Barkley Sound and surrounding waters on the southwest coast of Vancouver Island (see Fig. 1), the west and east coasts of Haida Gwaii, and the north and central coasts of B.C. (DFO 2012). The west and east coasts of Haida Gwaii and the north and central coasts of mainland B.C. habitats were identified due to their historical significance in production to the former commercial abalone fishery; the Barkley Sound habitat was identified as an important rebuilding area (DFO 2012).

Abalone are typically found in shallow waters <10 m attached to hard substratum such as rocks, boulders, and bedrock (DFO 2012). Within the identified geographic boundaries, not all habitat comprises critical habitat, but rather only those areas with sites at least 20 m^2 in size with a density of ≥0.1 abalone/m^2 that contain the following physical attributes: appropriate primary substrate consisting of bedrock or boulders for attachment or secondary substrate including some cobble; water with salinity >30 ppt and moderate to high water exchange from tidal currents or wave action; presence of encrusting coralline algae such as *Lithothamnium* spp.; and the presence of macroalgae such as *Nereocystic*, *Macrocystic*, *Pterygophora*, or *Laminaria* spp. Encrusting coralline algae is a primary site of larval settlement and provides feeding and refuge grounds for juveniles (DFO 2012). The critical habitat is located at least 23 km from the closest seismic transect (see Fig. 1).

3.2.3 Other Conservation Areas in U.S. Waters

There are two portions of U.S. military land which are closed to access near the mouth of the Columbia River, referred to as Warrenton/Camp Rilea (USGS 2019). All conservation areas near the project area are listed below and shown on Fig. 1. Only those areas within 100 km of the proposed survey area are discussed below.

***Washington Islands National Wildlife Refuges*.—**The Washington Islands National Wildlife Refuges (NWRs) are located along 161 km of the outer coast of the Olympic Peninsula, encompassing more than 600 islands, sea stacks, rocks, and reefs. The area is comprised of three NWRs: Copalis NWR (47.13–47.48ºN), Quillayute Needles NWR (47.63–48.03ºN), and Flattery Rocks NWR (48.03–48.38ºN). The refuges do not include islands that are part of designated Native American reservations. Along much of the coastline adjacent to the islands lies the Olympic National Park (ONP). In 1970, all three of the Washington Islands NWRs were designated as Wilderness Areas, except for Destruction Island in Quillayute Needles NWR. As many as 500 Steller sea lions haul out and 150,000 pelagic birds nest annually on these islands (USFWS 2007). The Olympic Coast National Marine Sanctuary (OCNMS) incorporates the entire area surrounding the islands and rocks of all three refuges (USFWS 2007). At its closest point, the Washington Islands NWR is ~7 km east of the nearest seismic transect (see Fig. 1).

***Olympic Coast National Marine Sanctuary*.—**The OCNMS, designated in 1994, includes 8259 km^2 of marine waters off the Washington coast, extending 40–72 km seaward and covering much of the continental shelf and several major submarine canyons (NOAA 2011). The sanctuary protects a productive upwelling zone with high productivity and a diversity of marine life (NOAA 2011). This area also has numerous shipwrecks. The OCNMS management plan provides a framework for the sanctuary to manage potential threats to the sanctuary's marine resources under the *National Marine Sanctuaries Act*. Federal law provides national marine sanctuaries the authority to adopt regulations and issue permits for certain activities, including taking any marine mammal, sea turtle, or seabird in or above the sanctuary, except as authorized by the MMPA, the ESA, and the *Migratory Bird Treaty Act*. The easternmost portions of some seismic transects enter the OCNMS (Fig. 1).

The OCNMS shares an overlapping boundary in the intertidal zone with the ONP. The ONP, designated in 1938, is a zone of exclusive federal jurisdiction encompassing 3734 km^2 and including some of the beaches and headlands along the coast (USFWS 2007). Approximately 75% of the coastal strip is in Congressionally designated wilderness, which is afforded additional protections under the *Wilderness Act*. The OCNMS is a partner in the management of the ONP marine resources.

***Lewis and Clark National Wildlife Refuge*.—**The Lewis and Clark NWR includes ~20 islands stretching over 43.5 km of the Columbia River, from the mouth upstream to nearly Skamakowa, WA (USFWS 2019). This refuge was established in 1972 to preserve the fish and wildlife habitat of the Columbia River estuary and supports large numbers of waterfowl, gulls, terns, wading birds, shorebirds, raptors, and songbirds. It is located ~50 km southeast of the closest seismic transect (see Fig. 1).

***Willapa National Wildlife Refuge*.—**The Willapa NWR is located within Willapa Bay and Columbia River, WA. It was established in 1973 by President Franklin D. Roosevelt to protect migrating birds and their habitat (USFWS 2013). It consists of multiple segments, with the nearest located ~20 km northeast of the closest seismic transect (see Fig. 1).

***Oregon Islands National Wildlife Refuge*.—**The Oregon Islands NWR (OINWR) spans 515 km of the Oregon coast from the Oregon/California border to Tillamook Head (~45.9°N) and includes all rocks and islands above the line of mean high tide, except for rocks and islands of the Three Arch Rocks NWR.

All of the island acreage is designated National Wilderness, with the exception of Tillamook Rock (USFWS 2015a). The OINWR is located ~7 km east of the nearest seismic transect (see Fig. 1).

***Three Arch Rocks National Wildlife Reserve*.—**Three Arch Rocks NWR consists of 60 m^2 on three large and six small rocky islands located ~1 km from shore. It is one of the smallest designated wilderness areas in the U.S. and is the only pupping site for the Steller sea lion in northern Oregon (USFWS 2016a). This NWR is located ~12 km southeast from the closest seismic transect (see Fig. 1).

***Washington State Seashore Conservation Area*.—**The Washington State Seashore Conservation Area includes all seashore between the line of ordinary high tide and the line of extreme low tide between Cape Disappointment (~46.3°N) and Griffiths Priday State Park (~47.1°N). The Conservation Area is under the jurisdiction of the Washington state parks and recreation commission (Washington State Parks n.d.). The Seashore Conservation Area is ~15 km east of the closest seismic transect (see Fig. 1).

***Cape Falcon Marine Reserve*.—**The Cape Falcon Marine Reserve combines a marine reserve and two marine protected areas (MPAs) located at ~45.7ºN, 124ºW. The entire protected area extends ~7 km along the coast of Oregon and out to ~7 km (see Fig. 1). The reserve and MPA portions are 32 km^2 and 20 km^2, respectively (ODFW 2019a). No animals or seaweed may be taken from the reserve (ODFW 2019a). The Cape Falcon Marine Reserve is located ~5 km east of the closest seismic transect (see Fig. 1).

***Cascade Head Marine Reserve*.—**This site includes a marine reserve surrounded by three MPAs and is located off the central Oregon coast at ~45°N, 124ºW. The entire protected area extends 16 km along the coast (see Fig. 1) and out to 5.6 km (ODFW 2019a), with total areas of 25.1 km^2 and 59.7 km^2 for the marine reserve and MPA portions, respectively. No animals or seaweed may be taken from the reserve (ODFW 2019a). Cascade Head Marine Reserve is located ~6 km east of the closest seismic transect (see Fig. 1).

***Otter Rock Marine Reserve*.—**The Otter Rock Marine Reserve encompasses 3 km^2 of nearshore rocky intertidal habitat at ~44.72–44.75°N (ODFW 2019a). No animals or seaweed may be taken from the reserve (ODFW 2019a). The Otter Rock Marine Reserve is located ~11 km east of the closest seismic transect (see Fig. 1).

***Cape Perpetua Marine Reserve*.—**This site combines a marine reserve, two MPAs, and a seabird protection area. It is located off the central coast of OR at ~44.2ºN, 124.1ºW. The entire protected area extends ~26.5 km along the coast (see Fig. 1) and out to ~5 km, with total areas of 37 km^2 and 49 km^2 for the reserve and MPA portions, respectively (ODFW 2019a). This marine reserve is located ~7 km east of the closest seismic transect (see Fig. 1).

***Redfish Rock Marine Reserve and Marine Protected Area*.—**The Redfish Rock Marine Reserve and MPA is located at ~42.67–44.70°N. The marine reserve encompasses 7 km^2 of nearshore water, and the adjacent MPA covers an additional ~13 km^2 (ODFW 2019a). Redfish Rock Marine Reserve is located 12 km east of the closest seismic transect (see Fig. 1).

3.2.4 Other Conservation Areas in Canada

Only those conservation areas within 100 km of the proposed survey area are discussed below. Race Rocks Ecological Reserve is located in the Strait of Juan de Fuca ~101 km from the nearest survey transect; it is currently under consideration for designation as an MPA and is an Area of Interest (AOI) (DFO 2019a). Hecate Strait/Queen Charlotte Sound Glass Sponge Reefs MPA is located 112 km from the nearest proposed seismic transect. There are several rockfish conservation areas (RCAs) adjacent to the proposed survey area; these are discussed in Section 3.6.5.

***Offshore Pacific Area of Interest/Proposed Offshore Pacific MPA*.—**The Offshore Pacific Area of Interest encompasses 139,700 km^2 of the Offshore Pacific Bioregion (OPB) west of Vancouver Island (DFO 2019b). It has unique seafloor features such as seamounts and hydrothermal vents and ecosystems that support the OPB. It includes the Offshore Pacific Seamounts and Vents Closure area, where all bottom contact from recreational and commercial fishing is prohibited, as well as other activities incompatible with the conservation of the ecological components. An advisory committee has been established for this AOI, and a management approach is being developed to move towards the protection of this area, which could come into effect in 2020. The western-most seismic transects enter the AOI (see Fig. 1).

***Endeavour Hydrothermal Vents MPA*.—**The Endeavour Hydrothermal Vents (EHV) were designated as the first MPA under Canada's *Oceans Act* in 2003 (DFO 2018b). The EHV area covers 97 km^2 and is located on the Juan de Fuca Ridge, 256 km offshore from Vancouver Island, 2250 m below the ocean's surface (Tunnicliffe and Thompson 1999); it occurs within the AOI. Under the Canadian *Oceans Act*, underwater activities that may result in the disturbance, damage, destruction, or removal of the seabed, or any living marine organism or any part of its habitat, are prohibited in this MPA (Government of Canada 2019a). The EHV area is located ~84 km west of the closest seismic transect (see Fig. 1).

***Scott Islands Marine National Wildlife Area*.—**This area (11,546 km^2) was established in June 2018 under Canada's *Wildlife Act* and consists of the marine waters extending out from the northwestern tip of Vancouver Island and surrounding the five islands of the Scott Islands (Government of Canada 2019b). The Scott Islands support the greatest concentration of breeding seabirds on the Pacific coast of Canada, hosting over 1 million nesting seabirds a year, including tufted puffins, common murres, Cassin's auklets, and rhinoceros auklets (Government of Canada 2019b). It also attracts up to 10 million migratory birds annually, including short-tailed albatross, black-footed albatross, pink-footed shearwater, marbled murrelet, and ancient murrelet (Government of Canada 2019b). Pinniped rookeries are also located at the Scott Islands (Hoyt 2011), and the region encompasses a RCA. This National Wildlife Area is located ~30 km from the closest proposed seismic transect (see Fig. 1).

This area is also an Ecologically and Biologically Significant Area (EBSA) as determined by DFO due to its biologically rich environment, the diversity of marine mammals and fish, and it is important habitat for marine mammal species listed under SARA. In this National Wildlife Reserve, regulations prohibit any activity that is likely to disturb, damage, or destroy wildlife or its habitat. Among other restrictions, it is not permitted to be within 300 m of the low water mark of Triangle, Sartine, or Beresford islands, and vessels exceeding 400 t cannot anchor within 1 n.mi. of the aforementioned three islands (Government of Canada 2019c).

***Checleset Bay Ecological Reserve*.—**This ecological reserve is 346.5 km^2 and is located between Kyuquot and the Brooks Peninsula, off the northwest coast of Vancouver Island. It encompasses marine habitat for a reintroduced population of sea otters to increase their range and abundance; it also includes an RCA (B.C. Parks 2019). Fisheries restrictions are in effect in the reserve and research activities may be carried out but only under permit (B.C. Parks 2019). The Checleset Bay Ecological Reserve is located adjacent to the survey area (see Fig. 1).

***Pacific Rim National Park Reserve*.—**The marine component of this National Park Reserve covers 220.5 km^2 (Hoyt 2011). It is located in coastal and nearshore waters of southwestern Vancouver Island, including parts of Barkley Sound, and encompasses habitat for gray whales, in particular during the summer, as well as for numerous other marine species (Hoyt 2011). It is located 16 km east of the closest seismic transect. The National Park Reserve is partially located within the Clayoquot Sound UNESCO World Biosphere Reserve and includes several RCAs.

Clayoquot Sound UNESCO Biosphere Reserve encompasses a diverse range of ecosystems; it was designated in 2000 (UNESCO 2019). The marine component of Clayoquot Sound supports mudflats, beaches, and estuaries and contains the largest cover of eelgrass on the west coast of Vancouver Island. The marine area is important for gray whales, humpback whales, killer whales, and a variety of other marine mammal species.

***B.C. Northern Shelf MPA Network*.—**This initiative aims to build a network of MPAs for the shelf of B.C., stretching from the western shelf of northern Vancouver Island to Alaska (MPANetwork 2019), including the northern portion of the survey area. The Northern Shelf consists of diverse ecosystems that provides important habitat for a variety of species. The network is being developed by the Government of Canada, the Province of B.C., and First Nations.

***Ecologically and Biologically Significant Areas*.—**An EBSA is an area of relatively higher ecological or biological significance than surrounding areas (Rubridge et al. 2018). The scientific criteria to identify an EBSA have been established at the national level by DFO (2004a) and at the international level by the Convention on Biological Diversity (CBD 2008). The identification of an EBSA does not imply specific protection, rather it is a means of recognizing the special features within the area and the management of activities within the area are required to exhibit greater risk aversion (Ban et al. 2016). In order for an area to be protected under the *National Marine Conservation Areas Act* or be designated as an MPA in Canada, it must first be identified as an EBSA, and the societal values and potential threats must be identified, in addition to the implementation of a management plan (Ban et al. 2016). There are five EBSAs within the survey area, and two EBSAs adjacent to the survey area (Fig. 2; Table 4).

3.3 Marine Mammals

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 5). 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).

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.

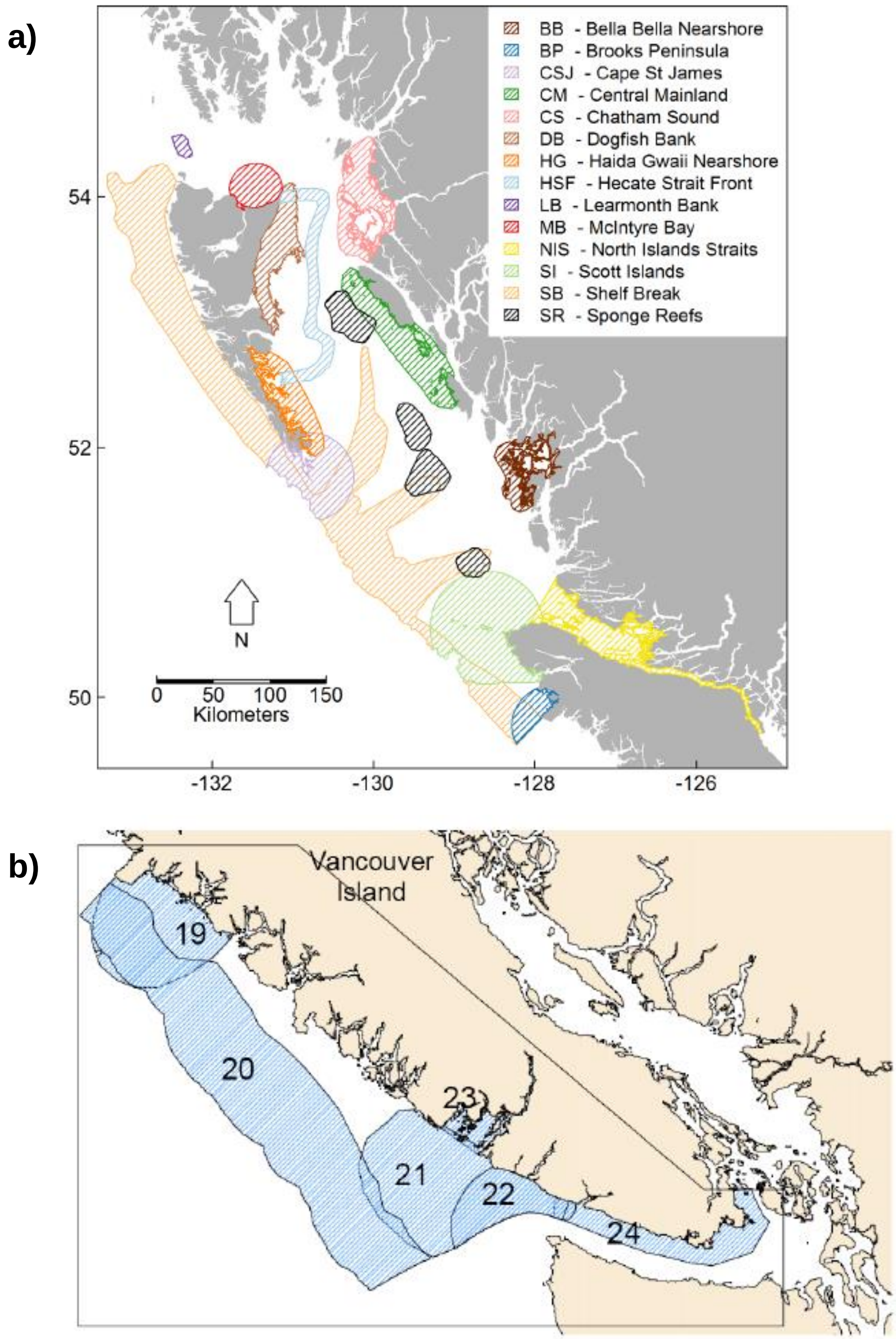

FIGURE 2. EBSAs off the B.C. coast in (a) the Pacific Northern Shelf Bioregion (Source: Rubidge et al. 2018) and (b) the Southern Shelf Bioregion (Source: DFO 2013b; 19 = Brooks Peninsula; 20 = Shelf Break; 21 = Continental Shelf Off Of Barkley Sound; 22 = Juan de Fuca Eddy; 23 = Barkley Sound and Alberni Inlet; 24 = Strait of Juan de Fuca).

TABLE 4. Summary of the Ecologically or Biologically Significant Marine Areas (a) within Canadian waters of the proposed survey area, and (b) adjacent to the proposed survey area.

(a)

EBSA	Location	Significance	References
Scott Islands (SI)	Archipelago of five islands (Lanz, Cox, Sartine, Beresford, Triangle Island) located off the northwestern point of Vancouver Island, ~10 km off Cape Scott Provincial Park	• Area of significant upwelling and tidal mixing • High plankton productivity Important Species: • Spawning, breeding, or rearing: Pacific cod, lingcod, sablefish, arrowtooth flounder, Petrale sole, butter sole, rock sole, dover sole, English sole, widow rockfish, Steller sea lion, Cassin's auklet, rhinoceros auklet, tufted puffin, common murre, cormorants, pigeon guillemot, storm petrel, glaucous winged gull • Feeding: Pacific hake, Pacific herring, gray whale, northern fur seal • Aggregation: humpback whale, sea otter	Clarke and Jamieson (2006); DFO (2013b); Ban et al. (2016); Rubidge et al. (2018)
Brooks Peninsula (BI)	West coast of Vancouver Island. Brooks Peninsula juts 20 km into the Pacific Ocean and is home to a Provincial Park	• High diversity of breeding and migrating bird species • High plankton productivity • Bottleneck between Brooks Peninsula and the Southern Shelf Break Important Species: • Spawning, rearing, or breeding: lingcod, common murre, tufted puffin, glaucous-winged gull, rhinoceros auklet • Aggregation: sea otter • Migration: possibly green sturgeon	DFO (2013b); Ban et al. (2016); Rubidge et al. (2018)
Southern Shelf Break (SSB)	West coast of Vancouver Island from the Brooks Peninsula down to Barkley Sound along the shelf	• High productivity and aggregation of plankton • Site of strong trophic transfers Important Species: • Spawning, rearing, or breeding: sablefish, dover sole, rockfish • Feeding: humpback whale, hake, northern fur seal • Aggregation: sperm, fin, blue, and sei whale; coral; tanner crab; possibly leatherback turtle	DFO (2013b); Ban et al. (2016)
Continental Shelf off Barkley Sound	West coast of Vancouver Island that forms the entrance Alberni Inlet	• High productivity and aggregation of plankton • Submarine banks, convergent circulation, and shallow depths • High trophic transfer Important Species: • Spawning, rearing, or breeding: Pacific herring, Pacific cod, sand lance • Feeding: humpback whale, southern resident killer whale, porpoise, northern fur seal, Steller sea lion, Pacific sardine, Pacific hake, candlefish • Aggregation: green sturgeon, dungeness crab, shrimp • Migration: Pacific sardine, candlefish, gray whale	DFO (2013b)
Juan de Fuca Eddy	West coast of Vancouver Island and to the northwest coast of the Olympic Peninsula, WA	• Geographical bottleneck Important Species: • Spawning, rearing, or breeding: Pacific herring • Feeding: gray whale, Pacific salmon • Aggregation: harbor porpoise, Dover sole, Pacific hake, green sea urchin • Migration: Pacific salmon, Pacific herring, candlefish	DFO (2013b)

(b)

EBSA	Location	Significance	References
Barkley Sound and Alberni Inlet	West coast of Vancouver Island that forms the entrance to Alberni Inlet	• Geographical bottleneck Important Species: • Spawning, rearing, or breeding: Pacific herring, juvenile eulachon, flatfish, gull, pelagic cormorant, • Feeding: gray whale, humpback whale, harbor seal, Steeler sea lion, salmon, sardine, surf scoter • Aggregation: Pacific loon, pigeon guillemot, marbles murrelets, Olympia oyster, Pacific oyster • Migration: green sturgeon, Pacific salmon • Uniqueness: Pacific hake (resident) inshore stock, historical basking shark records	DFO (2013b)
Juan de Fuca Strait	West coast of Vancouver Island and to the northwest coast of the Olympic Peninsula of Washington	• Geographical bottleneck Important Species: • Spawning, rearing, or breeding: Pacific herring • Feeding: gray whale, Pacific salmon • Aggregation: harbor porpoise, Dover sole, Pacific hake, green sea urchin, dungeness crab • Migration: Pacific salmon, eulachon • Uniqueness: killer whale critical habitat	DFO (2013b)

3.3.1 Mysticetes

3.3.1.1 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 2019c). 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

TABLE 5. 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**		**IUCN[6]**	**CITES[7]**
					COSEWIC[4]	**SARA[5]**		
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; 25,000[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	1,647[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	77[23] 243[24] 261[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	20,000	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	41,638[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	2,058[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. (2019), 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. 2019).
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. 2019).
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 (Calambokidis and Barlow 2013).
20 Eastern Temperate Pacific; estimate based on visual sightings (Barlow and Taylor 2005).
21 All mesoplodont whales (Moore and Barlow 2017; Carretta et al. 2019).
22 California/Oregon//Washington offshore stock (Carretta et al. 2019).
23 Eastern North Pacific Southern Resident stock (Carretta et al. 2019).
24 West Coast Transient stock; minimum estimate (Muto et al. 2019).
25 Northern Resident stock (Muto et al. 2019).
26 North Pacific Offshore stock (Carretta et al. 2019).
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. 2019).
30 Northern California/Southern Oregon stock (Carretta et al. 2019).
31 California stock (Carretta et al. 2019).
32 Eastern Pacific stock (Muto et al. 2019).
33 California breeding stock (Carretta et al. 2019).
34 Oregon and Washington Coast stock (Carretta et al. 2019).
35 Eastern U.S. stock (Muto et al. 2019).
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 (Muto et al. 2019).
39 Washington (Jeffries et al. 2017).
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).

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 2017a). The third and most recent sighting was made off Haida Gwaii in June 2018 (CBC 2018a). 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 2011a; 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.

3.3.1.2 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. 2019). 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 (2019e) 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 2019e).

3.3.1.3 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. 2019). 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).

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 B.C., including the waters of the proposed survey area off southwestern Vancouver Island (DFO 2013a). Humpback whales were detected acoustically on La Pérouse Bank off southwestern Vancouver Island 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.

3.3.1.4 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. 2019). 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.

3.3.1.5 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. 2019). 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.

3.3.1.6 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. 2019), 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. 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.

3.3.1.7 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: the eastern and central (formerly western) stocks (Carretta et al. 2019). 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 2017a) 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.

3.3.2 Odontocetes

3.3.2.1 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 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.

3.3.2.2 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. 2019). 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.

3.3.2.3 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.

3.3.2.4 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. 2019) 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.

3.3.2.5 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.

3.3.2.6 Hubbs' 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. (2019). 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.

3.3.2.7 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.

3.3.2.8 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. 2019). 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. 2019). 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.

3.3.2.9 Striped Dolphin (*Stenella coeruleoalba*)

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. 2019). However, few sightings have been made off Oregon, and no sightings have been reported for Washington (Carretta et al. 2019). 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.

3.3.2.10 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. 2019). 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.

3.3.2.11 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.

3.3.2.12 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.

3.3.2.13 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. 2019). 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.

3.3.2.14 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.

3.3.2.15 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. 2019; Carretta et al. 2019). 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 Chinook, 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. 2019). These areas have been designated as critical habitat either by the U.S. or Canada. In the fall, this population is known to occur in Puget Sound, and during the winter, they occur along the outer coast and do not spend a lot of time in critical habitat areas (Ford 2014).

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. 2019). Many sightings have been made in Dixon Entrance (which is designated as critical habitat) and eastern Hecate Strait, which is also considered important habitat (Ford 2014). Critical habitat for this population in B.C. also includes the waters off southwestern Vancouver Island, where both northern and southern resident killer whales often forage 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. 2019). 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 off Washington and Oregon in the summer, and sightings in the Strait of Juan de Fuca during spring. 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.

3.3.2.16 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. 2019). 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. (2019) 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.

3.3.2.17 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. 2019). Harbor porpoises from the Northern Oregon/Washington and the Northern

California/Southern Oregon stocks could occur in the proposed project area (Carretta et al. 2019).

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 2016a). 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.

3.3.2.18 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. 2019). 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.

3.3.3 Pinnipeds

3.3.3.1 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. 2019). 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. 2019; 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. 2019). 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.

3.3.3.2 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. 2019). 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. 2019). 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. 2019). In the U.S., two stocks are recognized—the Eastern Pacific and the California stocks (Muto et al. 2019). 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. 2019).

When not on rookery islands, northern fur seals are primarily pelagic but occasionally haul out on rocky shorelines (Muto et al. 2019). 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. 2019; Muto et al. 2019). 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.

3.3.3.3 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.

3.3.3.4 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. 2019). 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. 2019). 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. 2019). 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.

3.3.3.5 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 2019f). 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. 2019). The Western DPS is listed as *endangered* and includes animals that occur in Japan and Russia (Muto et al. 2019); 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. 2019). Breeding adults occupy rookeries from late-May to early-July (NMFS 2008a).

Non-breeding adults use haulouts or occupy sites at the periphery of rookeries during the breeding season (NMFS 2008a). 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 2008a). Females with pups generally stay within 30 km of the rookeries in shallow (30–120 m) water when feeding (NMFS 2008a). 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.

3.3.3.6 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. 2019). 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.

3.3.4 Fissiped

3.3.4.1 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 2058 (Jeffries et al. 2017). 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 2015a; 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 2015a; 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.

3.4 Sea Turtles

Four species of sea turtles have been reported in the waters of B.C., Washington, and Oregon: the leatherback (*Dermochelys coriacea*), green (*Chelonia mydas*), loggerhead (*Caretta caretta*) and olive ridley (*Lepidochelys olivacea*) turtles (McAlpine et al. 2004; CBC 2011a,b; Halpin et al. 2018). Reports of leatherbacks are numerous, and green turtles have been seen occasionally in the survey area compared to occurrences of loggerhead and olive ridley turtles, which are rare. In B.C., there is a single record for the loggerhead (Halpin et al. 2018) and four records of olive ridley turtles, with the most recent one reported on 30 September 2019 (The Marine Detective 2019). The loggerhead was spotted ~45 n.mi. west of Tofino in February 2015.

All four species of turtles have also been documented off the coasts of Oregon and Washington (Buchanan et al. 2001; Dutton et al. 2009). However, green, loggerhead, and olive ridley sea turtles are considered accidental in Oregon (ODFW 2013). For Oregon, there are two occurrences of loggerheads from 2007–2017, and at least seven occurrences of olive ridleys from 2010–2018 (Oregonian 2012; Oregon Coast Aquarium 2019). Strandings have increased in recent years, particularly for olive ridley sea turtles, possibly due to warmer ocean conditions or El Niño (Boyer 2017). For Washington, there are eight records of loggerhead turtles from 1980–2017 (the most recent occurrence was November 2010; Sato 2017a) and few records of olive ridleys (e.g., Richardson 1997; Komo News 2015; Seattle Times 2017). However, the loggerhead and olive ridley turtles are generally warm-water species and are considered extralimital occurrences in these areas (Buchanan et al. 2001) and are not discussed further here. Thus, only leatherback turtles are likely to occur in the survey area, and green turtles could potentially occur there.

Under the ESA, the leatherback turtle and the North Pacific Ocean DPS of the loggerhead turtle are listed as ***endangered***, the olive ridley population on the Pacific coast of Mexico is listed as ***endangered*** whereas other populations are listed as ***threatened***, and the East Pacific DPS of the green turtle is listed as ***threatened***. The leatherback turtle is also listed as endangered under SARA; the other turtle species are not listed. General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of sea turtles are given in § 3.4.1 of the PEIS. General distribution of sea turtles off B.C. and just south of the survey area off California are discussed in § 3.4.3.2 and 3.4.2.3 of the PEIS, respectively. The rest of this section deals specifically with their distribution within the proposed survey area in the Northeast Pacific Ocean.

3.4.1 Leatherback Turtle (*Dermochelys coriacea*)

The leatherback is the largest and most widely distributed sea turtle, ranging far from its tropical and subtropical breeding grounds to feed (Plotkin 2003). There have been significant declines and some extirpations of nesting populations in the Pacific (Spotila et al. 2000; Dutton et al. 2007). Leatherback turtles in the Pacific are divided into two genetically distinct stocks: the East Pacific stock nests at rookeries along the west coast of the Americas from Mexico to Ecuador; and the West Pacific stock nests at rookeries in Papua, Indonesia; Papua New Guinea; and the Solomon Islands (Dutton 2006; Wallace and Hutchinson 2016). The beaches of Birdshead Peninsula in Papua are the largest remaining nesting sites for leatherbacks in the Pacific Ocean (Dutton et al. 2007; Hitipeuw et al. 2007; Benson et al. 2008). Turtles that hatch during the boreal summer in the western Pacific feed and grow in the northern Pacific, including along the west coast of North America (Dutton 2006; Dutton et al. 2009; Benson 2012; Bailey et al. 2012a; Wallace and Hutchinson 2016). The West Pacific subpopulation has declined by 83% over the past three generations and continues to be threatened by human exploitation of females and eggs, low hatching success, fisheries bycatch, low foraging success, and plastic ingestion (Bailey et al. 2012b; Gregr et al. 2015; Wallace and Hutchinson 2016). Nesting beaches in the western Pacific have been estimated to have 2700–4500 breeding females (NMFS and USFWS 2013).

The leatherback turtle is the most widely distributed sea turtle, occurring from 71°N to 47°S (Eckert et al. 2012). During the non-breeding season, it ranges far from its tropical and subtropical nesting grounds, which are located between 38°N and 34°S (Dutton et al. 2009; Eckert et al. 2012). Leatherbacks feed exclusively on gelatinous zooplankton (Fossette et al. 2010, 2012; Dodge et al. 2011; Heaslip et al. 2012) and their presence has been associated with oceanic front systems, such as shelf breaks and the edges of oceanic gyre systems where their prey is concentrated (Morreale et al. 1994; Eckert 1995; Lutcavage 1996; Benson et al. 2011).

Adult leatherbacks appear to migrate along bathymetric contours from 200–3500 m (Morreale et al. 1994). Adults spend the majority of their time in water >1000 m deep and possibly swim more than 10,000 km each year (Eckert 1995). They appear to use the Kuroshio Extension during migrations from Indonesia to the high seas and eastern Pacific (Benson et al. 2008). Hatchling leatherbacks are pelagic, but nothing is known about their distribution for the first four years (Musick and Limpus 1997). Leatherback turtles undertake long migrations from the western, central, or South Pacific toward the California Current LME (Block et al. 2011; Bailey et al. 2012a,b). Frair et al. (1972) and Greer et al. (1973) reported that leatherback turtles have evolved physiological and anatomical adaptations to cold water, allowing them to venture into higher latitudes than other species of turtle.

Leatherbacks forage in pelagic and nearshore waters off the coasts of Washington, Oregon and California during the summer and fall when brown sea nettles (*Chrysaora fuscescens*) and moon jellies (*Aurelia labiata*) aggregate (Sato 2017b). Benson et al. (2011) identified the Columbia River Plume as an important foraging area off southern Washington/northern Oregon. Leatherback turtles satellite-tagged at western Pacific nesting beaches were observed to arrive along the coasts of California to Washington during April–July, and foraging behavior was recorded through late November (Benson et al. 2011). In Washington, 78 occurrences of leatherbacks were documented during 1975–2013 from the mouth of the Columbia River north to Cape Flattery; 70 occurrences occurred during July–October (Sato 2017b). Aerial surveys of California/Oregon/Washington waters suggest that most leatherbacks occur in continental slope waters and fewer occur over the continental shelf. Sightings off Oregon/Washington have been made 8–149 km offshore (Green et al. 1992, 1993; Bowlby et al. 1994; Buchanan et al. 2001). Bowlby et al. (1994) noted that most sightings (13 of 19) during their surveys occurred in waters 200–2000 m deep, with one sighting in waters >2000 m deep.

In B.C., leatherbacks are considered an “uncommon seasonal resident” (McAlpine et al. 2004), and the size of the population that forages there seasonally is not known (COSEWIC 2012). Leatherbacks have been sighted off B.C. in all months except December and January, with a peak during late spring to early-fall when sea surface temperatures are highest (MacAskie and Forrester 1962; Spaven et al. 2009). Sightings of leatherbacks have been made throughout the waters of B.C., including offshore of Vancouver Island (McAlpine et al. 2004; Pacific leatherback Turtle Recovery Team 2006; Spaven et al. 2009; Holst 2017; CBC 2018b). Seventy-seven of the 118 sightings summarized by Spaven et al (2009) occurred along the south coast of B.C.; most of these overlap with the proposed survey area and were recorded during July–September. The majority of sightings in B.C. have been made in coastal waters, although turtles have also been sighted farther offshore in water >2000 m deep (Spaven et al. 2009; Holst 2017). In the absence of direct observations of leatherback foraging in Pacific Canadian waters, critical feeding habitat along the Pacific coast of Canada was modelled based on habitat preferences inferred from limited sightings data and was predicted to predominantly occur along the west coast of Vancouver Island (Gregr et al. 2015). Leatherback turtles could be encountered in the proposed project area.

3.4.2 Green Turtle (*Chelonia mydas*)

The green turtle is widely distributed in tropical, subtropical, and to a lesser extent, temperate waters, where it often occurs along continental coasts and around islands (SWOT 2011; Seminoff et al. 2015). Green turtles typically migrate along coastal routes from rookeries to feeding grounds, although some populations conduct trans-oceanic migrations (SWOT 2011). Hatchlings are epipelagic (surface dwelling in the open sea) for ~1–3 years. Subsequently, they live in bays and along protected shorelines and feed during the day on seagrass and algae (Bjorndal 1982). Juvenile and sub-adult green turtles may travel thousands of kilometers before they return to breeding and nesting grounds (Carr et al. 1978). Though primarily known to forage in coastal areas, adult green turtles have also been recorded feeding in oceanic waters (Hatase et al. 2006).

Movement of green turtles across the Pacific appears to be restricted by the East Pacific Barrier; thus only turtles from the East Pacific DPS are expected to occur in the eastern Pacific (Seminoff et al. 2015). The East Pacific DPS is estimated at 20,062 nesting females, ~58% of which nest in Michoacán, Mexico, and the population is likely to increase (Seminoff et al. 2015). Nesting occurs in Michoacán from August–January, with a peak in October–November (Alvarado and Figueroa 1995).

Stinson (1984) reviewed sea turtle sighting records from northern Baja California to Alaska, and reported only three sightings each of green turtles for Oregon, Washington, and B.C., and two sightings for Alaska; most sightings occurred in California (78%). Green turtles are considered rare in Washington, where 28 occurrences, mostly strandings, were documented between 1950 and 2017; the most recent occurrence was in November 2010 (Sato 2017a). There are at least three occurrences for Oregon from 2010–2017 (Oregonian 2012; Oregon Coast Aquarium 2019).

Green turtles are also considered rare vagrants in B.C. waters (McAlpine et al. 2004). Most records of green turtles in B.C. have been of stranded carcasses, often relatively fresh, discovered from November–January (McAlpine et al. 2004). Two of the six records listed in McAlpine et al. (2004) occurred in the study area off the coast of Vancouver Island. Three live green turtles have recently washed ashore on Vancouver Island, all in the vicinity of the study area (CBC 2011b, 2016). A questionnaire that was sent out to commercial fisherman in 2003 reported 14 sightings of green turtles for B.C. (Spaven 2009). It is possible although unlikely that a green turtle would be encountered in the proposed project area.

3.5 Seabirds

Four seabird species that are listed as threatened or endangered under the ESA or SARA could occur in or near the proposed survey area. The short-tailed albatross (*Phoebastria albatrus*) is listed as ***endangered*** under the ESA and SARA, the Hawaiian petrel (*Phoebastria albatrus*) is listed as ***endangered*** under the ESA (no SARA listing), the pink-footed shearwater (*Puffinus creatopus*) is listed as *endangered* under SARA (no ESA listing), and the marbled murrelet (*Brachyramphus marmoratus*) is listed as ***threatened*** under the ESA and SARA. Critical habitat has been designated for the marbled murrelet in Canada and in the US from Washington to California. An additional ESA-listed species, the western snowy plover (*Charadrius nivosus nivosus*), would be present on shorelines adjacent to proposed survey area, but does not occur in pelagic habitats, so it is not discussed further. The tufted puffin (*Fratercula cirrhata*) is currently under review by USFWS for listing under the ESA and is expected to occur along survey transects in low densities.

In addition to the above species, there are six species listed as *special concern* under SARA which may be encountered in the survey area. These include the offshore black-footed albatross (*Phoebastria nigripes*), Cassin's auklet (*Ptychoramphus aleuticus*), ancient murrelet (*Synthliboramphus antiquus*), nearshore horned grebe (*Podiceps auratus*), and western grebe (*Aechmophorus occidentalis*); and the red-necked phalarope (*Phalaropus lobatus*) which occurs in offshore as well as nearshore locations. In addition, both the horned puffin (*Fratercula corniculate*) and common murre (*Uria aalge*) are considered candidates for endangered or threatened status in B.C. (B.C. CDC 2019) and could also occur within the survey area.

3.5.1 Short-tailed Albatross

Historically, millions of short-tailed albatrosses bred in the western North Pacific on islands off the coast of Japan (USFWS 2008). This species was the most abundant albatross in the North Pacific. However, the entire global population was nearly wiped out during the last century by feather hunters at Japanese breeding colonies. In addition to hunting pressures, the breeding grounds of the remaining birds were threatened by volcanic eruptions in the 1930s. This species was believed to be extinct by 1949; however, breeding was detected in 1950 and 1951, aided by pelagic-dwelling maturing birds which escaped the slaughter (USFWS 2008; BirdLife International 2019a). Due to conservation and management actions the population is increasing; the most recent population estimate is 4200 individuals (Birdlife International 2019a). Current threats to this population include volcanic activity on Torishima, commercial fisheries, and pollutants (USFWS 2008). Interactions with vessels in the eastern Pacific have been noted. Incidental take due to commercial fisheries has been documented, with one short-tailed albatross taken as bycatch off Oregon during the sablefish demersal fishery in 2011 (USFWS 2017), and 11 mortalities between 1995 and 2015 in the Alaska hook-and-line groundfish fishery (NMFS 2015b; USFWS 2017).

Currently, nearly all short-tailed albatrosses breed on two islands off the coast of Japan: Torishima and Minami-kojima (USFWS 2008; BirdLife International 2019a). Single nests have been found in recent years on other islands, including Kita-Kojima, Senkaku; Yomejima Island; and Midway Island, Hawaii; however, nesting attempts in Hawaii have not been successful (USFWS 2008). During the breeding season (December–May), the highest densities are found around Japan (BirdLife International 2019a), with albatross being seen as far south (23°N) as the Northwestern Hawaiian Islands between November and April (USFWS 2008).

During the non-breeding season, short-tailed albatross roam much of the North Pacific Ocean; females spend more time offshore from Japan and Russia, whereas males and juveniles spend more time around the Aleutian Islands and Bering Sea (Suryan et al. 2007). Post-breeding dispersal occurs from April through August (USFWS 2008). After leaving the breeding areas, short-tailed albatrosses seem to spend the majority of time within the EEZs of Japan, Russia, and the U.S., primarily in the Aleutian Islands and Bering Sea (Suryan et al. 2007). They are considered a continental shelf-edge specialist (Piatt et al. 2006). Most short-tailed albatross sightings off the Pacific coast of North America (south to California) are juveniles and sub-adults (USFWS 2008; O'Connor 2013). Satellite-tracked first and second year birds were found in Oregon waters most often during winter and spring, possibly in response to ice conditions in the Bering Sea (O'Connor 2013). Sightings in the eastern North Pacific are increasing, corresponding with global population increases (COSEWIC 2013a). The short-tailed albatross could be encountered in small numbers in the proposed project area.

3.5.2 Hawaiian Petrel

The Hawaiian petrel has an estimated population size of 6000–11,000 (Birdlife International 2019b). Large declines in overall numbers and in the number of breeding colonies appear to pre-date European arrival on the Hawaiian Islands, tracing back to animal introductions, habitat modifications, and hunting by Polynesians (Simons and Hodges 1998). The population of Hawaiian petrels continues to decline, mainly because of predation by introduced vertebrates, including mongooses, cats, and goats, and due to collisions and light attraction (USFWS 2005; Raine et al. 2017).

The Hawaiian petrel is endemic to Hawaii, where it nests at high elevation. Known nesting habitats include lava cavities, burrows on cliff faces or steep slopes, and beneath ferns (USFWS 2005). The majority of eggs are laid in May and June, and most young fledge in December (Mitchell et al. 2005). Hawaiian petrels can travel up to 1300 km away from colonies during foraging trips; at-sea densities decrease with distance from the colony (Spear et al. 1995). Spear et al. (1995) showed the distribution of Hawaiian petrels to be concentrated in the southern portion of the Main Hawaiian Islands (below 20°N) during spring and autumn. However, in recent years, the Hawaiian petrel has been recognized to be a regularly occurring offshore species to the eastern Pacific in waters from southern California to B.C. In California, where observer coverage is perhaps highest, there are records from March through September (eBird 2019). There are two accepted records of Hawaiian petrel in Washington (September 2008 and May 2014; WBRC 2018) and three in B.C. (July 2013, May 2014, and July 2014; BCBRC 2018), although occurrences are likely more frequent than observations suggest owing to the minimal observer coverage at the distance from shore which these petrels typically frequent. The Hawaiian petrel could be encountered in small numbers in the proposed project area, but is more likely to occur along the southern transects.

3.5.3 Marbled Murrelet

Marbled murrelets are widespread along the Pacific coast and are generally found in nearshore waters, usually within 5 km of shore (Nelson 1997). The population(s) of marbled murrelets in California, Oregon, and Washington has declined by nearly 30% from 23,700 individuals in 2000 to 16,700 individuals in 2010 (Miller et al. 2012). The primary reason for declining populations is the fragmentation and destruction of old-growth forest nesting habitat. Marbled murrelets are also threatened by gillnet fishing, nest predation, and oil spills.

Nesting critical habitat for marbled murrelets consists of forest stands containing large trees with potential nest platforms (including large branches, deformities, mistletoe infestations) at least 10 m in height; high canopy cover is also important for nesting murrelets (USFWS 2016b). Although terrestrial critical habitat has been identified in B.C., Washington, and Oregon, no critical marine habitat has been designated for marbled murrelets to date, although it could be identified in B.C. in the future (B.C. Government 2018). Marbled murrelet nesting occurs between late March and August, but the birds remain in the waters of that region during the non-breeding season.

Marbled murrelets feed at sea where they forage on small schooling fish and invertebrates in bays and fiords and in the open ocean (Nelson 1997). Feeding habitat for marbled murrelets is mostly within 2 km of shore in waters up to 30 m deep (USFWS 2006). Although they have been observed more than 40 km from shore in water deeper than 200 m (Adams et al. 2014), the mean offshore distance over a 3-year tracking study was 1.4 km (Hébert and Golightly 2008). Marbled murrelets are unlikely to occur in the offshore waters of the proposed study area; however, they can be expected on survey transects that approach within a few kilometers from shore.

3.5.4 Pink-footed Shearwater

The pink-footed shearwater is mostly found in the eastern Pacific from Chile north to Alaska, but only breeds on three islands off the coast of Chile (CEC 2005). On the breeding islands of Isla Mocha, Robinson Crusoe and Santa Clara, pink-footed shearwater populations have declined due to increased nest predation from introduced predators and humans, human disturbance, and habitat degradation (CEC 2005). The total global population is estimated at about 28,000 breeding pairs, plus non-breeders (COSEWIC 2016b), or about 59,000 individuals (BirdLife International 2019c). It has been estimated that up to 20,000 pink-footed shearwaters use B.C. waters annually (COSEWIC 2016b), a potentially significant portion of the total population.

Pink-footed shearwaters are found in continental shelf (to the 200 m isobath), shelf-break, and continental slope (between the 200 and 500 m isobaths) waters of the eastern Pacific (COSEWIC 2016b). They occur off the North American coast during the northern spring, summer, and autumn, with birds returning southwards in October and November to breed off Chile (CEC 2005). Off the B.C. coast, pink-footed shearwaters are regular summer visitors, with numbers peaking in June–October (COSEWIC 2016b). Pink-footed shearwaters could be encountered within the proposed survey area.

3.5.5 Tufted Puffin

The tufted puffin is being reviewed for listing under the ESA. A petition to list the species identifies the contiguous U.S. population as a DPS constituting Washington, Oregon, and California, and recommends listing it as either ***endangered*** or ***threatened*** (USFWS 2015b). Most of the global population (~80%) breeds in North America, from Alaska, south along the eastern Pacific as far as the Channel Islands in California (Piatt and Kitaysky 2002). The majority of these are in Alaska, with only a small proportion in B.C. (3.1%), Washington (0.9%), Oregon (0.2%), and California (0.01%) (Piatt and Kitaysky 2002). Threats to the species include incidental capture in fisheries, climate change, predation by introduced species (e.g., rats), human disturbance, and oil spills (BirdLife International 2019d).

Tufted puffins forage widely over continental shelf areas, and during the breeding season generally forage within 100 km of colonies (Piatt and Kitaysky 2002). Densities of foraging birds are low and decline with smaller population sizes; for example <1 birds/km^2 off Washington and Oregon and <0.1 birds/km^2 off California (Ainley and Boekelheide 1990; Tyler et al. 1993). Non-breeders and wintering birds stay in deep, oceanic waters (Piatt and Kitaysky 2002). This species attends breeding colonies from late March through September (Piatt and Kitaysky 2002; Campbell et al. 1990). Tufted puffins are likely to be encountered in low densities in the survey area.

3.6 Fish and Marine Invertebrates, Essential Fish Habitat, and Habitat Areas of Particular Concern

3.6.1 ESA-Listed Fish Species

The term "species" under the ESA includes species, subspecies, and, for vertebrates only, DPSs or "evolutionarily significant units (ESUs)"; for Pacific salmon, ESUs are essentially equivalent to DPSs for the purpose of the ESA. There are several ESA-listed fish species or populations that occur off the coasts of Washington/Oregon including the ESUs of chinook (*Oncorhynchus tshawytscha*), chum (*O. keta*), coho

(*O. kisutch*), and sockeye salmon (*O. nerka*), and DPSs of steelhead (Oncorhynchus mykiss), bocaccio (*Sebastes paucispinis*), yellow-eye rockfish (*S. ruberrimus*), Pacific eulachon (*Thaleichthys pacificus*), and green sturgeon (*Acipenser medirostris*) (Table 6). Although the ***threatened*** giant manta ray (*Manta birostris*) and oceanic whitetip shark (*Carcharhinus longimanus*), and the ***endangered*** Eastern Pacific DPS of scalloped hammerhead shark (*Sphyrna lewini*) occur in the Northeast Pacific Ocean, their most northerly extent is California. No ESA-listed marine invertebrate species occur in the proposed survey area.

3.6.1.1 Salmonids

Pacific salmon and steelhead trout typically spend the majority of their time in the upper water column while at sea (e.g., Daly et al. 2014; PFMC 2014). However, Chinook typically occur at depths >30 m from the sea surface (PFMC 2014). The degree to which Pacific salmon and steelhead migrate offshore varies considerably among seasons, years, life stages and/or populations, with stronger upwelling conditions generally leading to wider dispersal from shore (Pearcy 1992). Tag recoveries from high seas fisheries indicate that chinook occur beyond the shelf break (Myers et al. 1996). Once coho salmon emigrate from freshwater, they spend at least several weeks and up to a summer season in coastal waters before migrating north and offshore (PFMC 2014). Tag recoveries from fisheries indicate that coho are distributed as far west as 175ºE (Myers et al. 1996). However, the oceanic distribution of chum salmon is likely the broadest of any Pacific salmon species; it occurs throughout the North Pacific Ocean north of Oregon/Washington (Neave et al. 1976). Sockeye are thought to follow a similar migration pattern as chum once they enter the ocean, moving north and west along the coast before moving offshore (Quinn 2005; Byron and Burke 2014). Sockeye primarily occur east of 160ºW and north of 48ºN; most fish likely depart offshore waters by early August of their second at-sea year to spawn in their natal rivers (French et al. 1976). Steelhead appear to rely on offshore waters for feeding than any other Pacific salmonids, making more extensive migrations offshore in their first year (Quinn and Myers 2004). Light et al. (1989) found that steelhead is distributed throughout the North Pacific year-round, occurring in higher abundance closer to the coasts during spring and winter and being distributed more evenly during summer and autumn. Larval and pelagic juvenile bocaccio tend to occur within surficial waters and have been found as far as 480 km offshore the west coast (NMFS 2014).

3.6.1.2 Bocaccio

Bocaccio are distributed in coastal waters over rocky bottoms from the Gulf of Alaska to Baja California, Mexico down to depths of 478 m, but are most common between 50–250 m (NMFS 2008b). There are only two demographic clusters of Bocaccio, and the B.C. population likely overlaps with U.S. populations centered on the central and southern coasts of California (COSEWIC 2013b). Bocaccio are most common from Oregon to California, and genetic analysis suggests three population regions including Haida Gwaii, Vancouver Island to Point Conception, and southwards of Point Conception (NMFS 2008b). Bocaccio are bycaught in commercial groundfish fisheries in B.C., and population biomass has declined by over 90% since the 1950s, and by 28% since 2002, with no signs of recovery (COSEWIC 2013b).

3.6.1.3 Yelloweye Rockfish

Yelloweye rockfish are found in coastal waters from the Alaskan Aleutian Islands down to Baja California. They are found in depths ranging from 15–549 m over hard, complex bottoms but are most common in waters 91–180 m (COSEWIC 2008; NMFS 2008b). COSEWIC (2008) divided the population into two Designatable Units (DUs) of "inside" and "outside" populations. The inside DU includes the Strait of Georgia, Johnstone Strait, and the Queen Charlotte Strait, and the outside DU includes waters from

TABLE 6. Fish "species" listed under the ESA that could occur in the proposed survey area off Washington and Oregon (NOAA 2019d)

Species	ESU or DPS	Status	Critical Habitat
Bocaccio	Puget Sound/Georgia Basin DPS	Endangered	Marine
Yelloweye Rockfish	Puget Sound/Georgia Basin DPS	Threatened	Marine
Pacific eulachon/smelt	Southern DPS	Threatened	Freshwater/estuarine
Green sturgeon	Southern DPS	Threatened	Marine/freshwater/estuarine
Chinook salmon	Sacramento River winter-run ESU	Endangered	Freshwater
	Upper Columbia River spring-run ESU	Endangered	Freshwater
	California Coastal ESU	Threatened	Freshwater
	Central Valley spring-run ESU	Threatened	Freshwater
	Lower Columbia River ESU	Threatened	Freshwater
	Puget Sound ESU	Threatened	Freshwater/marine
	Snake River fall-run ESU	Threatened	Freshwater
	Snake River spring/summer-run ESU	Threatened	—
	Upper Willamette River ESU	Threatened	Freshwater
	Upper Klamath-Trinity River ESU	Candidate	—
Chum salmon	Columbia River ESU	Threatened	Freshwater
	Hood Canal summer-run ESU	Threatened	Freshwater/marine
Coho salmon	Central California Coast ESU	Endangered	—
	Lower Columbia River ESU	Threatened	Freshwater
	Oregon Coast ESU	Threatened	Freshwater
	S. Oregon and N. California coasts ESU	Threatened	—
Sockeye salmon	Ozette Lake ESU	Threatened	Freshwater
	Snake River ESU	Endangered	—
Steelhead trout	Northern California Summer Population DPS	Candidate	—
	Southern California DPS	Endangered	Freshwater
	California Central Valley DPS	Threatened	Freshwater
	Central California Coast DPS	Threatened	Freshwater
	Northern California DPS	Threatened	Freshwater
	South-Central California Coast DPS	Threatened	Freshwater
	Lower Columbia River DPS	Threatened	Freshwater
	Middle Columbia River DPS	Threatened	Freshwater
	Puget Sound DPS	Threatened	Freshwater
	Snake River Basin DPS	Threatened	Freshwater
	Upper Columbia River DPS	Threatened	Freshwater
	Upper Willamette River DPS	Threatened	Freshwater

southwest Alaska to northern Oregon, including offshore B.C. and the north and central coast waters (COSEWIC 2008). Yelloweye rockfish are exceptionally long-lived and individuals have been aged at 115 years in B.C. (COSEWIC 2008). Yelloweye rockfish are caught commercially in groundfish trawls and recreationally by hook and line.

3.6.1.4 Eulachon

Eulachon are a small species of smelt that spend 95% of their lives in the marine environment, migrating to freshwater rivers to spawn. Their marine range extends from the Bering Sea to California, and three DUs have been identified that include the Central Pacific Coast, Nass/Skeena Rivers, and the Fraser River (COSEWIC 2011). Eulachon spawn after three years, typically in coastal rivers that are associated with glaciers or snowpacks (COSEWIC 2011). To date, eulachon have been reported to spawn in at least 40 rivers in B.C. (Schweigert et al. 2012). Eulachon have an exceptionally high lipid content (approximately 20%) and are an important species in FSC fisheries (Schweigert et al. 2012). In B.C., eulachon are bycaught in commercial groundfish and shrimp trawls and in pelagic hake nets; however, there is no targeted commercial or recreational fishery (COSEWIC 2011). However, they are taken commercially in Oregon (NOAA 2019g) and Washington (NMFS 2017).

3.6.1.5 Green Sturgeon

The green sturgeon is distributed from Alaska to California primarily in marine waters up to 110 m deep, migrating to freshwater during the spawning season. It is found from Grave Harbor, AK, and along the entire coast of B.C. during the spring and winter months. Green sturgeon have been identified in large concentrations near Brooks Peninsula off the northwestern Vancouver Island during May–June and October–November (DFO 2019i). During spawning season in the summer and fall, aggregations of green sturgeon are found in the Columbia River estuary, Willapa Bay, and Grays Harbor, WA, and in the Umpqua River estuary, OR (NMFS 2018b). The Rogue River, Klamath River, Eel River, Sacramento River, and Feather River have been confirmed as spawning rivers for green sturgeon in the U.S. (NMFS 2018b). There are no documented spawning rivers in Canada (COSEWIC 2004; DFO 2019i). There are currently no directed fisheries for green sturgeon (DFO 2019i; NOAA 2019g); however, adults are bycaught in commercial groundfish trawls and in recreational fisheries (DFO 2019i).

3.6.2 Essential Fish Habitat

Under the 1976 *Magnuson Fisheries Conservation and Management Act* (renamed *Magnuson Stevens Fisheries Conservation and Management Act* in 1996), Essential Fish Habitat (EFH) is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity". "Waters" include aquatic areas and their associated physical, chemical, and biological properties that are used by fish. "Substrate" includes sediment, hard bottom, structures underlying the waters, and associated biological communities (NOAA 2002). The *Magnuson Stevens Fishery Conservation and Management Act* (16 U.S.C.§1801–1882) established Regional Fishery Management Councils and mandated that Fishery Management Plans (FMPs) be developed to manage exploited fish and invertebrate species responsibly in federal waters of the U.S. When Congress reauthorized the act in 1996 as the *Sustainable Fisheries Act*, several reforms and changes were made. One change was to charge NMFS with designating and conserving EFH for species managed under existing FMPs. In Washington and Oregon, there are four FMPs covering groundfish, coastal pelagic species, highly migratory species, and Pacific salmon. The entire western seaboard from the coast to the limits of the EEZ is EFH for one or more species for which EFH has been designated. The proposed project area encompasses several EFHs (Fig. 3).

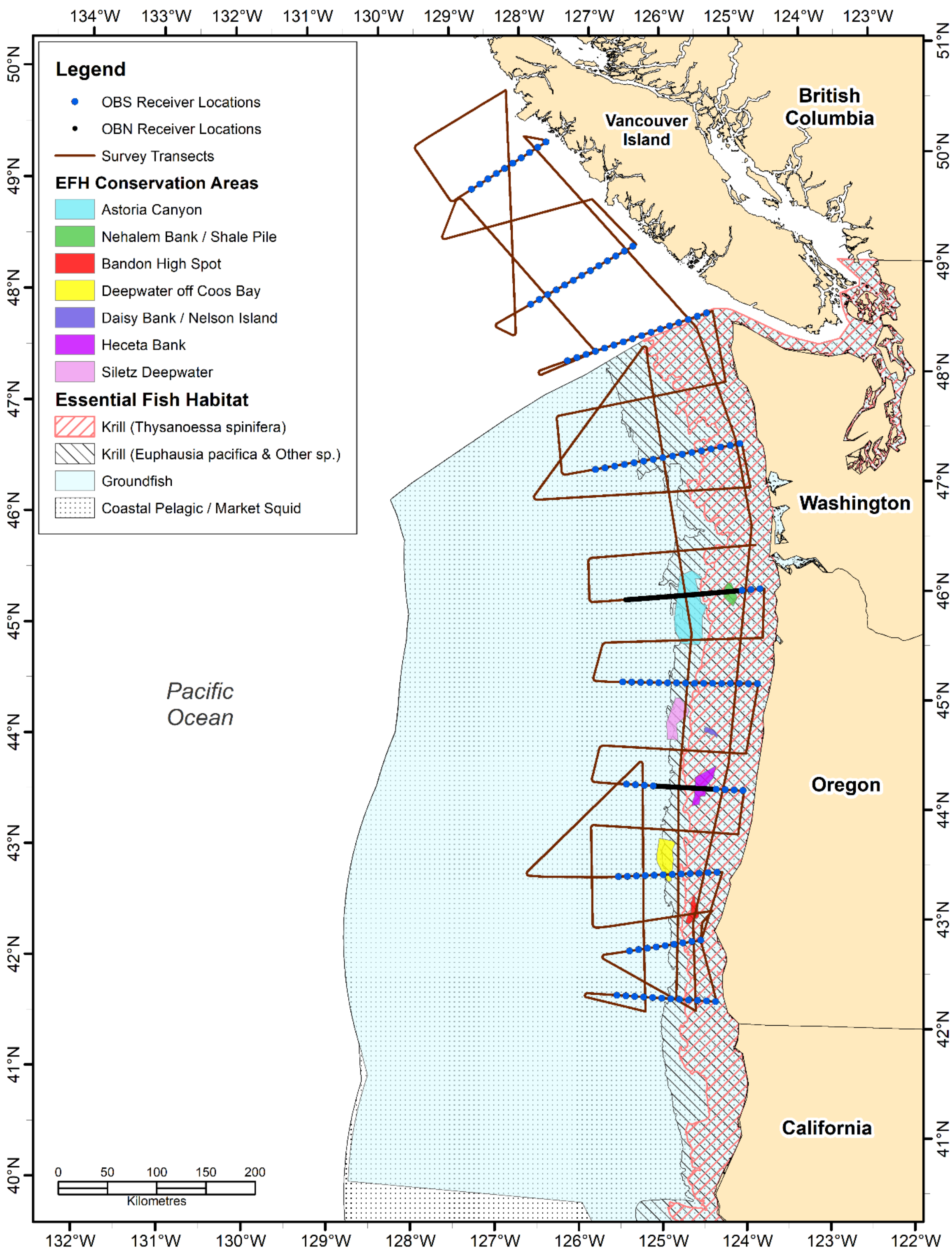

FIGURE 3. EFH in Washington and Oregon. Sources: NOAA 2018; NOAA WCR 2019; ODFW 2019b; USGS 2019.

Groundfish EFH.—The Pacific Coast Groundfish FMP manages more than 90 species (160 species/life stage combinations). The FMP provides a description of groundfish EFH for each of the species and their life stages (PFMC 2016a). When the EFH are taken together, the EFH for Pacific Coast groundfish includes all waters and substrate from the mean higher high water level or the upriver extent of saltwater intrusion along the coasts of Washington, Oregon, and California to within water depths <3500 m and seamounts in depths >3500 m (PMFC 2016a). In addition to the EFH parameters mentioned above, there are seven distinct EFH Conservation Areas within the proposed project area that are closed to bottom trawl fishing gear (Fig. 3) (NOAA 2018; NOAA WCR 2019; ODFW 2019b; USGS 2019).

Coastal Pelagic Species EFH.—The FMP for Pacific coast Coastal Pelagic Species (CPS) includes four finfish (Pacific sardine, Pacific [chub] mackerel, northern anchovy, and jack mackerel), market squid and all euphausiids (krill) species that occur in the west coast EEZ (PFMC 2016b). EFH for these species is defined both through geographic boundaries and by sea-surface temperature ranges. Because of similarities in their life histories and similarities in their habitat requirements, the four CPS finfish are treated as a single species complex for the purposes of EFH. Market squid are also treated in this same complex because they are similarly fished above spawning aggregations. The geographic boundary of EFH for CPS finfish and market squid is defined to be all marine and estuarine waters from the shoreline along the coasts of California, Oregon, and Washington offshore to the limits of the EEZ and above the thermocline where sea surface temperatures range between 10°C and 26°C; the southern extent of the EFH is the U.S.-Mexico boundary (Fig. 3). The northern boundary of the range of CPS finfish is the position of the 10°C isotherm which varies both seasonally and annually (PFMC 2016b). EFH for krill (*Thysanoessa spinifera*) extends from the shoreline outwards to a depth of 1000 m, while EFH for *Euphausia pacifica* and other krill species in the area extends from the shoreline to ~2000-m depth (NOAA 2018).

Pacific Coast Salmon EFH.—The FMP for Pacific coast salmon includes the coast-wide aggregate of natural and hatchery salmon species that is contacted by salmon fisheries in the EEZ off the coasts of Washington, Oregon, and California (PFMC 2016c). The PFMC manages the fisheries for coho, chinook, and pink (odd-numbered years) salmon and has defined EFH for these three species. Pacific coast salmon EFH includes marine areas within the EEZ, from the extreme high tide line in nearshore and tidal submerged environments within state territorial waters out to the full extent of the EEZ, along with estuarine and all currently or historically occupied freshwater habitat within the internal waters of Washington, Oregon, Idaho, and California north of Point Conception (PFMC 2016c).

Highly Migratory Species EFH.—The FMP for the U.S. west coast fisheries for highly migratory species includes dorado/dolphinfish and important species of tunas (North Pacific albacore, yellowfin, bigeye, skipjack, and northern bluefin), billfish/swordfish (striped marlin and swordfish), and sharks (common thresher, shortfin mako/bonito and blue) which are harvested by west coast fisheries (PFMC 2016d). EFH for each life stage of these species is described in the FMP (PFMC 2016d); collectively the highly migratory species EFH extends outwards from near shore (~10 m water depth) to the limit of the EEZ off of Washington, Oregon, and California (NOAA 2018).

3.6.3 Habitat Areas of Particular Concern

Habitat Areas of Particular Concern (HAPCs) are a subset of EFH that provide important ecological functions, are especially vulnerable to degradation, or include habitat that is rare (NOAA 2019h). There are several HAPCs within or near the proposed survey area for groundfish (Fig. 4). There are no HAPCs designated at this time for highly migratory species (PFMC 2016d).

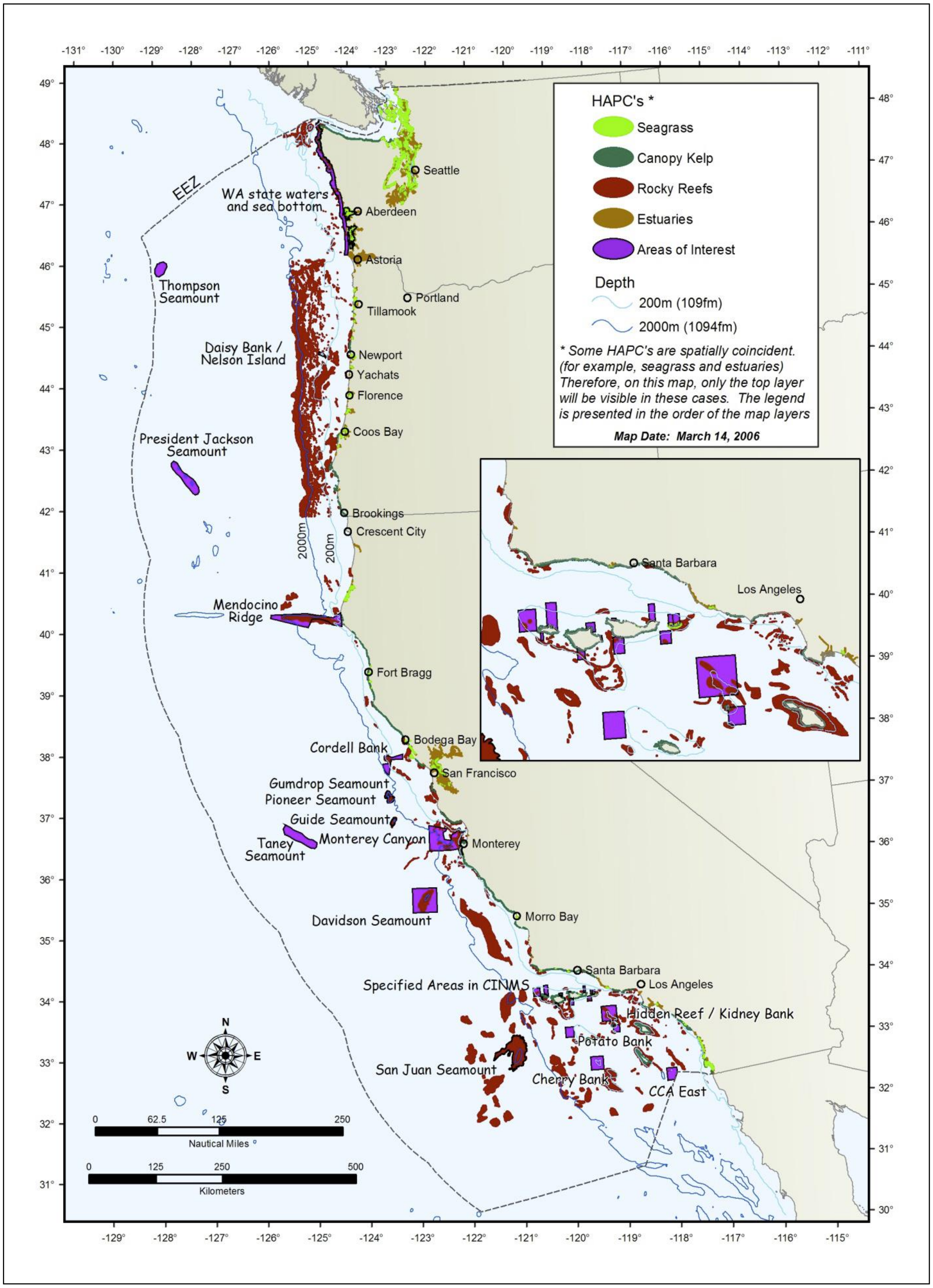

FIGURE 4. Groundfish HAPC in Washington, Oregon, and California. Source: PFMC (2016a).

Rocky Reefs HAPC.—The rocky reefs HAPC includes waters, substrates, and other biogenic features associated with hard substrate (bedrock, boulders, cobble, gravel, etc.) to mean higher high water level. The HAPC occurs primarily in Oregon waters 200–2000 m deep, including in the proposed survey area (Fig. 4). The rocky reefs HAPC in Washington are mostly scattered in <200 m depth, including in the northern portion of the OCNMS (PFMC 2016a).

Daisy Bank/Nelson Island HAPC.—Daisy Bank area of interest HAPC is a highly unique geological feature that occurs in Federal waters west of Newport, Oregon (44°38'N) and appears to play a unique and potentially rare ecological role for groundfish and large invertebrate sponge species. The bank supports more than 600,000 juvenile rockfish per km^2. Daisy Bank also supports more and larger lingcod and large sponges than other nearby banks (*in* PFMC 2016a). It is located within the survey area (Fig. 4).

Washington State Waters HAPC.—The Washington State Waters HAPC encompasses all waters and sea bottom in state waters shoreward from the 5.6 km boundary of the territorial sea shoreward to mean higher high water level. The HAPC encompasses a variety of habitats important to groundfish, including other HAPCs such as rocky reef habitat supporting juvenile rockfish (primarily north of 47.2°N). Sandy substrates within state waters (primarily south of 47.2°N) are important habitat for juvenile flatfish. A large proportion of this area occurs within the OCNMS (PFMC 2016a). This HAPC is adjacent to the survey area (Fig. 4).

Thompson and President Jackson Seamounts HAPC.—Seamounts have relatively high biodiversity and up to a third of species occurring on these features may be endemic (de Forges et al. 2000 *in* PFMC 2016a). Currents generated by seamounts retain rockfish larvae and zooplankton, a principal food source for rockfish (Genin et al. 1988, Mullineaux and Mills 1997, Haury et al. 2000, and Dower and Perry 2001 *in* PFMC 2016a). Deep-sea corals also occur on seamounts (Monterey Bay National Marine Sanctuary 2005 *in* PFMC 2016a). The Thompson Seamount HAPC has an area of ~430 km^2 and is closed to all bottom contact gear (Oren and DeVogelaere 2014). The HAPCs are west of the survey area (Fig. 4).

3.6.4 SARA-Listed Fish and Marine Invertebrate Species

There are two species that could occur within or near the survey area that are listed as *endangered* under SARA, including the basking shark and northern abalone (Table 7). However, northern abalone are not expected to occur in water deeper than 10 m and are not discussed further here; information regarding critical habitat was provided in Section 2.1.3. The *endangered* basking shark is the only SARA-listed fish species that could occur in the survey area. The Canadian Pacific population has been classified as *endangered* status under the SARA since 2010 and by COSEWIC since 2007 (DFO 2019d). In addition, several other fish species, as well as the Olympia oyster, are listed as *special concern*.

The basking shark is the second largest fish in the world reaching lengths of 12.2 m and an age of 50 years (DFO 2011b, 2019d). Basking sharks are slow to grow and mature, and exhibit low fecundity making them vulnerable to environmental change and anthropogenic threats. They are planktivorous and primarily filter-feed on copepod zooplankton in surface waters, where they spend ~19% of their time, along coastal shelf areas (DFO 2011b, 2019d). In Canadian Pacific waters, basking sharks are considered a migratory species that winter off California and spend the spring and summer months off B.C. (McFarlane et al. 2009 *in* DFO 2019d). Historically, basking sharks aggregated in large numbers ranging from the hundreds to the thousands in the Canadian Pacific; however, present populations may only number 321–535 individuals, and that estimate is uncertain (DFO 2019d). From 1996–2018, only 37 confirmed or reliable basking shark sightings were recorded in Canadian Pacific waters (DFO 2019d). The main threats posed to basking sharks are primarily anthropogenic and include net entanglement, collision with vessels, harassment from marine

TABLE 7. Marine fishes that may occur within the study area identified as species at risk under SARA, and their status under COSEWIC and their spatial distribution. Currently, only those species on Schedule 1 of SARA and designated as endangered or threatened are afforded protection measures.

Species	*SARA*[1,2]			COSEWIC[1]			Water Depth Range[2]	Distributional Range[2]
	E	T	SC	E	T	SC		
Marine Fish								
Basking Shark (*Cetorhinus maximus*) Pacific Ocean population	S1			X			1000	B.C. to California
Bluntnose Sixgill Shark (*Hexanchus griseus*) Pacific Ocean population			S1			X	2500	Pacific Coast including the Strait of Georgia
Green Sturgeon (*Acipenser medirostris*) Pacific Ocean population			S1			X	610	Alaska to Mexico
Longspine Thornyhead (*Sebastolobus altivelis*) Pacific Ocean population			S1			X	1600	Alaska to Baja California, Mexico
Rougheye Rockfish Type I and Type II (*Sebastes* sp.) Pacific Ocean population			S1			X	800	Alaska to southern California
Yelloweye Rockfish (*Sebastes ruberrimus*) Pacific Ocean Inside Waters population			S1			X	232	Strait of Georgia, Johnstone Strait, Queen Charlotte Strait
Pacific Ocean Outside Waters population			S1			X	232	Alaska to northern Oregon
Tope (*Galeorhinus galeus*) Pacific Ocean population			S1			X	471	Hecate Strait, B.C., to Gulf of California
Marine Invertebrates								
Northern Abalone (*Haliotis kamtschatkana*) Pacific Ocean population	S1			X			100	Alaska to Baja California, Mexico
Olympia Oyster (*Ostrea lurida*) Central Coast population			S1			X	50	Gale Passage, B.C., to Baja California, Mexico
Johnstone Strait population			S1			X	50	
Queen Charlotte population			S1			X	50	
Strait of Georgia population			S1			X	50	
Strait of Juan de Fuca population			S1			X	50	
West Coast Vancouver Island population			S1			X	50	

1 Government of Canada (2019d). E = Endangered; T = Threatened; SC = Special Concern; S1 = Schedule 1.
2 DFO (2019e).

/

based activities, and prey availability. Historically, net entanglement, bycatch, sport harpooning, government eradication efforts (occurring from 1942–1969), and directed fisheries (during the 1920s and 1940s) were the cause of the dramatic population decline (DFO 2009, 2011b, 2019d).

3.6.5 Rockfish Conservation Areas

***Rockfish Conservation Areas*.—**RCAs were established in 2002 to alleviate rockfish population declines. RCAs are located in marine waters along the B.C. coast, including adjacent to the proposed survey area (Fig. 5). Inshore rockfish are protected from mortality associated with recreational and commercial fishing in the RCAs; in addition, fishery monitoring and stock assessment programs are conducted. There are 37 species of rockfish that are typically caught by hook and line in rocky reef habitat along the B.C. coast (DFO 2015b). Inshore rockfish are found at shallow depth, but may occur in water as deep as 600 m; they include yelloweye, quillback, *S. maliger*; copper, *S. caurinus*; china, *S. nebulosus*; and tiger rockfish, *S. nigrocinctus* (DFO 2018c). Shelf species (e.g., bank, *S. rufus*; canary; bocaccio) are typically found in intermediate depths, but also occur at depths up to 600 m (DFO 2018c). Slope species are found at depths of 100–2000 m, and include the Pacific Ocean perch, *S. alutus* (DFO 2018c). Although none of the rockfish species are listed as *endangered* or *threatened* under SARA, rougheye rockfish (e.g., *S. aleutianus*) and yelloweye rockfish are considered *special concern* (Table 7).

3.7 Fisheries

3.7.1 Commercial Fisheries

The commercial Oregon and Washington fisheries harvest at least 170 species, including fish such as salmon, rockfish, flatfish, sharks, and tuna; crustaceans; mollusks; and other invertebrates (NOAA 2019g; ODFW 2019c). The highest landings (in metric tons) occur during July and August (NOAA 2017). In order of descending catch weight, the primary fish species recorded during 2014 in the Oregon, Washington, and Vancouver Coast and Shelf Marine Ecoregion included North Pacific hake (583.19 t), shrimp (63.46 t), Pacific cupped oyster (55.53 t), dungeness crab (29.13 t), chum salmon (11.06 t), coho salmon (8.44 t), pink salmon (2.89 t), Alaska pollock (1.8 t), and redfishes (1.42 t). Other species accounted for 174.48 t of the total catch (Sea Around Us 2016a). North Pacific hake has been the primary species caught since the 1960s, dropping off between the 1980s and 1990s, but landings have steadily increased to present day levels (Sea Around Us 2016a). The most common gear type used in the ecoregion as well as in the U.S. west coast fishery in 2014 was pelagic trawls (Sea Around Us 2016a,b). In B.C., harvests for commercial pelagic species are primarily taken using mobile gear such as seines, gillnets, and trawls, and fixed gear such as longlines and traps, in addition to hand harvesting for bivalve species (DFO 2019f).

3.7.2 Recreational Fisheries

Most marine recreational fisheries on the U.S. west coast occur within non-federal (shore to 5.6 km off the coast) waters, but some effort also occurs in federal waters (5.6 km to the extent of the EEZ); anglers fish from shore, private boats, and commercial passenger fishing vessels (NOAA 2019i). Species typically taken during recreational fisheries on the west coast include highly migratory species (albacore and other tunas, striped marlin, common thresher shark, shortfin mako shark), salmon (Chinook, coho), steelhead, groundfish (rockfish, lingcod scorpionfish, greenling, flatfish, sharks), halibut, coastal pelagic species (Pacific sardine, northern anchovy, market squid, Pacific mackerel), various state-managed species (barracuda, bass, bonito, sturgeon, surfperches), and invertebrates (abalone, lobster, crab, clams, oysters) (NOAA 2019i). During 2016, 1.2 million anglers took 5.2 million saltwater fishing trips, supporting $3 billion in sales on the U.S. west coast (NOAA 2019i).

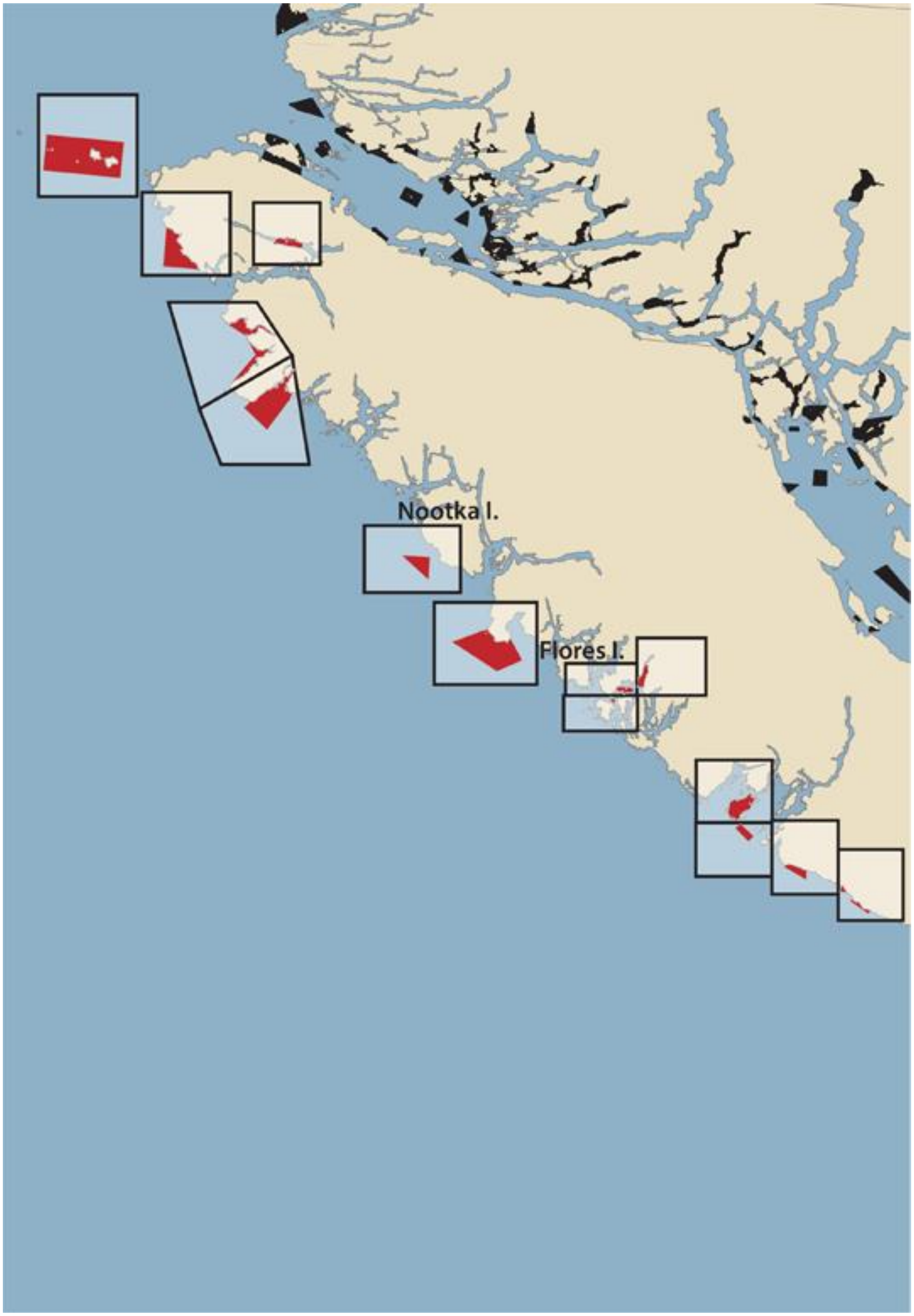

FIGURE 5. Rockfish Conservation Areas adjacent to the proposed project area. Source: DFO (2015b)

Recreational oceanic salmon fisheries off Oregon are open from March–November (location- and species-dependent); during 2018, there were 63,829 angler trips for this fishery (ODFW 2019d). Recreational groundfish taken off Oregon for which catch quotas are set include black rockfish, blue and deacon rockfishes, cabezon, canary rockfish, kelp and rock greenlings, "minor nearshore rockfishes" (China, copper, black-and-yellow, brown, calico, gopher, grass, kelp, olive, treefish, and quillback), and yelloweye rockfish; these species are primarily fished during spring and summer, with peak catches typically during July and August (ODFW 2019e). Pacific halibut are also caught during both nearshore and offshore recreational fisheries off Oregon, with the season running from May–October, with peak catches occurring from May–August (ODFW 2019f).

Recreational fisheries off Washington include marine salmon (Chinook, coho, chum, pink, sockeye and jacks), marine fish (bottomfish [e.g., rockfish, lingcod, sole, flounder], forage fish [e.g., herring, smelt], tunas and mackerels, Pacific halibut), and shellfish (e.g., clams, oysters, shrimp, crab) (Kraig and Scalici 2017). The recreational fishing season varies by species and location, but generally runs from May–October with peaks typically during mid-summer to early-fall (Kraig and Scalici 2017). The main species that contribute to the recreational fishery in B.C. include coho and chinook salmon, and Pacific halibut (MaPP 2015; DFO 2019g). Other species of finfish are also caught recreationally, in addition to bivalve shellfish, crabs, and other invertebrates (DFO 2019g). In 2010, a total of 1260 t were taken in the recreational fishery (Ainsworth 2015).

3.7.3 Subsistence Fisheries

The coast and nearshore areas are of cultural importance to indigenous peoples for fishing, hunting, gathering, and ceremonial purposes. In the U.S. Pacific Northwest, salmon play an integral role in tribal religion, culture, and sustenance in particular, within the Columbia River Basin (CRITFC 2019). Under jurisdiction, the tribal treaty-reserved fishing rights in western Washington permit "usual and accustomed" fishing practices and include many species in addition to salmon and steelhead trout (NOAA 2019j). Part of the proposed survey off Washington occurs within "usual and accustomed" fishing areas for the Hoh, Makah, and Quileute tribes, and the Quinault Nation. Some tribes collect shellfish such as clams, crab, oysters, and shrimp as part of the ceremonial/subsistence fishery (NWIFC 2019).

In Canada, subsistence fishing activity is known as "Food, Social, and Ceremonial (FSC)" harvesting and is practiced by indigenous groups. Salmon are the main species harvested by indigenous communities in FSC fisheries due to their nutritional, cultural, and spiritual significance, but marine mammals, birds, and plants are also taken (Weatherdon et al. 2016). Small quantities of sockeye salmon are principally harvested for subsistence purposes on the west coast Vancouver Island in areas including Clayoquot Sound, Barkley Sound, and Nitinat Inlet (DFO 1999). Halibut as well as herring roe are also harvested (Ainsworth 2015). Under the AAROM (Aboriginal Aquatic resource and Oceans Management) program, DFO supports indigenous groups as they "develop, grow and maintain aquatic resource and oceans management departments" (DFO 2019g). Domestic fishing areas for the Maa-nulth First Nation are located within the proposed study off Vancouver Island. Artisanal fisheries occur for butter clams, lingcod, and abalone; in 2010, subsistence fishing totaled 3690 t, and artisanal landings totaled 2160 t (Ainsworth 2015).

3.8 Aquaculture

In Oregon, the only marine species that is harvested is the Pacific oyster which makes up 44% of the number of the farms within the state and is valued at $10 million (ODA 2015). There is significant room to diversify and expand the current practices, and to explore possibilities of farming other marine invertebrate species such as the Manila clam, purple varnish clam, mussel, abalone, sea cucumber, and sea urchin (ODA 2015). Classified commercial shellfish growing areas in Oregon include Clatsop beaches, Tillamook Bay, Netarts Bay, Yaquina Bay, Umpqua Triangle, Umpqua River, Coos Bay, and South Slough (ODA 2019).

In 2011, shellfish farming in Washington state contributed $270 million to the economy (Washington Sea Grant 2015). Shellfish aquaculture production regions along the coast include the Strait of Juan de Fuca, Grays Harbor, Willapa Bay, and Puget Sound. The most important farmed species are the Pacific, eastern, and Kumamoto oysters, Olympia oyster, Manila clam, mussels, and geoduck (Washington Sea Grant 2015). The Pacific oyster makes up 38% of the total production of aquaculture in Washington, followed by geoduck (27%) and the Manila clam (19%) (Washington Sea Grant 2015). In 2017, a sea cage site owned by Cooke Aquaculture near Cypress Island, Puget Sound, failed and released 240,000 Atlantic salmon (non-native) into the surrounding waters. Since then, House Bill 2957 was passed by Washington Legislature which stated that all remaining Atlantic salmon pens will be phased out by 2022, and new commercial non-native finfish aquaculture is prohibited (Washington State Department of Ecology 2019).

In 2016, there were 41 licensed marine finfish aquaculture facilities and 63 licensed shellfish aquaculture facilities on the west coast of Vancouver Island (DFO 2019h). During 2010–2015, finfish aquaculture production generated $454 million (77, 209 t) and shellfish aquaculture generated $21 million (9, 146 t) for B.C. (VIEA 2017). Most marine finfish aquaculture licenses are issued for Atlantic salmon, chinook, coho, and sockeye salmon, and to a lesser degree, sablefish, steelhead trout, sturgeon, and tilapia (DFO 2017b; VIEA 2019). The majority of finfish aquaculture facilities are located around northern and western Vancouver Island, particularly in Clayoquot Sound. Shellfish aquaculture licenses are issued for Pacific oysters, Manila clams, geoduck, blue and Gallo mussels, and Japanese scallops (BCSGA 2019). On the west coast of Vancouver Island in Barkley Sound several kelp species are farmed and harvested commercially. These species include giant kelp, bull kelp, kombu, and sugar kelp (Canadian Kelp 2019; VIEA 2019).

3.9 Shipwrecks and SCUBA Diving

There are at least 17 shore-accessible SCUBA diving sites along the Oregon coast (ShoreDiving 2019). Wreck dives are popular along the Olympic Peninsula of Washington. Although the Columbia River Bar is nicknamed the *Graveyard of the Pacific* with ~2000 shipwrecks (TheOregonCoast.info 2019), the survey area is located >50 km from the mouth of the Columbia River and would occur in water depths >60 m, outside the range for recreational SCUBA diving. The West Coast Trail, originally the Dominion Lifesaving Trail, runs for 75 km along the southwest coast of Vancouver Island, and was built to facilitate the rescue of survivors of more than 484 shipwrecks along this stretch of coastline (West Coast Trail Guide 2019). The locations of 25 shipwrecks are included in the West Coast Trail Guide, though there are not visible remains of all 25 wrecks (West Coast Trail Guide 2019). Scuba diving makes up <5% of visitor motivations to travel to Vancouver Island North as tourism is centrally driven by other nature-based activities (Vancouver Island North Tourism Plan 2015). The majority of dive operators (41%) are located on southern Vancouver Island, and 10% are located on northern Vancouver Island and Haida Gwaii (Ivanova 2004). Most diving trips occur during the summer, but diving on the west coast takes place throughout the year (Ivanova 2004). Alberni-Clayoquot is a popular diving area on the west coast of Vancouver Island.

IV ENVIRONMENTAL CONSEQUENCES

4.1 Proposed Action

4.1.1 Direct Effects on Marine Mammals and Sea Turtles and Their Significance

The material in this section includes a summary of the expected potential effects (or lack thereof) of airgun sounds on marine mammals and sea turtles given in the PEIS, and reference to recent literature that has become available since the PEIS was released in 2011. A more comprehensive review of the relevant background information appears in § 3.4.4.3, § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS. Relevant background information on the hearing abilities of marine mammals and sea turtles can also be found in the PEIS.

This section also includes estimates of the numbers of marine mammals that could be affected by the proposed seismic surveys. A description of the rationale for NSF's estimates of the numbers of individuals exposed to received sound levels ≥160 dB re 1 μPa_{rms} is also provided. Acoustic modeling for the Proposed Action was conducted by L-DEO, consistent with past EAs and determined to be acceptable by NMFS for use in the calculation of estimated Level A and B takes under the MMPA.

4.1.1.1 Summary of Potential Effects of Airgun Sounds

As noted in the PEIS (§ 3.4.4.3, § 3.6.4.3, § 3.7.4.3, § 3.8.4.3), the effects of sounds from airguns could include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and at least in theory, temporary or permanent hearing impairment, or non-auditory physical or physiological effects (Richardson et al. 1995; Gordon et al. 2004; Nowacek et al. 2007; Southall et al. 2007; Erbe 2012; Peng et al. 2015; Erbe et al. 2016; Kunc et al. 2016; National Academies of Sciences, Engineering, and Medicine 2017; Weilgart 2017a). 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 (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. We are not aware of any information concerning masking of hearing in sea turtles.

***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., 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 µPa^2 · 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 2007).

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

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

Bowhead whale calls detected in the presence and absence of airgun sounds have been studied extensively in the Beaufort Sea. Bowheads continue to produce calls of the usual types when exposed to airgun sounds on their summering grounds, although numbers of calls detected are significantly lower in the presence than in the absence of airgun pulses (Blackwell et al. 2013, 2015). Blackwell et al. (2013) reported that calling rates in 2007 declined significantly where received SPLs from airgun sounds were 116–129 dB re 1 µPa; at SPLs <108 dB re 1 µPa, calling rates were not affected. When data for 2007–2010 were analyzed, Blackwell et al. (2015) reported an initial increase in calling rates when airgun pulses became detectable; however, calling rates leveled off at a received $CSEL_{10\text{-min}}$ (cumulative SEL over a 10-min period) of ~94 dB re 1 µPa^2 · s, decreased at $CSEL_{10\text{-min}}$ >127 dB re 1 µPa^2 · s, and whales were nearly silent at $CSEL_{10\text{-min}}$ >160 dB re 1 µPa^2 · 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 1994–2010 showed that the detection rate for minke whales was significantly higher when airguns were not operating; however, during surveys with small arrays, the detection rates for minke whales were similar during seismic and non-seismic periods (Stone 2015). Sighting rates for fin and sei whales were similar when large arrays of airguns were operating vs. silent (Stone 2015). All baleen whales combined tended to exhibit localized avoidance, remaining significantly farther (on average) from large arrays (median closest point of approach or CPA of ~1.5 km) during seismic operations compared with non-seismic periods (median CPA ~1.0 km; Stone 2015). In addition, fin and minke whales were more often oriented away from the vessel while a large airgun array was active compared with periods of inactivity (Stone 2015). Singing fin whales in the Mediterranean moved away from an operating airgun array, and their song notes had lower bandwidths during periods with vs. without airgun sounds (Castellote et al. 2012).

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

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

Toothed Whales

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

Observations from seismic vessels using large arrays off the U.K. from 1994–2010 indicated that detection rates were significantly higher for killer whales, white-beaked dolphins, and Atlantic white-sided dolphins when airguns were not operating; detection rates during seismic vs. non-seismic periods were similar during seismic surveys using small arrays (Stone 2015). Detection rates for long-finned pilot whales, Risso's dolphins, bottlenose dolphins, and short-beaked common dolphins were similar during seismic (small or large array) vs. non-seismic operations (Stone 2015). CPA distances for killer whales, white-beaked dolphins, and Atlantic white-sided dolphins were significantly farther

(>0.5 km) from large airgun arrays during periods of airgun activity compared with periods of inactivity, with significantly more animals traveling away from the vessel during airgun operation (Stone 2015). Observers' records suggested that fewer cetaceans were feeding and fewer delphinids were interacting with the survey vessel (e.g., bow-riding) during periods with airguns operating (Stone 2015).

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

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

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

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

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

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

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

Odontocete reactions to large arrays of airguns are variable and, at least for delphinids, seem to be confined to a smaller radius than has been observed for the more responsive of the mysticetes and some other odontocetes. A ≥170 dB disturbance criterion (rather than ≥160 dB) is considered appropriate for delphinids, which tend to be less responsive than the more responsive cetaceans. NMFS is developing new guidance for predicting behavioral effects (Scholik-Schlomer 2015). As behavioral responses are not consistently associated with received levels, some authors have made recommendations on different approaches to assess behavioral reactions (e.g., Gomez et al. 2016; Harris et al. 2017; Tyack and Thomas 2019).

Pinnipeds

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

Sea Turtles

Several recent papers discuss the morphology of the turtle ear (e.g., Christensen-Dalsgaard et al. 2012; Willis et al. 2013) and the hearing ability of sea turtles (e.g., Martin et al. 2012; Piniak et al. 2012a,b; Lavender et al. 2014). The limited available data indicate that sea turtles will hear airgun sounds and sometimes exhibit localized avoidance (see PEIS, § 3.4.4.3). In additional, Nelms et al. (2016) suggest that sea turtles could be excluded from critical habitats during seismic surveys.

DeRuiter and Doukara (2012) observed that immediately following an airgun pulse, small numbers of basking loggerhead turtles (6 of 86 turtles observed) exhibited an apparent startle response (sudden raising of the head and splashing of flippers, occasionally accompanied by blowing bubbles from the beak and nostrils, followed by a short dive). Diving turtles (49 of 86 individuals) were observed at distances from the center of the airgun array ranging from 50–839 m. The estimated sound level at the median distance of 130 m was 191 dB re 1 μPa_{peak}. These observations were made during ~150 h of vessel-based monitoring from a seismic vessel operating an airgun array (13 airguns, 2440 in^3) off Algeria; there was no corresponding observation effort during periods when the airgun array was inactive (DeRuiter and Doukara 2012).

Based on available data, it is likely that sea turtles will exhibit behavioral changes and/or avoidance within an area of unknown size near a seismic vessel. To the extent that there are any impacts on sea turtles, seismic operations in or near areas where turtles concentrate would likely have the greatest impact. There are no specific data that demonstrate the consequences to sea turtles if seismic operations with large or small arrays of airguns occur in important areas at biologically important times of the year. However, a number of mitigation measures can, on a case-by-case basis, be considered for application in areas important to sea turtles (e.g., Pendoley 1997; van der Wal et al. 2016).

***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).

Studies have shown that the SEL required for TTS onset to occur increases with intermittent exposures, with some auditory recovery during silent periods between signals (Finneran et al. 2010b;

Finneran and Schlundt 2011). Studies on bottlenose dolphins by Finneran et al. (2015) indicate that the potential for seismic surveys using airguns to cause auditory effects on dolphins could be lower than previously thought. Based on behavioral tests, no measurable TTS was detected in three bottlenose dolphins after exposure to 10 impulses from a seismic airgun with a cumulative SEL of up to ~195 dB re 1 µPa2 · 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. 372ff; Gedamke et al. 2011). In terrestrial animals, exposure to sounds sufficiently strong to elicit a large TTS induces physiological and structural changes in the inner ear, and at some high level of sound exposure, these phenomena become non-recoverable (Le Prell 2012). At this level of sound exposure, TTS grades into PTS. Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage, but repeated or (in some cases) single exposures to a level well above that causing TTS onset might elicit PTS (e.g., Kastak and Reichmuth 2007; Kastak et al. 2008).

The noise exposure criteria for marine mammals that were released by NMFS (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 (e.g., baleen whales), MF cetaceans (e.g., most delphinids), HF cetaceans (e.g., porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW).

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

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

Since 1991, there have been 70 Marine Mammal Unusual Mortality Events (UME) in the U.S. (NOAA 2019k). 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.

Sea Turtles

There is substantial overlap in the frequencies that sea turtles detect versus the frequencies in airgun pulses. We are not aware of measurements of the absolute hearing thresholds of any sea turtle to waterborne sounds similar to airgun pulses. In the absence of relevant absolute threshold data, we cannot estimate how far away an airgun array might be audible. Moein et al. (1994) and Lenhardt (2002) reported TTS for loggerhead turtles exposed to many airgun pulses (see § 3.4.4 of the PEIS). This suggests that sounds from an airgun array might cause temporary hearing impairment in sea turtles if they do not avoid the (unknown) radius where TTS occurs (see Nelms et al. 2016). However, exposure duration during the proposed surveys would be much less than during the aforementioned studies. Also, recent monitoring studies show that some sea turtles do show localized movement away from approaching airguns. At short distances from the source, received sound level diminishes rapidly with increasing distance. In that situation, even a small-scale avoidance response could result in a significant reduction in sound exposure.

The U.S. Navy has proposed the following criteria for the onset of hearing impairment for sea turtles: 232 dB re 1 µPa SPL (peak) and 204 dB re 1 $\mu Pa^2 \cdot s$ SEL_{cum} (weighted) for PTS; and 226 dB peak and 189 dB weighted SEL for TTS (USN 2017). Although it is possible that exposure to airgun sounds could cause mortality or mortal injuries in sea turtles close to the source, this has not been demonstrated and seems highly unlikely (Popper et al. 2014), especially because sea turtles appear to be resistant to explosives (Ketten et al. 2005 *in* Popper et al. 2014). Nonetheless, Popper et al. (2014) proposed sea turtle mortality/mortal injury criteria of 210 dB SEL or >207 dB_{peak} for sounds from seismic airguns; however, these criteria were largely based on impacts of pile-driving sound on fish.

The PSOs stationed on R/V *Langseth* would watch for sea turtles, and airgun operations would be shut down if a turtle enters the designated EZ.

4.1.1.2 Possible Effects of Other Acoustic Sources

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

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

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

Lurton (2016) modeled MBES radiation characteristics (pulse design, source level, and radiation directivity pattern) applied to a low-frequency (12-kHz), 240-dB source-level system like that used on 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 gray seals to echosounders with frequencies of 200 and 375 kHz. Short-finned pilot whales increased their heading variance in response to an EK60 echosounder with a resonant frequency of 38 kHz (Quick et al. 2017), and significantly fewer beaked whale vocalizations were detected while an EK60 echosounder was active vs. passive (Cholewiak et al. 2017).

Despite the aforementioned information that has recently become available, this Draft EA remains in agreement with the assessment presented in § 3.4.7, 3.6.7, 3.7.7, and 3.8.7 of the PEIS that operation of MBESs, SBPs, and pingers is not likely to impact marine mammals and is not expected to affect sea turtles, (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 or sea turtle given the movement and speed of the vessel. Also, for sea turtles, the associated frequency ranges are above their known hearing range.

4.1.1.3 Other Possible Effects of Seismic Surveys

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

Ship noise, through masking, can reduce the effective communication distance of a marine mammal if the frequency of the sound source is close to that used by the animal, and if the sound is present for a significant fraction of time (e.g., Richardson et al. 1995; Clark et al. 2009; Jensen et al. 2009; Gervaise et al. 2012; Hatch et al. 2012; Rice et al. 2014; Dunlop 2015; Erbe et al. 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 areas during seismic operations. Reactions of gray and humpback whales to vessels have been studied, and there is limited information available about the reactions of right whales and rorquals (fin, blue, and minke whales). Reactions of humpback whales to boats are variable, ranging from approach to avoidance (Payne 1978; Salden 1993). Baker et al. (1982, 1983) and Baker and Herman (1989) found humpbacks often move away when vessels are within several kilometers. Humpbacks seem less likely to react overtly when actively feeding than when resting or engaged in other activities (Krieger and Wing 1984, 1986). Increased levels of ship noise have been shown to affect foraging by humpback whales (Blair et al. 2016). Fin whale sightings in the western Mediterranean were negatively correlated with the number of vessels in the area (Campana et al. 2015). Minke whales and gray seals have shown slight displacement in response to construction-related vessel traffic (Anderwald et al. 2013).

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

There are few data on the behavioral reactions of beaked whales to vessel noise, though they seem to avoid approaching vessels (e.g., Würsig et al. 1998) or dive for an extended period when approached by a vessel (e.g., Kasuya 1986). Based on a single observation, Aguilar Soto et al. (2006) suggest foraging efficiency of Cuvier's beaked whales may be reduced by close approach of vessels. Tyson et al. (2017) suggested that a juvenile green sea turtle dove during vessel passes and remained still near the sea floor.

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 or sea turtles, 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 or sea turtles (e.g., Redfern et al. 2013). Information on vessel strikes is reviewed in § 3.4.4.4, § 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.

Entanglement of sea turtles in seismic gear is also a concern (Nelms et al. 2016). There have been reports of turtles being trapped and killed between the gaps in tail-buoys offshore from West Africa (Weir 2007); however, these tailbuoys are significantly different than those used on R/V *Langseth*. In April

2011, a dead olive ridley turtle was found in a deflector foil of the seismic gear on R/V *Langseth* during equipment recovery at the conclusion of a survey off Costa Rica, where sea turtles were numerous. Such incidents are possible, but that was the only case of sea turtle entanglement in seismic gear for R/V *Langseth*, which has been conducting seismic surveys since 2008, or for its predecessor, R/V *Maurice Ewing*, during 2003–2007. Towing the seismic equipment during the proposed surveys is not expected to significantly interfere with sea turtle movements, including migration.

4.1.1.4 Mitigation Measures

Several mitigation measures are built into the proposed seismic surveys as an integral part of the planned activity. These measures include the following: ramp ups; typically two, however a minimum of one dedicated observer maintaining a visual watch during all daytime airgun operations; two observers for 30 min before and during ramp ups; PAM during the day and night to complement visual monitoring (unless the system and back-up systems are damaged during operations); and power downs (or if necessary shut downs) when mammals or sea turtles are detected in or about to enter designated EZ. These mitigation measures are described in § 2.4.4.1 of the PEIS and summarized earlier in this document, in § II (2.1.3). The fact that the airgun array, because of its design, would direct the majority of the energy downward, and less energy laterally, is also an inherent mitigation measure.

Previous and subsequent analysis of the potential impacts takes account of these planned mitigation measures. It would not be meaningful to analyze the effects of the planned activity without mitigation, as the mitigation (and associated monitoring) measures are a basic part of the activity and would be implemented under the Proposed Action.

4.1.1.5 Potential Numbers of Cetaceans Exposed to Received Sound Levels ≥160 dB

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 A and Level B sound levels and present estimates of the numbers of marine mammals that could be affected during the proposed seismic surveys. The estimates are based on consideration of the number of marine mammals that could be disturbed appreciably by the seismic surveys but exclude potential takes in Canadian Territorial Waters.

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 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. 2010a).

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 from 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 8 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 their 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.

TABLE 8. 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*.

	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*	*1,647*	*4.7*	*77*
Fin whale	*94*	*6*	*18,680*	*0.5*	*100*
Sei whale	*35*	*2*	*27,197*	*0.1*	*37*
Minke whale	115	7	25,000	0.5	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	1	0	1,924	0	1
Striped dolphin	7	0	29,211	0	7
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[6]	N.A.	N.A.	N.A.	N.A.	5
Killer whale[7]	86	0	881	9.8	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	5,504	8	620,660	0.9	5,512
Guadalupe fur seal	1,553	2	20,000	7.8	*1,555*
California sea lion	1,280	2	257,606	0.5	1,282
Steller sea lion	7,942	9	45,675	17.4	7,951
Phocid Seal					
Northern elephant seal	2,971	18	179,000	1.7	2,989
Harbor seal	7,608	37	129,732	5.9	7,645
Marine Fissiped					
Northern Sea Otter	496	0	2,058	24.1	496
Sea Turtle					
Leatherback turtle	*4*	*0*	*N.A.*	*N.A.*	*4*

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, 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 5).
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 (Mobley et al. 2000).
7 Includes individuals from all stocks, including up to 8 killer whales from the southern resident stock.

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

The estimate of the number of marine mammals that could be exposed to seismic sounds with received levels ≥160 dB re 1 μPa_{rms} in the proposed survey area is 44,303 cetaceans and 26,934 pinnipeds (Table 8). That total includes 500 ***endangered*** cetaceans: 213 humpback whales, 100 fin whales, 77 blue whales, 38 sei whales, 72 sperm whales, representing 2.1%, 0.5%, 4.7%, 0.1%, and 0.3%, respectively. In addition, 1555 ***threatened*** Guadalupe fur seals could be exposed (7.8% of their regional population), and 340 beaked whales.

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. 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. Also, 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).

4.1.1.6 Conclusions for Marine Mammals and Sea Turtles

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".

***Marine Mammals*.**—In § 3.6.7, § 3.7.7, § 3.8.7, and § 3.9.7 of the PEIS concluded that airgun operations with implementation of the proposed monitoring and mitigation measures could result in a small number of Level B behavioral effects in some mysticete, odontocete, and pinniped species, as well as sea otters, and that Level A effects were highly unlikely. NMFS required the calculation of and request for potential Level A takes for the Proposed Action (following a different methodology than used in the PEIS and most previous analyses for NSF-funded seismic surveys). For 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).

In this analysis, estimates of the numbers of marine mammals that could be exposed to airgun sounds during the proposed program have been presented, together with the requested "take authorization". The estimated numbers of animals potentially exposed to sound levels sufficient to cause Level A and/or B harassment are low percentages of the regional population sizes (Table 8). The proposed activities are likely to adversely affect ESA-listed species for which takes are being requested (Table 9). However, the relatively short-term exposures are unlikely to result in any long-term negative consequences for the individuals or their populations.

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. A similar survey conducted in the region in the past (Marine Geophysical Surveys by R/V *Marcus G. Langseth* in the Northeastern Pacific Ocean, June–July 2012) had no observed significant impacts. Also, 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 2014b). 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.

***Sea Turtles*.—**In § 3.4.7, the PEIS concluded that with implementation of the proposed monitoring and mitigation measures, no significant impacts of airgun operations are likely to sea turtle populations in any of the analysis areas, and that any effects are likely to be limited to short-term behavioral disturbance and short-term localized avoidance of an area of unknown size near the active airguns. 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 sea turtle injuries or mortality. Given the proposed activities, impacts would not be anticipated to be significant or likely to adversely affect green turtles, but they would likely adversely affect the leatherback sea turtle (Table 10).

4.1.2 Direct Effects on Marine Invertebrates, Fish, and Fisheries, and Their Significance

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. Relevant new studies on the effects of sound on marine invertebrates, fish, and fisheries that have been published since the release of the PEIS are summarized below. Although research on the effects of exposure to airgun sound on marine invertebrates and fishes is increasing, many data gaps remain (Hawkins et al. 2015; Carroll et al. 2017), including how particle motion rather than sound pressure levels affect invertebrates and fishes that are exposed to sound (Hawkins and Popper 2017; Popper and Hawkins 2018). It is important to note that while all invertebrates and fishes are likely sensitive to particle motion, no invertebrates and not all fishes (e.g., sharks) are sensitive to the sound pressure component.

TABLE 9. ESA determination for marine mammal species expected to be encountered during the proposed surveys in the Northeast Pacific Ocean during late spring/summer 2020.

Species	ESA Determination		
	No Effect	May Affect – Not Likely to Adversely Affect	May Affect – Likely to Adversely Affect
North Pacific Right Whale		√	
Humpback Whale (Central America DPS)			√
Humpback Whale (Mexico DPS)			√
Sei Whale			√
Fin Whale			√
Blue Whale			√
Sperm Whale			√
Killer Whale (Southern Resident DPS)			√
Guadalupe Fur Seal			√

TABLE 10. ESA determination for sea turtle species expected to be encountered during the proposed surveys in the Northeast Pacific Ocean during late spring/summer 2020.

Species	ESA Determination		
	No Effect	May Affect – Not Likely to Adversely Affect	May Affect – Likely to Adversely Affect
Leatherback Turtle			√
Green Turtle (East Pacific DPS)		√	

Substrate vibrations caused by sounds may also affect the epibenthos, but sensitivities are largely unknown (Roberts and Elliott 2017). Activities directly contacting the seabed would be expected to have localized impacts on invertebrates and fishes that use the benthic habitat. A risk assessment of the potential impacts of airgun surveys on marine invertebrates and fish in Western Australia concluded that the greater the intensity of sound and the shallower the water, the greater the risk to these animals (Webster et al. 2018). In water >250 m deep, the impact of seismic surveying on fish and marine invertebrates was assessed as acceptable, while in water <250 m deep, risk ranged from negligible to severe, depending on depth, resource-type, and sound intensity (Webster et al. 2018). Immobile organisms, such as molluscs, were deemed to be the invertebrates most at risk from seismic impacts.

4.1.2.1 Effects of Sound on Marine Invertebrates

Effects of anthropogenic sounds on marine invertebrates are varied, ranging from no overt reactions to behavioral/physiological responses, injuries, or mortalities (Aguilar de Soto 2016; Edmonds et al. 2016; Carroll et al. 2017; Weilgart 2017b; Elliott et al. 2019). The available information suggests that invertebrates, particularly crustaceans, may be relatively resilient to airgun sounds (Day et al. 2016a,b).

Fields et al. (2019) conducted laboratory experiments to study effects of exposure to airgun sound on the mortality, predator escape response, and gene expression of the copepod *Calanus finmarchicus* and concluded that the airgun sound had limited effects on the mortality and escape responses of copepods exposed within 10 m of the airgun source but no measurable impact beyond that distance. McCauley et al. (2017) conducted a 2-day study to examine the potential effects of sound exposure of a 150 in^3 airgun on zooplankton off the coast of Tasmania; they concluded that exposure to airgun sound decreased zooplankton abundance compared to control samples and caused a two- to three-fold increase in adult and larval zooplankton mortality. They observed impacts on the zooplankton as far as 1.2 km from the exposure location – a much greater impact range than previously thought; however, there was no consistent decline in the proportion of dead zooplankton as distance increased and received levels decreased. The conclusions by McCauley et al. (2017) were based on a relatively small number of zooplankton samples, and more replication is required to increase confidence in the study findings.

Richardson et al. (2017) presented results of a modeling exercise intended to investigate the impact of exposure to airgun sound on zooplankton over a much larger temporal and spatial scale than that employed by McCauley et al. (2017). The exercise modeled a hypothetical survey over an area 80 km by 36 km during a 35-day period. Richardson et al. (2017) postulated that the decrease in zooplankton abundance observed by McCauley et al. (2017) could have been due to active avoidance behavior by larger zooplankton. The modeling results did indicate that there would be substantial impact on the zooplankton populations at a local spatial scale but not at a large spatial scale; zooplankton biomass recovery within the exposure area and out to 15 km occurred 3 days after completion of the seismic survey.

Fewtrell and McCauley (2012) exposed captive squid (*Sepioteuthis australis*) to pulses from a single airgun; the received sound levels ranged from 120–184 dB re 1 dB re 1 $\mu Pa^2 \cdot s$ SEL. Increases in alarm responses were seen at SELs >147–151 dB re 1 $\mu Pa^2 \cdot s$; the squid were seen to discharge ink or change their swimming pattern or vertical position in the water column. Solé et al. (2013a,b) exposed four cephalopod species held in tanks to low-frequency (50–400 Hz) sinusoidal wave sweeps (with a 1-s sweep period for 2 h) with received levels of 157 ± 5 dB re 1 μPa and peak levels up to 175 dB re 1 μPa. Besides exhibiting startle responses, all four species examined received damage to the statocyst, which is the organ responsible for equilibrium and movement. The animals also showed stressed behavior, decreased activity, and loss of muscle tone (Solé et al. 2013a). To examine the contribution from near-field particle motion from the tank walls on the study, Solé et al. (2017) exposed common cuttlefish (*Sepia officinalis*) in cages in their natural habitat to 1/3 octave bands with frequencies centered at 315 Hz and 400 Hz and levels ranging from 139–141 re 1 μPa^2. The study animals still incurred acoustic trauma and injury to statocysts, despite not being held in confined tanks with walls.

When New Zealand scallop (*Pecten novaezelandiae*) larvae were exposed to recorded seismic pulses, significant developmental delays were reported, and 46% of the larvae exhibited body abnormalities; it was suggested that the malformations could be attributable to cumulative exposure (Aguilar de Soto et al. 2013). Their experiment used larvae enclosed in 60-mL flasks suspended in a 2-m diameter by 1.3-m water depth tank and exposed to a playback of seismic sound at a distance of 5–10 cm.

There have been several *in situ* studies that have examined the effects of seismic surveys on scallops. Although most of these studies showed no short-term mortality in scallops (Parry et al. 2002; Harrington et al. 2010; Przeslawski et al. 2016, 2018), one study (Day et al. 2016a,b, 2017) did show adverse effects including an increase in mortality rates. Przeslawski et al. (2016, 2018) studied the potential impacts of an industrial seismic survey on commercial (*Pecten fumatus*) and doughboy (*Mimachlamys asperrima*) scallops. *In situ* monitoring of scallops took place in the Gippsland Basin, Australia, using dredging, and autonomous underwater vehicle deployment before the seismic survey, as well as two, and ten months after the survey. The airgun array used in the study was a single 2530 in^3 array made up of 16 airguns operating at 2000 psi with a maximum SEL of 146 dB re 1 $\mu Pa^2 \cdot s$ at 51 m depth. Overall, there was little to no detectable impact of the seismic survey on scallop health as measured by scallop shell size, adductor muscle diameter, gonad size, or gonad stage (Przeslawski et al. 2016). No scallop mortality related to airgun sounds was detected two or ten months after the seismic survey (Przeslawski et al. 2016, 2018).

Day et al. (2016a,b, 2017) exposed scallops (*P. fumatus*) and egg-bearing female spiny lobsters (*Jasus edwardsi*) at a location 10–12 m below the surface to airgun sounds. The airgun source was started ~1–1.5 km from the study subjects and passed over the animals; thus, the scallops and lobsters were exposed to airgun sounds as close as 5–8 m away and up to 1.5 km from the source. Three different airgun configurations were used in the field: 45 in^3, 150 in^3 (low pressure), and 150 in^3 (high pressure), each with maximum peak-to-peak source levels of 191–213 dB re 1 μPa; maximum cumulative SEL source levels were 189–199 dB re 1 $\mu Pa^2 \cdot s$. Exposure to seismic sound was found to significantly increase mortality in the scallops, especially over a chronic time scale (i.e., months post-exposure), although not beyond naturally occurring rates of mortality (Day et al. 2017). Non-lethal effects were also recorded, including changes in reflex behavior time, other behavioral patterns, haemolymph chemistry, and apparent damage to statocysts (Day et al. 2016b, 2017). However, the scallops were reared in suspended lantern nets rather than their natural environment, which can result in higher mortality rates compared to benthic populations (Yu et al. 2010). The female lobsters were maintained until the eggs hatched; no significant differences were found in the quality or quantity of larvae for control versus exposed subjects, indicating that the embryonic development of spiny lobster was not adversely affected by airgun sounds (Day et al. 2016a,b). No mortalities were reported for either control or exposed lobsters (Day et al. 2016a,b). When Day et al. (2019) exposed rock lobster to the equivalent of a full-scale commercial seismic survey passing within 100–500 m, lobsters exhibited impaired righting and damage to the sensory hairs of the statocyst.

Fitzgibbon et al. (2017) also examined the impact of airgun exposure on spiny lobster through a companion study to the Day et al. (2016a,b, 2017) studies; the same study site, experimental treatment methodologies, and airgun exposures were used. The objectives of the study were to examine the haemolymph biochemistry and nutritional condition of groups of lobsters over a period of up to 365 days post-airgun exposure. Overall, no mortalities were observed across both the experimental and control groups; however, lobster total haemocyte count decreased by 23–60% for all lobster groups up to 120 days post-airgun exposure in the experimental group when compared to the control group. A lower haemocyte count increases the risk of disease through a lower immunological response. The only other haemolyph parameter that was significantly affected by airgun exposure was the Brix index of haemolymph at 120 and 365 days post-airgun exposure in one of the experiments involving egg-laden females. Other studies conducted in the field have shown no effects on Dungeness crab larvae or snow crab embryos to seismic sounds (Pearson et al. 1994; DFO 2004b; Morris et al. 2018).

Payne et al. (2015) undertook two pilot studies which (i) examined the effects of a seismic airgun recording in the laboratory on lobster (*Homerus americanus*) mortality, gross pathology, histopathology, serum biochemistry, and feeding; and (ii) examined prolonged or delayed effects of seismic air gun pulses in the laboratory on lobster mortality, gross pathology, histopathology, and serum biochemistry. For experiment (i), lobsters were exposed to peak-to-peak and root-mean-squared received sound levels of 180 dB re 1 μPa and 171 dB re 1 μPa_{rms} respectively. Overall there was no mortality, loss of appendages, or other signs of gross pathology observed in exposed lobster. No differences were observed in haemolymph, feeding, ovary histopathology, or glycogen accumulation in the heptapancreas. The only observed differences were greater degrees of tubular vacuolation and tubular dilation in the hepatopancreas of the exposed lobsters. For experiment (ii), lobsters were exposed to 20 airgun shots per day for five successive days in a laboratory setting. The peak-to-peak and root-mean-squared received sound levels ranged from ~176–200 dB re 1 µPa and 148–172 dB re 1 μPa_{rms}, respectively. The lobsters were returned to their aquaria and examined after six months. No differences in mortality, gross pathology, loss of appendages, hepatopancreas/ovary histopathology or glycogen accumulation in the hepatopancreas were observed between exposed and control lobsters. The only observed difference was a slight statistically significant difference for calcium-protein concentration in the haemolymph, with lobsters in the exposed group having a lower concentration than the control group.

Celi et al. (2013) exposed captive red swamp crayfish (*Procambarus clarkia*) to linear sweeps with a frequency range of 0.1–25 kHz and a peak amplitude of 148 dB re 1 μPa_{rms} at 12 kHz for 30 min. They found that the noise exposure caused changes in the haemato-immunological parameters (indicating stress) and reduced agonistic behaviors. Wale et al. (2013a,b) showed increased oxygen consumption and effects on feeding and righting behavior of shore crabs when exposed to ship sound playbacks.

Leite et al. (2016) reported observing a dead giant squid (*Architeuthis dux*) while undertaking marine mammal observation work aboard a seismic vessel conducting a seismic survey in offshore Brazil. The seismic vessel was operating 48-airgun array with a total volume of 5085 in^3. As no further information on the squid could be obtained, it is unknown whether the airgun sounds played a factor in the death of the squid.

Heyward et al. (2018) monitored corals *in situ* before and after exposure to a 3-D seismic survey; the maximum SEL and SPL $_{0\text{-}pk}$ were 204 dB re 1 $\mu Pa^2 \cdot s$ and 226 dB re 1 µPa. No macroscopic effects on soft tissues or the skeleton were noted days or months after the survey.

4.1.2.2 Effects of Sound on Fish

Popper et al. (2019a) recently reviewed the hearing ability of fishes, and potential impacts of exposure to airgun sound on marine fishes have been reviewed by Popper (2009), Popper and Hastings (2009a,b), Fay and Popper (2012), Weilgart (2017b), Hawkins and Popper (2018), Popper et al. (2019b), and Slabbekoorn et al. (2019); they include pathological, physiological, and behavioral effects. Radford et al. (2014) and Putland et al. (2017) noted that masking of key environmental sounds or social signals could also be a potential negative effect from sound. Popper et al. (2014) presented guidelines for seismic sound level thresholds related to potential effects on fish. The effect types discussed include mortality, mortal injury, recoverable injury, temporary threshold shift, masking, and behavioral effects. Seismic sound level thresholds were discussed in relation to fish without swim bladders, fish with swim bladders, and fish eggs and larvae. Hawkins and Popper (2017) cautioned that particle motion as well as sound pressure should be considered when assessing the effects of underwater sound on fishes.

Bruce et al. (2018) studied the potential behavioral impacts of a seismic survey in the Gippsland Basin, Australia, on three shark species: tiger flathead (*Neoplatycephalus richardsoni*), gummy shark (*Mustelus antarcticus*), and swellshark (*Cephaloscylum laticeps*). Sharks were captured and tagged with acoustic tags before the survey and monitored for movement via acoustic telemetry within the seismic area. The energy source used in the study was a 2530 in^3 array consisting of 16 airguns with a maximum SEL of 146 dB re 1 $\mu Pa^2 \cdot s$ at 51 m depth. Flathead and gummy sharks were observed to move in and around the acoustic receivers while the airguns in the survey were active; however, most sharks left the study area within 2 days of being tagged. The authors of the study did not attribute this behavior to avoidance, possibly because the study area was relatively small. Overall, there was little conclusive evidence of the seismic survey impacting shark behavior, though flathead shark did show increases in swim speed that was regarded by the authors as a startle response to the airguns operating within the area.

Peña et al. (2013) used an omnidirectional fisheries sonar to determine the effects of a 3-D seismic survey off Vesterålen, northern Norway, on feeding herring (*Clupea harengus*). They reported that herring schools did not react to the seismic survey; no significant changes were detected in swimming speed, swim direction, or school size when the drifting seismic vessel approached the fish from a distance of 27 km to 2 km over a 6-h period. Peña et al. (2013) attributed the lack of response to strong motivation for feeding, the slow approach of the seismic vessel, and an increased tolerance to airgun sounds.

Miller and Cripps (2013) used underwater visual census to examine the effect of a seismic survey on a shallow-water coral reef fish community in Australia. The census took place at six sites on the reef before and after the survey. When the census data collected during the seismic program were combined with historical data, the analyses showed that the seismic survey had no significant effect on the overall abundance or species richness of reef fish. This was in part attributed to the design of the seismic survey (e.g., ≥400 m buffer zone around reef), which reduced the impacts of seismic sounds on the fish communities by exposing them to relatively low SELs (<187 dB re 1 $\mu Pa^2 \cdot s$).

Fewtrell and McCauley (2012) exposed pink snapper (*Pagrus auratus*) and trevally (*Pseudocaranx dentex*) to pulses from a single airgun; the received sound levels ranged from 120–184 dB re 1 dB re 1 $\mu Pa^2 \cdot s$ SEL. Increases in alarm responses were seen in the fish at SELs >147–151 dB re 1 $\mu Pa^2 \cdot s$; the fish swam faster and formed more cohesive groups in response to the airgun sounds.

Hastings and Miksis-Olds (2012) measured the hearing sensitivity of caged reef fish following exposure to a seismic survey in Australia. When the auditory evoked potentials (AEP) were examined for fish that had been in cages as close as 45 m from the pass of the seismic vessel and at water depth of 5 m, there was no evidence of TTS in any of the fish examined, even though the cumulative SELs had reached 190 dB re 1 $\mu Pa^2 \cdot s$.

Davidsen et al. (2019) outfitted Atlantic cod and saithe with acoustic transmitters to monitor their behaviors (i.e., swimming speed, movement in water column) in response to exposure to seismic airgun sound. The study was conducted in Norway using a large sea cage with a 30 m diameter and 25 m depth. Both sound pressure and particle motion were measured within the sea cage. An airgun firing every 10 s was towed toward the sea cage from an initial distance of 6.7 km from the cage to a minimum distance of 100 m from the cage. The SEL_{cum} ranged from 172–175 dB re 1 $\mu Pa^2 \cdot s$. Both the cod and saithe changed swimming depth and horizontal position more frequently during exposure to the sound. The saithe became more dispersed in response to elevated sound levels. Both species exhibited behavioral habituation to the repeated exposures to sound.

Radford et al. (2016) conducted experiments examining how repeated exposures of different sounds to European seabass (*Dicentrarchus labrax*) can reduce the fishes' response to that sound. They exposed post-larval seabass to playback recordings of seismic survey sound (single strike SEL 144 dB re 1 $\mu Pa^2 \cdot s$) in large indoor tanks containing underwater speakers. Their findings indicated that short-term exposure of seismic sound increased the ventilation rate (i.e., opercular beat rate [OBR]) of seabass that were not previously exposed to seismic relative to seabass in controlled, ambient sound conditions. Fish that were reared in tanks that were repeatedly exposed to seismic sound over a 12-week period exhibited a reduced OBR response to that sound type, but fish exposed over the same time period to pile-driving noise displayed a reduced response to both seismic and pile-driving noise. An increased ventilation rate is indicative of greater stress in seabass; however, there was no evidence of mortality or effects on growth of the seabass throughout the 12-week study period.

Popper et al. (2016) conducted a study that examined the effects of exposure to seismic airgun sound on caged pallid sturgeon (*Scaphirhynchus albus*) and paddlefish (*Polyodon spathula*); the maximum received peak SPL in this study was 224 dB re 1 µPa. Results of the study indicated no mortality, either during or seven days after exposure, and no statistical differences in effects on body tissues between exposed and control fish.

Andrews et al. (2014) conducted functional genomic studies on the inner ear of Atlantic salmon (*Salmo salar*) that had been exposed to seismic airgun sound. The airguns had a maximum SPL of ~145 dB re 1 μPa^2/Hz and the fish were exposed to 50 discharges per trial. The results provided evidence that fish exposed to seismic sound either increased or decreased their expressions of different genes, demonstrating that seismic sound can affect fish on a genetic level.

Sierra-Flores et al. (2015) examined broadcast sound as a short-term stressor in Atlantic cod (*Gadus morhua*) using cortisol as a biomarker. An underwater loudspeaker emitted SPLs ranging from 104–110 dB re 1 μPa_{rms}. Plasma cortisol levels of fish increased rapidly with sound exposure, returning to baseline levels 20–40 min post-exposure. A second experiment examined the effects of long-term sound exposure on Atlantic cod spawning performance. Tanks were stocked with male and female cod and exposed daily to six noise events, each lasting one hour. The noise exposure had a total SPL of 133 dB re 1 µPa. Cod eggs were collected daily and measured for egg quality parameters as well as egg cortisol content. Total egg volume, floating fraction, egg diameter and egg weight did not appear to be negatively affected by sound exposure. However, fertilization rate and viable egg productivity were reduced by 40% and 50%, respectively, compared with the control group. Mean egg cortisol content was found to be 34% greater in the exposed group as compared to the control group. Elevated cortisol levels inhibit reproductive physiology for males and can result in a greater frequency of larval deformities for spawning females.

4.1.2.3 Effects of Sound on Fisheries

Handegard et al. (2013) examined different exposure metrics to explain the disturbance of seismic surveys on fish. They applied metrics to two experiments in Norwegian waters, during which fish distribution and fisheries were affected by airguns. Even though the disturbance for one experiment was greater, the other appeared to have the stronger SEL, based on a relatively complex propagation model. Handegard et al. (2013) recommended that simple sound propagation models should be avoided and that the use of sound energy metrics like SEL to interpret disturbance effects should be done with caution. In this case, the simplest model (exposures per area) best explained the disturbance effect.

Hovem et al. (2012) used a model to predict the effects of airgun sounds on fish populations. Modeled SELs were compared with empirical data and were then compared with startle response levels for cod. This work suggested that in the future, particular acoustic-biological models could be useful in designing and planning seismic surveys to minimize disturbance to fishing. Their preliminary analyses indicated that seismic surveys should occur at a distance of 5–10 km from fishing areas, in order to minimize potential effects on fishing.

In their introduction, Løkkeborg et al. (2012) described three studies in the 1990s that showed effects on fisheries. Results of a study off Norway in 2009 indicated that fishes reacted to airgun sound based on observed changes in catch rates during seismic shooting; gillnet catches increased during the seismic shooting, likely a result of increased movement of exposed fish, whereas longline catches decreased overall (Løkkeborg et al. 2012).

Streever et al. (2016) completed a Before-After/Control-Impact (BACI) study in the nearshore waters of Prudhoe Bay, Alaska in 2014 which compared fish catch rates during times with and without seismic activity. The air gun arrays used in the geophysical survey had sound pressure levels of 237 dB re 1µ$Pa_{0\text{-}p}$, 243 dB re 1µ$Pa_{p\text{-}p}$, and 218 dB re 1µPa_{rms}. Received SPL_{max} ranged from 107–144 dB re 1 µPa, and received SEL_{cum} ranged from 111–141 dB re 1µPa^2-s for air gun pulses measured by sound recorders at four fyke net locations. They determined that fyke nets closest to air gun activities showed decreases in catch per unit effort (CPUE) while nets further away from the air gun source showed increases in CPUE.

Bruce et al. (2018) studied the potential impacts of an industrial seismic survey in the Gippsland Basin, Australia, on catches in the Danish seine and gillnet fishing sectors for 15 fish species. Catch data were examined from three years before the seismic survey to six months after completion of the survey in an area 13,000 km^2. Overall, there was little evidence of consistent adverse impacts of the seismic survey on catch rates. Six of the 15 species were found to have increased catch rates.

Paxton et al. (2017) examined the effects of seismic sounds on the distribution and behavior of fish on a temperate reef during a seismic survey conducted in the Atlantic Ocean on the inner continental shelf of North Carolina. Hydrophones were set up near the seismic vessel path to measure SPLs, and a video camera was set up to observe fish abundances and behaviors. Received SPLs were estimated at ~202–230 dB re 1 µPa. Overall abundance of fish was lower when undergoing seismic activity as opposed to days when no seismic occurred. Only one fish was observed to exhibit a startle response to the airgun shots. The authors claim that although the study was based on limited data, it contributes evidence that normal fish use of reef ecosystems is reduced when they are impacted by seismic sounds.

Morris et al. (2018) conducted a two-year (2015–2016) BACI study examining the effects of 2-D seismic exploration on catch rates of snow crab (*Chionoecetes opilio*) along the eastern continental slope (Lilly Canyon and Carson Canyon) of the Grand Banks of Newfoundland, Canada. The airgun array used was operated from a commercial seismic exploration vessel; it had a total volume of 4880 in^3, horizontal zero-to-peak SPL of 251 dB re 1 µPa, and SEL of 229 dB re 1 µPa^2·s. The closest approach of the survey vessel to the treatment site in 2015 (year 1 of the study) was 1465 m during 5 days of seismic operations; in 2016 (year 2), the vessel passed within 100 m of the treatment site but the exposure lasted only 2 h. Overall, the findings indicated that the sound from the commercial seismic survey did not significantly reduce snow crab catch rates during days or weeks following exposure. Morris et al. (2018) attributed the natural temporal and spatial variations in the marine environment as a greater influence on observed differences in catch rates between control and experimental sites than exposure to seismic survey sounds.

4.1.2.4 Conclusions for Invertebrates, Fish, Fisheries, EFH, and HAPC

The newly available information does not affect the outcome of the effects assessment as presented in the PEIS. The PEIS concluded that there could be changes in behavior and other non-lethal, short-term, temporary impacts, and injurious or mortal impacts on a small number of individuals within a few meters of a high-energy acoustic source, but that there would be no significant impacts of NSF-funded marine seismic research on populations. The PEIS also concluded that seismic surveys could cause temporary, localized reduced fish catch to some species, but that effects on fisheries would not be significant.

Interactions between the proposed surveys and fishing operations in the study area are expected to be limited. Two possible conflicts in general are R/V *Langseth*'s streamer entangling with fishing gear and the temporary displacement of fishers from the survey area. Fishing activities could occur within the proposed survey area; a safe distance would need to be kept from R/V *Langseth* and the towed seismic equipment. Conflicts would be avoided through communication with the fishing community during the surveys. PSOs would also watch for any impacts the acoustic sources may have on fish during the survey.

Given the proposed activities, impacts would not be anticipated to be significant or likely to adversely affect (including ESA-listed) marine invertebrates, marine fish (Table 11), and their fisheries, including commercial, recreational, and subsistence fisheries. In decades of seismic surveys carried out by R/V *Langseth* and its predecessor, R/V *Ewing*, PSOs and other crew members have not observed any seismic sound-related fish or invertebrate injuries or mortality. During a similar survey conducted in the region in the past (Marine Geophysical Surveys by R/V *Marcus G. Langseth* in the Northeastern Pacific Ocean, June–July 2012), there were no observed significant impacts. In addition, no adverse effects on EFH or HAPC are expected given the short-term nature of the study (~40 days) and minimal bottom disturbance.

TABLE 11. ESA determination for DPSs or ESUs of fish species expected to be encountered during the proposed surveys in the Northeast Pacific Ocean during late spring/summer 2020.

	ESA Determination		
Species	**No Effect**	**May Affect – Not Likely to Adversely Affect**	**May Affect – Likely to Adversely Affect**
Bocaccio (Puget Sound/Georgia Basin DPS)		√	
Yelloweye Rockfish (Puget Sound/Georgia Basin DPS)		√	
Steelhead Trout (Various DPSs)		√	
Chinook Salmon (Various ESUs)		√	
Chum Salmon (Various ESUs)		√	
Coho Salmon (Various ESUs)		√	
Sockeye Salmon (Various ESUs)		√	
Pacific Eulachon (Southern DPS)		√	
Green Sturgeon (Southern DPS)		√	

4.1.3 Direct Effects on Seabirds and Their Significance

The underwater hearing of seabirds (including loons, scaups, gannets, and ducks) has recently been investigated, and the peak hearing sensitivity was found to be between 1500 and 3000 Hz (Crowell 2016). The best sensitivity of underwater hearing for great cormorants was found to be at 2 kHz, with a hearing threshold of 71 dB re 1 μPa_{rms} (Hansen et al. 2017). Great cormorants were also found to respond to underwater sounds and may have special adaptations for hearing underwater (Johansen et al. 2016; Hansen et al. 2017). African penguins (*Spheniscus demersus*) outfitted with GPS loggers showed strong avoidance of preferred foraging areas and had to forage further away and increase their foraging effort when a seismic survey was occurring within 100 km of the breeding colony (Pichegru et al. 2017). However, the birds resumed their normal behaviors when seismic operations concluded.

Potential effects of seismic sound and other aspects of seismic operations (collisions, entanglement, and ingestion) on seabirds are discussed in § 3.5.4 of the PEIS. The PEIS concluded that there could be transitory disturbance, but that there would be no significant impacts of NSF-funded marine seismic research on seabirds or their populations. The acoustic source would be powered or shut down in the event an ESA-listed seabird was observed diving or foraging within the designated EZ. Given the proposed activities, impacts would not be anticipated to be significant or likely to adversely affect ESA-listed seabirds (Table 12). In decades of seismic surveys carried out by R/V *Langseth* and its predecessor, the R/V *Ewing*, PSOs and other crew members have seen no seismic sound-related seabird injuries or mortality.

Table 12. ESA determination for seabird species expected to be encountered during the proposed surveys in the Northeast Pacific Ocean during late spring/summer 2020.

	ESA Determination		
Species	No Effect	May Affect – Not Likely to Adversely Affect	May Affect – Likely to Adversely Affect
Short-tailed Albatross		√	
Hawaiian Petrel		√	
Marbled Murrelet		√	

4.1.4 Indirect Effects on Marine Mammals, Sea Turtles, Seabirds and Fish and Their Significance

The proposed seismic operations would not result in any permanent impact on habitats used by marine mammals, sea turtles, seabirds, or fish or to the food sources they use. The main impact issue associated with the proposed activity would be temporarily elevated anthropogenic sound levels and the associated direct effects on these species, as discussed above.

During the proposed seismic surveys, only a small fraction of the available habitat would be ensonified at any given time. Disturbance to fish species and invertebrates would be short-term, and fish would return to their pre-disturbance behavior once the seismic activity ceased. Thus, the proposed surveys would have little impact on the abilities of marine mammals or sea turtles to feed in the area where seismic work is planned. No significant indirect impacts on marine mammals, sea turtles, seabirds, or fish would be expected.

4.1.5 Direct Effects on Cultural Resources and Their Significance

The coast and nearshore areas are of cultural importance to indigenous peoples for fishing, hunting, gathering, and ceremonial purposes. As noted above in Section 4.1.2.4, impacts would not be anticipated to be significant or likely to adversely affect marine invertebrates, marine fish, and their fisheries, including subsistence fisheries. Interactions between the proposed surveys and fishing operations in the study area are expected to be limited. Although fishing would not be precluded in the survey area, a safe distance would need to be kept from R/V *Langseth* and the towed seismic equipment. Conflicts would be avoided through communication with subsistence fishers during the surveys. Additionally, there are thousands of shipwrecks along the coast of the Pacific Northwest from Oregon to B.C. However, the proposed activities are of short duration (~40 days), and most of the shipwrecks (and dive sites) are located in shallower water outside of the project area. Conflicts would be avoided through communication with dive operators during the surveys. Furthermore, OBSs and OBNs would be deployed to avoid shipwrecks and would only cause minimal seafloor disturbances. Therefore, no adverse impacts to cultural resources are anticipated.

4.1.6 Cumulative Effects

Cumulative effects refer to the impacts on the environment that result from a combination of past, existing, and reasonably foreseeable projects and human activities. Cumulative effects can result from multiple causes, multiple effects, effects of activities in more than one locale, and recurring events. Human activities, when conducted separately or in combination with other activities, could affect marine animals in the study area. However, understanding cumulative effects is complex because of the animals' extensive habitat ranges, and the difficulty in monitoring populations and determining the level of impacts that may result from certain activities.

According to Nowacek et al. (2015), cumulative impacts have a high potential of disturbing marine mammals. Wright and Kyhn (2014) proposed practical management steps to limit cumulative impacts, including minimizing exposure by reducing exposure rates and levels. The results of the cumulative impacts analysis in the PEIS indicated that there would not be any significant cumulative effects to marine resources from the proposed NSF-funded marine seismic research, including the combined use of airguns with MBES, SBP, and acoustic pingers. However, the PEIS also stated that, "A more detailed, cruise-specific cumulative effects analysis would be conducted at the time of the preparation of the cruise-specific EAs, allowing for the identification of other potential activities in the areas of the proposed seismic surveys that may result in cumulative impacts to environmental resources." Here we focus on activities (e.g., research, vessel traffic, and fisheries) that could impact animals specifically in the proposed survey area. However, the combination of the proposed surveys with the existing operations in the region would be expected to produce only a negligible increase in overall disturbance effects on marine mammals.

4.1.6.1 Past and Future Research Activities

Scripps Institution of Oceanography (SIO) conducted low-energy seismic surveys for ~4–7 days off the coast of Oregon/Washington during September 2007, July 2009, and September 2017. During July 2008, UTIG conducted a low-energy seismic survey for ~6 days off the coast of Oregon. In June–August 2004 and August–October 2005, the riserless drilling vessel *JOIDES Resolution* conducted coring off OR. Seismic surveys using a 36-airgun array were conducted in the EVH MPA, to the north of the proposed survey area, by R/V *Langseth* during summer 2009, and off the coast of Oregon/Washington during June–July 2012.

NSF funded the Cascadia Initiative (CI), an ambitious onshore/offshore seismic and geodetic experiment that took advantage of an amphibious array to study questions ranging from megathrust earthquakes, to volcanic arc structure, to the formation, deformation, and hydration of the Juan De Fuca and Gorda Plates (Toomey et al. 2014). CI involved a plate-scale seismic experiment that encompassed components of the Cascadia subduction zone as well as the underthrusting Juan de Fuca Plate. The onshore seismic component of the amphibious array consisted of the EarthScope USArray Transportable Array and the offshore seismic component consisted of OBSs. Over four field seasons from 2011–2014, oceanographic expeditions and OBSs deployments and recoveries were conducted in the region to collect data in support of the research objectives. As noted previously, an onshore research effort is also currently under consideration for NSF funding which would complement the proposed R/V *Langseth* activities. The proposed onshore component would vastly expand upon the marine-based dataset, providing a more complete geophysical dataset for the Cascadia region.

During May–June 2018, SIO conducted vibracoring and CHIRP profiles off the Oregon coast, and retrieved seafloor receivers collecting magnetotelluric and passive seismic data offshore OR utilizing R/V *Roger Revelle*. SIO deployed geodetic transponders from R/V *Roger Revelle* along the Cascadia Subduction Zone off Oregon during June 2018, to be retrieved during spring/summer 2020. During June–August 2018, SIO conducted a cabled array survey offshore Oregon using the remote operated vehicle (ROV) *Jason* and R/V *Roger Revelle*. As a component of this survey, a shallow profiler was installed and an ROV was deployed from R/V *Thompson* to turn instruments and/or moorings during July/August 2018. R/V *Sally Ride* was used by SIO to conduct biological sampling to assess mesozooplankton food webs off Oregon and northern California during July 2018, and deploy coastal surface moorings off Oregon and Washington during September–October 2018. SIO utilized two vessels to conduct sampling for a primary production study in the waters off the Northwest Pacific during August–September 2018, and collected atmospheric, water column and surficial sediment samples along 152ºW from Alaska to Tahiti using R/V *Roger Revelle* during September–October and October–November 2018.

The U.S. portion of the proposed survey area is the site of numerous other recent studies including of fluid seeps along the margin, and recent (2018 and 2019) as well as future high-resolution seismic studies by the USGS as part of their multi-year hazard assessment studies for the Pacific Northwest. There are also ongoing studies using the Ocean Observatories Initiative (OOI) regional cable underwater volcanic observatory, including nodes at Axial Seamount, Juan de Fuca Plate, Hydrate Ridge, and on the Oregon shelf. In addition to having an active volcano which erupted in 1998, 2011, and 2015, Axial Seamount has several hydrothermal fields (OOI 2018). Numerous geophysical, chemical, and biological sensors, as well as cameras, are deployed there, which provide real-time information on seismic events via a cabled array (OOI 2018).

Drilling as a component of the Deep Sea Drilling Project (DSDP) and Ocean Drilling Program (ODP) was undertaken during 1971, 1992, and 2002 off Oregon (IODP 2019). Drilling was also conducted off B.C. and Washington during several ODP legs from 1991–1996, and in 2010, as a component of the IODP (IODP 2019). In addition, the IODP is proposing to drill at locations to be sited on the proposed seismic lines (IODP 2019).

In addition, Ocean Networks Canada hosts NEPTUNE (North East Pacific Time-series Underwater Networked Experiments), an underwater fiber-optic cabled observatory network in the waters of B.C. This network consists of a 840-km loop of fibre optic cable with five nodes, located at Folger Passage (near Barkley Sound), Barkley Canyon, Clayoquot Sound, Cascadia Basin, and Endeavour Ridge (Ocean Networks Canada 2019a). Instrumentation at each node includes acoustic doppler current profilers, current meters, hydrophones, rotary sonars, bottom pressure recorders, video cameras, temperature probes, oxygen sensors, and LED lights (Ocean Networks Canada 2019b).

DFO and the Canadian Groundfish Research and Conservation Society (CGRCS) conduct regular surveys in B.C. to provide fishery independent abundance indices of all demersal fish species available to bottom trawling along the B.C. coast (DFO 2018d). A large-scale survey of marine megafauna off the coast of B.C. was undertaken by DFO during July to September 2018, as well as expeditions to offshore seamounts during July 2018 and July 2019 (DFO 2019j). At the Endeavour MPA, research projects, mainly by foreign vessels (4–7 per year) and Canadian Coast Guard (1–2 per year) vessels are undertaken (Conley 2006). The SWFSC conducts regular marine mammal surveys off the U.S. coast, including off Oregon/Washington. Other research activities may have been conducted in the past or may be conducted in the study area in the future; however, we are not aware of any research activities, in addition to the OOI, that are planned to occur in the proposed project area during late spring/summer 2020.

4.1.6.2 Naval Activities

In summer 2012, the U.S. Navy conducted a test sponsored by the Naval Sea Systems Command, who is responsible for the research, development, and construction of Navy systems. They tested a towed array with an active acoustic source and a passive receiver. The primary test took place during both a north and south ship transit between San Diego, CA, and Puget Sound, WA, in the Pacific Northwest, when the ship was >12 nmi (~22 km) from the coast of the U.S. The Rose Festival Fleet Week occurs annually during October, for which visiting U.S. Navy ships (e.g., destroyers and mine countermeasure ships) and fleet-related elements (e.g., submarines) transit to Portland, OR (PRFF 2019). Seafair annually hosts visiting vessels from the U.S. Navy, U.S. Coast Guard, and Royal Canadian Navy during Fleet Week and the Boeing Maritime Celebration during July/August on the Seattle, WA, waterfront (Seafair 2018). Navy vessels may transit within or near the proposed survey area during any given year while travelling to west coast Fleet Week ports, depending on a ship's originating location. Other Navy activities may have been or may be conducted in this region in the future as this area is included in the U.S. Navy's Northwest

Training and Testing Area, which extends up to 250 nmi offshore; however, we are not aware of any specific activities that are planned to occur in the proposed survey area during late spring/summer 2020.

4.1.6.3 Vessel Traffic

Several major ports are located on the northwestern coast of the U.S., including Seattle, Tacoma, and Portland, as well as Vancouver, B.C., and major shipping lanes originate there. Vessel traffic in the proposed survey area would consist mainly of commercial fishing and cargo vessels. Based on the data available through the Automate Mutual-Assistance Vessel Rescue (AMVER) system managed by the U.S. Coast Guard (USCG), most of the shipping lanes that intersect the survey area had 4 or fewer vessels travelling along them on a monthly basis during June–July 2019 (USCG 2019). At least 150 vessels occurred within the proposed survey area when live vessel traffic information (MarineTraffic 2019) was accessed on 1 October 2019; vessels mainly consisted of fishing vessels, but also included pleasure crafts, cruise ships, cargo vessels, tankers, and tugs. The total transit time by R/V *Langseth* (~40 days) would be minimal relative to the number of other vessels operating in the proposed survey area during late spring/summer 2020. Thus, the combination of R/V *Langseth*'s operations with the existing shipping operations is expected to produce only a negligible increase in overall ship disturbance effects on marine mammals.

4.1.6.4 Fisheries Interactions

The commercial fisheries in the region are described in § III. The primary contributions of fishing to potential cumulative impacts on marine mammals and sea turtles involve direct and indirect removal of prey items, sound produced during fishing activities, and potential entanglement (Reeves et al. 2003).

***Marine mammals*.—**According to Lewison et al. (2014), the northwest coast of the U.S. has relatively high bycatch rates for marine mammals. Between 1990 and 1996, an average of 456 cetaceans and 160 pinnipeds were killed or seriously injured per year in the California/Oregon driftnet fishery. As a result of regulatory action to reduce cetacean bycatch in 1997, bycatch was reduced to a yearly average of 105 cetaceans (8 odontocete species and fin, minke, and gray whales) and 77 pinnipeds (California sea lion and northern elephant seal) during the 1997–2006 period (Moore et al. 2009). Before 2000, high bycatch of harbor porpoises, southern sea otters, and pinnipeds (California sea lion, harbor seals, and elephant seals) occurred in the set gillnet fishery for California halibut. The bycatch likely led to the decline of the harbor porpoise. Restrictions applied between 2000 and 2002 effectively closed most of the fishery (Moore et al. 2009). In 2009, based on observed bycatch, the estimated total bycatch in the California/Oregon large-mesh drift gillnet fishery for thresher sharks and swordfish was 7 short-beaked common dolphins, 15 Pacific white-sided dolphins, and 37 California sea lions (Carretta and Enriquez 2010).

Three fisheries had marine mammal takes in the non-Pacific hake groundfish fisheries from 2002–2005 (NMFS 2008c). An estimated 250 marine mammals were killed in the limited-entry bottom trawl fishery; bycatch estimates included 227.6 California sea lions, 11.5 Steller sea lions, 7.5 Pacific white-sided dolphins, and 3.1 harbor porpoises (NMFS 2008c). Bycatch in the limited-entry sablefish fishery was estimated at 29 California sea lions. Eight California sea lions were also killed in the non-sablefish endorsed fishery during the same period (NMFS 2008c). A number of pinnipeds were also caught in the west coast Pacific hake fishery; estimated bycatch for 2002–2006 included 2.5 harbor seals, 8.3 Steller sea lions, 6.9 California sea lions, and 3.4 elephant seals (NMFS 2008c). During 2007–2009, bycatch totals for the U.S. west coast groundfish fishery included 19 California sea lions, 12 Steller sea lions, 12 northern elephant seals, 5 harbor seals, 1 Risso's dolphin, 1 bottlenose dolphin, and 1 sperm whale (Jannot et al. 2011). The extent of bycatch is unknown in some fisheries that receive little or no observer coverage. In 2005, ~87 short-beaked common dolphins were killed in squid purse seines; an estimated 5196 other marine mammals were caught but released alive across all other observed California purse seine fisheries (Carretta and Enriquez 2006). In 2005, the bycatch for the Northwest Region (including Oregon) for the sablefish-endorsed fixed gear, groundfish bottom trawl, and mid-water hake trawl fisheries was estimated at 37 animals, including 33.7 California sea lions, 2.4 Steller sea lions, and 1.2 harbor seals (NMFS 2011b). From 2010–2014, Carretta et al. (2016) reported 85 large whales and 116 small cetaceans entangled in fishing gear for the U.S. west coast; there were 180 cases of pinniped injuries and mortalities in the hook and line fishery.

Canada's Pacific groundfish bottom trawl fishery operates off the B.C. coast; during 1996–2006 the following marine mammals were caught and discarded: Steller sea lions (50 incidents), northern fur seals (1 incident), California sea lions (3) , harbor seals (16), northern elephant seal (1), eared seals and walruses (6), other pinnipeds (32), Pacific white-sided dolphins (5), common dolphins (1), and unidentified porpoises and dolphins (8) (Driscoll et al. 2009). Entanglement in fishing gear, and fishery-caused reduction in prey abundance, quality, and availability have been identified as threats to blue, fin, and sei whales (Gregr et al. 2006) and Pacific harbor porpoise (COSEWIC 2016a). Between 1987 and 2008, there were 40 reports of humpbacks entangled in fishing gear in B.C.; humpbacks were entangled in gear from gillnet fisheries (salmon, herring roe), trap fisheries (crab, prawn, sablefish), groundfish long-line fisheries, and seine fisheries (Ford et al. 2009). Inshore fisheries in B.C. are also known to by-catch Pacific white-sided dolphins, harbor porpoises, and Dall's porpoises (Stacey et al. 1997; Williams et al. 2008).

Sea turtles.—According to Lewison et al. (2014) and Roe et al. (2014), the northwest coast of the U.S. has relatively low bycatch rates for sea turtles. Finkbeiner et al. (2011) reported that between 1990 and 2007, the annual mean bycatch for sea turtles in the California/Oregon driftnet fishery was 30 individuals before regulations came into effect, and <10 after regulations were put in place. Moore et al. (2009) reported that an average of 14 leatherbacks were killed annually in the California/Oregon drift gillnet fishery before regulations were implemented to reduce bycatch in 1997 and 2001. There was no bycatch reported for 2005 (NMFS 2011b). One sea turtle (a leatherback in 2008) was killed or injured in the west coast groundfish fishery in 2002–2009 off California (Jannot et al. 2011). Carretta and Enriquez (2010) reported one leatherback caught and released alive in 2009.

***Seabirds*.—**According to Lewison et al. (2014), the northwest coast of the U.S. has relatively low bycatch rates for seabirds. Net fisheries for salmon in Puget Sound have killed thousands of birds annually, mostly murres and auklets (Moore et al. 2009). Annual seabird bycatch in the set net fishery for California halibut during 1990–2001 ranged from 308–3259; most bycatch consisted of common murres, loons, grebes, and cormorants (Moore et al. 2009). Closure of the central California fishery in depths <110 m in 2002 reduced bycatch to an estimated 61 seabirds in 2003 (Moore et al. 2009). The estimated take of seabirds in the non-Pacific hake fisheries during 2002–2005 totaled 575, half of which were common murres. Other species caught included Leach's storm petrel, Brandt's cormorant, black-footed albatross, western gull, and brown pelican (NMFS 2008c). Jannot et al. (2011) reported takes of 11 seabird species in the west coast groundfish fishery during 2002–2009, including marbled murrelets and short-tailed albatross; in 2009, northern fulmars made up most of the bycatch. The estimated take of seabirds in the Pacific hake fisheries during the same period was 50 birds, including seven black-footed albatrosses, five common murres, 23 northern fulmars, two sooty shearwaters, and 13 unidentified seabirds (NMFS 2008c). In 2005, the bycatch for the Northwest Region (including Oregon) was estimated at 106 birds for the west coast groundfish limited entry non-trawl, groundfish bottom trawl, and mid-water hake trawl fisheries, including 58.8 black-footed albatross, 35.6 brown pelicans, 3.8 gulls, 2 sooty shearwaters, 2 northern fulmars, 2 common murres, and 2 unidentified seabirds (NMFS 2011b). Smith and Morgan (2005) estimated that 12,085 seabirds were bycaught annually in the commercial gillnet fishery in B.C. between 1995 and 2001, of which 95% succumbed.

4.1.6.5 Tourism

Various companies offer whale and dolphin watching off the coast of Oregon and Washington. Whale watching can occur in this area year-round (Oregon Coast Visitors Association 2019). The main focus of the whale watch industry is the southward gray whale migration from mid-December through January and their northbound migration from March–June (Oregon Coast Visitors Association 2019). However, some whales are resident off Oregon in the summer and can be seen there from June through November (Oregon Coast Visitors Association 2019). There are at least 11 whale watching boat charters along the coast of Oregon, including at Newport and Depoe Bay; whale watching flights are also carried out by at least six companies (Oregon Coast Visitors Association 2019). Whale watching also takes place in Washington State, but most of the excursions occur near the San Juan Islands and inshore of the proposed project area. Whalewatch operations also occur in B.C. waters, including in the Strait of Juan de Fuca and off the west coast of Vancouver Island, from ports such as Port Renfrew, Tofino, and Ucluelet.

4.1.6.6 Whaling and Sealing

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 2019m). NOAA is currently considering a plan to cull sea lions on the Columbia River in order to benefit salmonid populations; under this plan, federal employees as well as indigenous tribes would remove sea lions (NOAA 2019n). In Canada, various First Nations harvest seals and sea lions, and some indigenous groups are advocating pinniped culls to benefit salmonid stocks.

4.1.7 Unavoidable Impacts

Unavoidable impacts to the species of marine mammals and turtles occurring in the proposed survey area would be limited to short-term, localized changes in behavior of individuals. For marine mammals, some of the changes in behavior may be considered to fall within the MMPA definition of "Level B Harassment" (behavioral disturbance; no serious injury or mortality). TTS, if it occurs, would be limited to a few individuals, is a temporary phenomenon that does not involve injury, and is unlikely to have long term consequences for the few individuals involved. No long-term or significant impacts would be expected on any of these individual marine mammals or turtles, or on the populations to which they belong; NMFS, however, requires NSF to request Level A takes. Effects on recruitment or survival would be expected to be (at most) negligible.

4.1.8 Coordination with Other Agencies and Processes

This Draft EA has been prepared by LGL on behalf of L-DEO and NSF pursuant to NEPA and Executive Order 12114. Potential impacts to marine mammals, endangered species, and critical habitat have also been assessed in the document; therefore, it will be used to support the ESA Section 7 consultation process with NMFS and USFWS and other regulatory processes. Due to their involvement with the Proposed Action, the USGS has agreed to be a Cooperating Agency. This document will also be used as supporting documentation for an IHA application submitted by L-DEO to NMFS, under the U.S. MMPA, for "taking by harassment" (disturbance) of small numbers of marine mammals, for the proposed seismic surveys. L-DEO and NSF will coordinate with applicable Canadian (e.g., DFO) and U.S. agencies (e.g., NMFS), and will comply with their requirements.

4.2 No Action Alternative

An alternative to conducting the proposed activity is the "No Action" Alternative, i.e., do not issue an IHA and do not conduct the operations. If the research were not conducted, the "No Action" alternative would result in no disturbance to marine mammals or sea turtles attributable to the proposed activity; however, valuable data about the marine environment would be lost. Research that would contribute to our understanding of the Cascadia Subduction Zone, providing new constraints on earthquake and tsunami potential in this heavily populated region of the Pacific Northwest. would not be collected. The No Action Alternative would not meet the purpose and need for the proposed activity.

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List of Appendices

APPENDIX A: DETERMINATION OF MITIGATION ZONES

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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)[3] 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.

[3] SEL (measured in dB re 1 µPa^2 · 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.

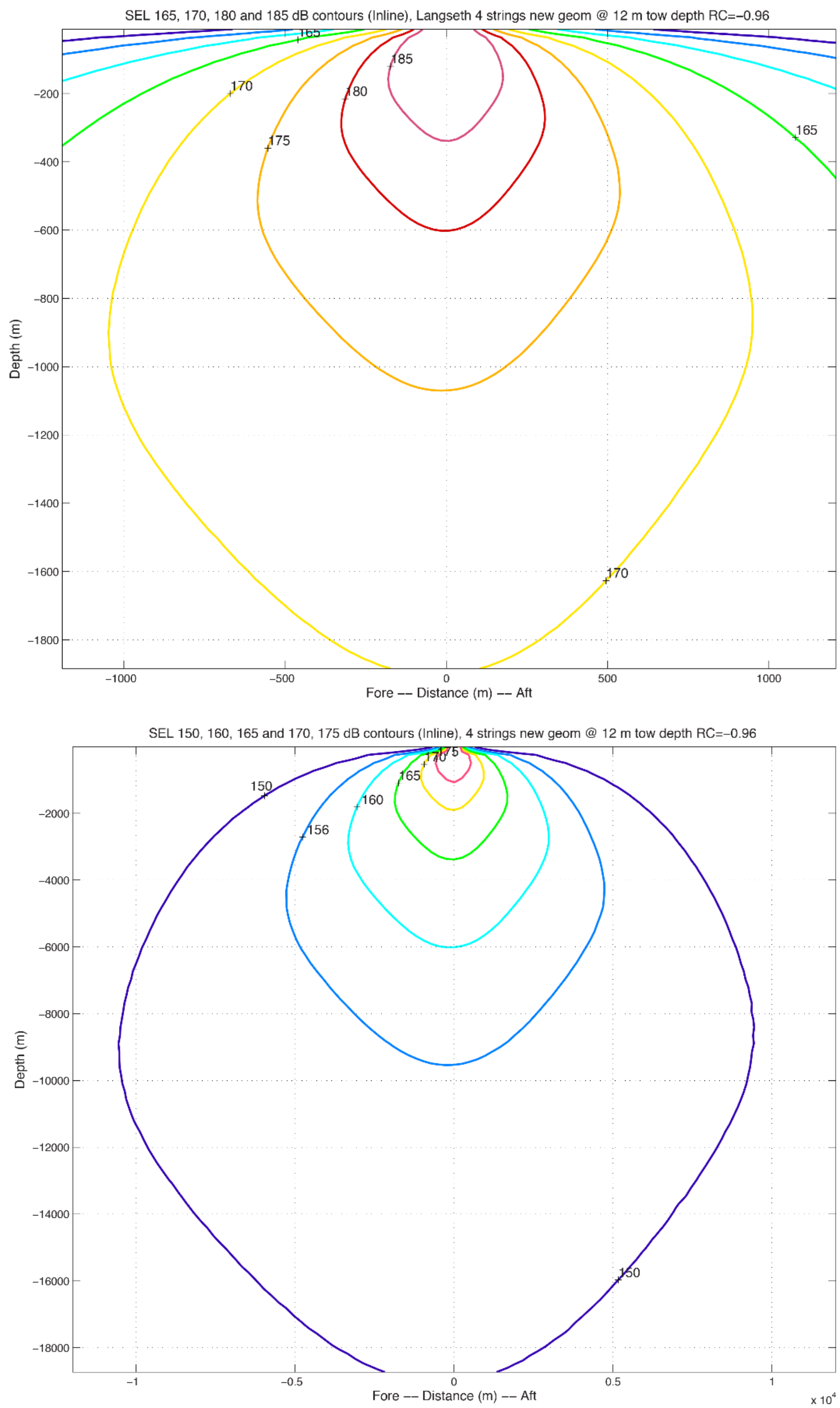
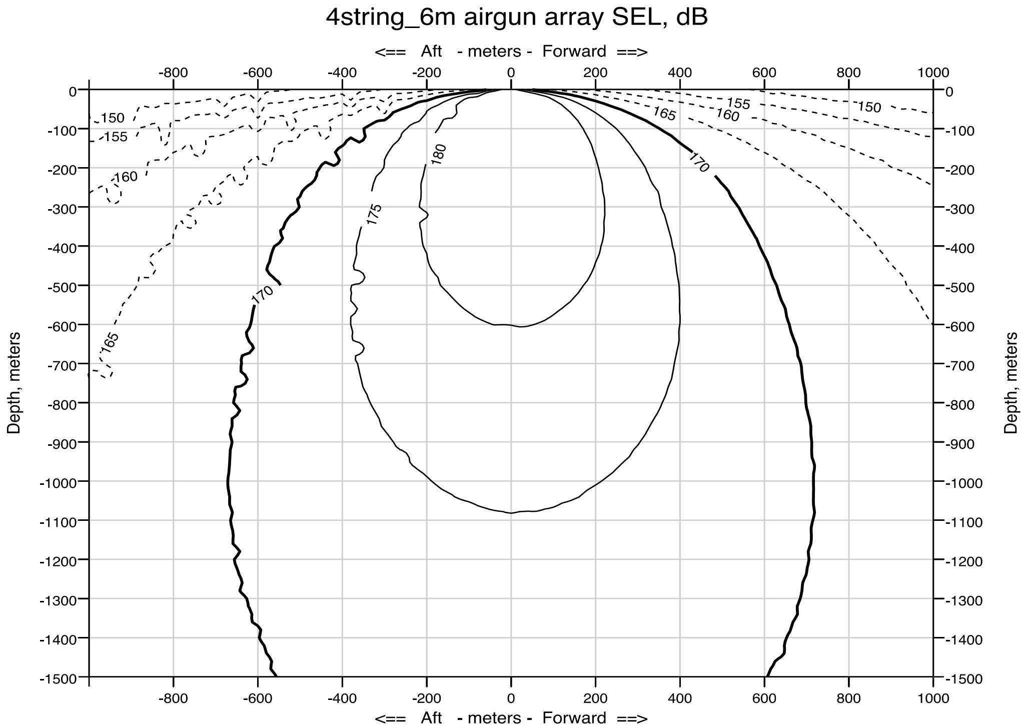


FIGURE A-1. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array at a 12-m tow depth planned for use during the proposed surveys in the Northeast Pacific Ocean. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB SEL isopleth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



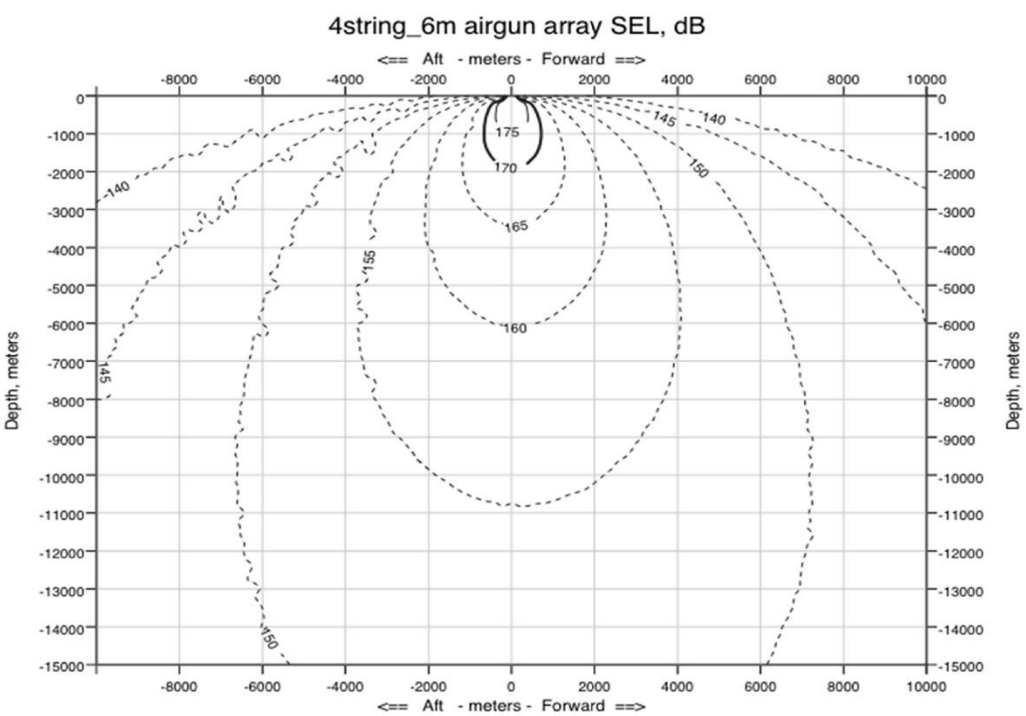


Figure A-2. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array at a 6-m tow depth used during the GoM calibration survey. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150 dB SEL isopleth is a proxy for the 160-dB rms isopleth.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

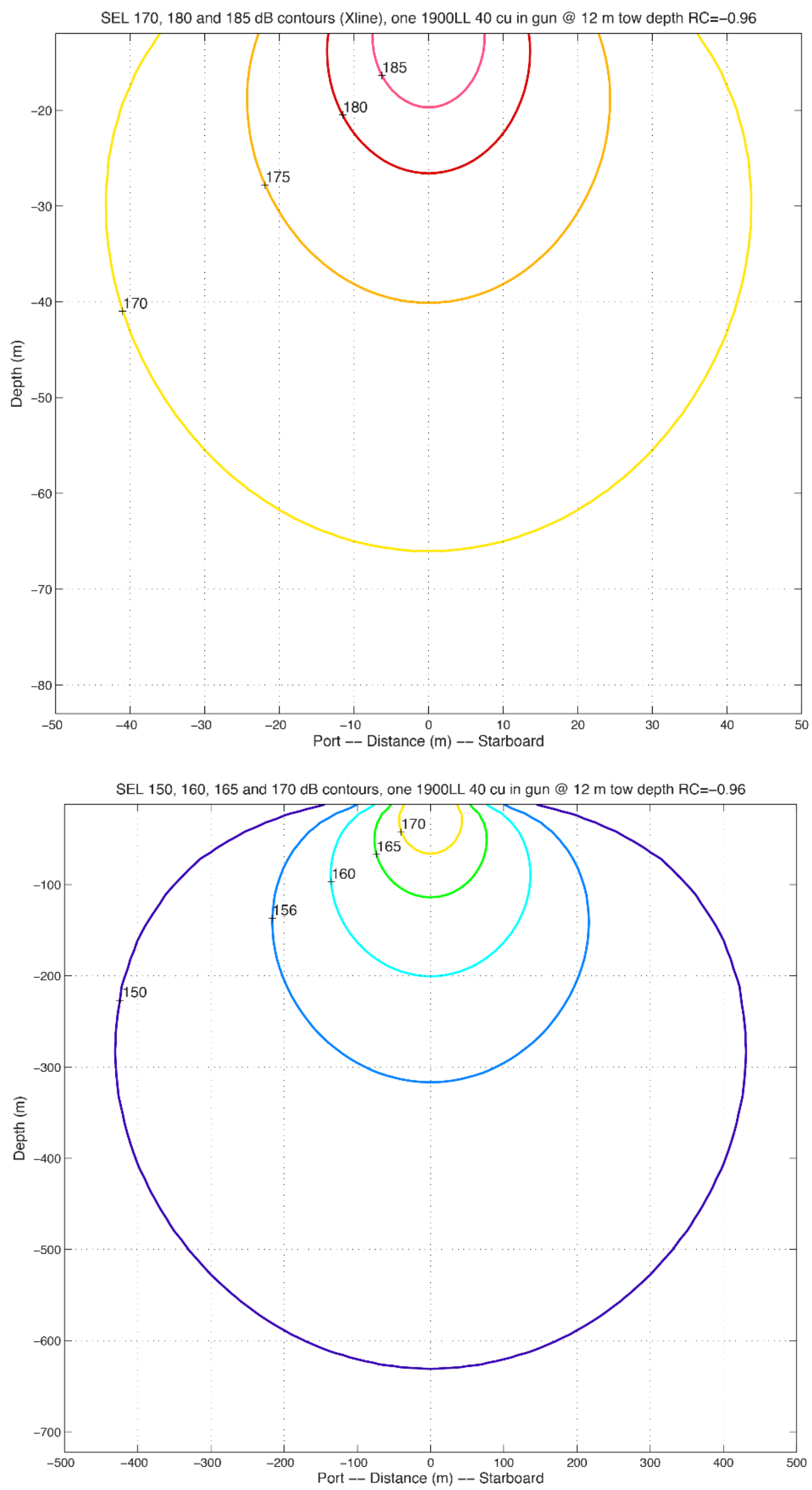


FIGURE A-3. Modeled deep-water received SELs from a single 40-in^3 airgun towed at a 12-m depth, which is planned for use as a mitigation airgun during the proposed surveys in the Northeast Pacific Ocean. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB 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[4] have confirmed that the L-DEO model generated conservative EZs, resulting in significantly larger EZs than required by National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS).

In July 2016, NMFS released new technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (NMFS 2016, 2018). The new guidance established new thresholds for permanent threshold shift (PTS) onset or Level A Harassment (injury), for marine mammal species. The new noise exposure criteria for marine mammals account for the newly-available scientific data on temporary threshold shifts (TTS), the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors, as summarized by Finneran (2016). For impulsive sources, onset of PTS was assumed to be 15 dB or 6 dB higher when considering SEL_{cum} and SPL_{flat}, respectively. The new guidance incorporates marine mammal auditory weighting functions (Fig. A-4) and dual metrics of cumulative sound exposure level (SEL_{cum} over 24 hours) and peak sound pressure levels (SPL_{flat}). Different thresholds are provided for the various hearing groups, including low-frequency (LF) cetaceans (e.g., baleen whales), mid-frequency (MF) cetaceans (e.g., most delphinids), high-frequency (HF) cetaceans (e.g., porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW). As required by NMFS (2016, 2018), the largest distance of the dual criteria (SEL_{cum} or Peak SPL_{flat}) was used to calculate takes and Level A threshold distances. The dual criteria for sea turtles (USN 2017) were also used here. The new NMFS guidance did not alter the current threshold, 160 dB re $1\mu Pa_{rms}$, 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

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

TABLE A-13. 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.

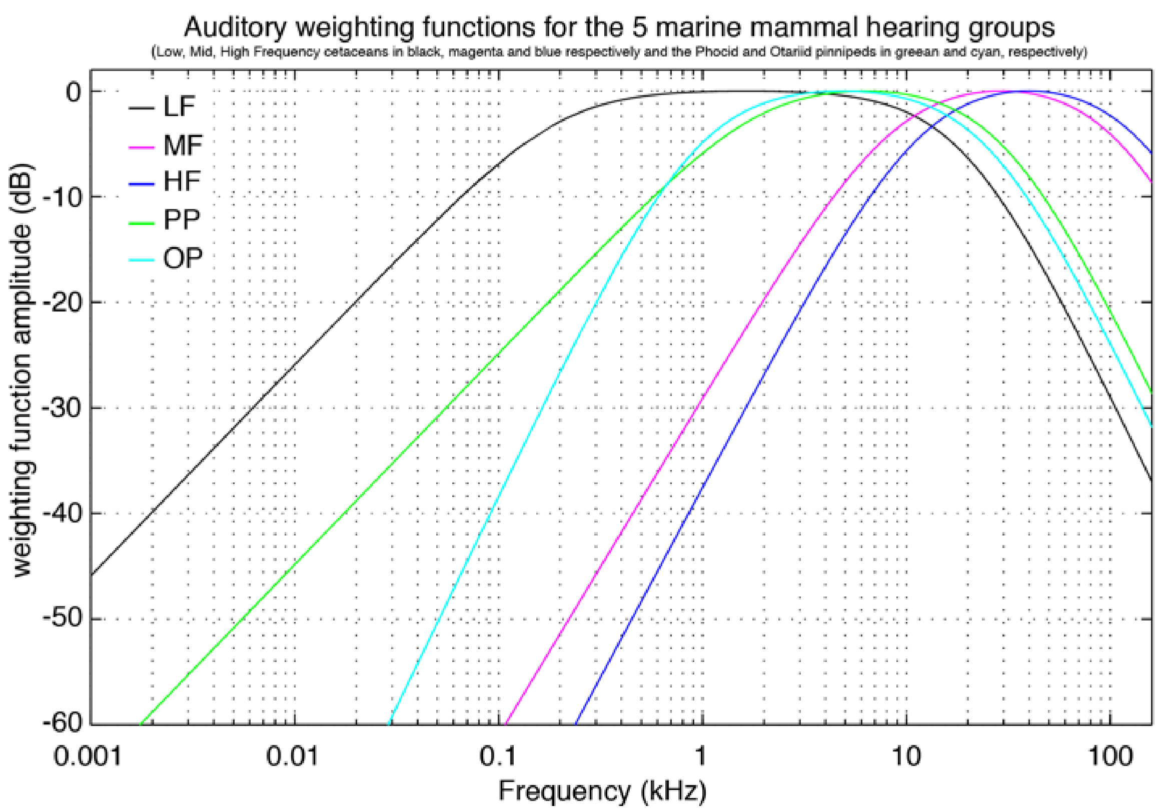


FIGURE A-4. Auditory weighting functions for five marine mammal hearing groups from the NMFS Technical Guidance Spreadsheet.

(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. A propagation of 20 $\log_{10}$ (Radial distance) is used to estimate the modified farfield SEL.

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	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 R. 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).

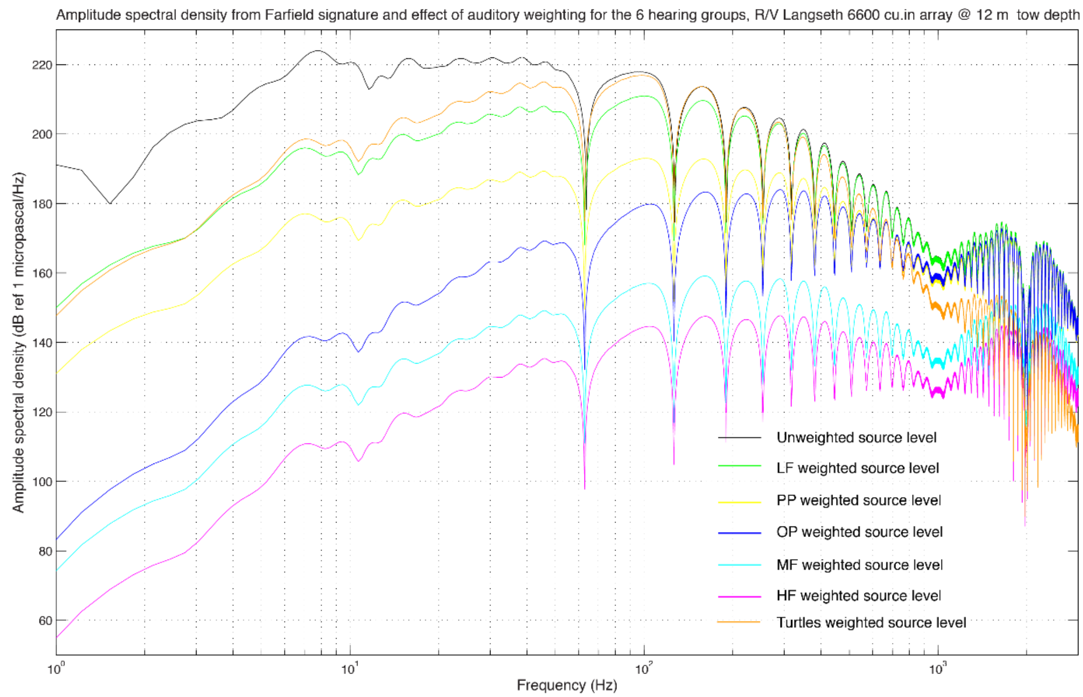


FIGURE A-5. Modeled amplitude spectral density of the 36-airgun array farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), Otariid Pinnipeds (OP), and Sea Turtles. Modeled spectral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

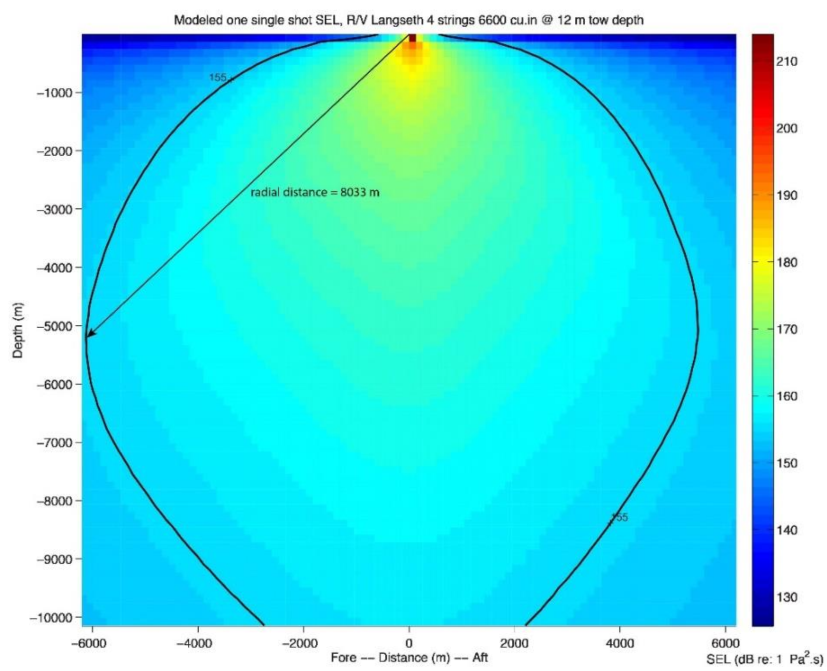


FIGURE A-6. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 155-dB SEL isopleth (8033 m). Radial distance allows us to determine the modified farfield SEL using a propagation of $20\log_{10}$(radial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

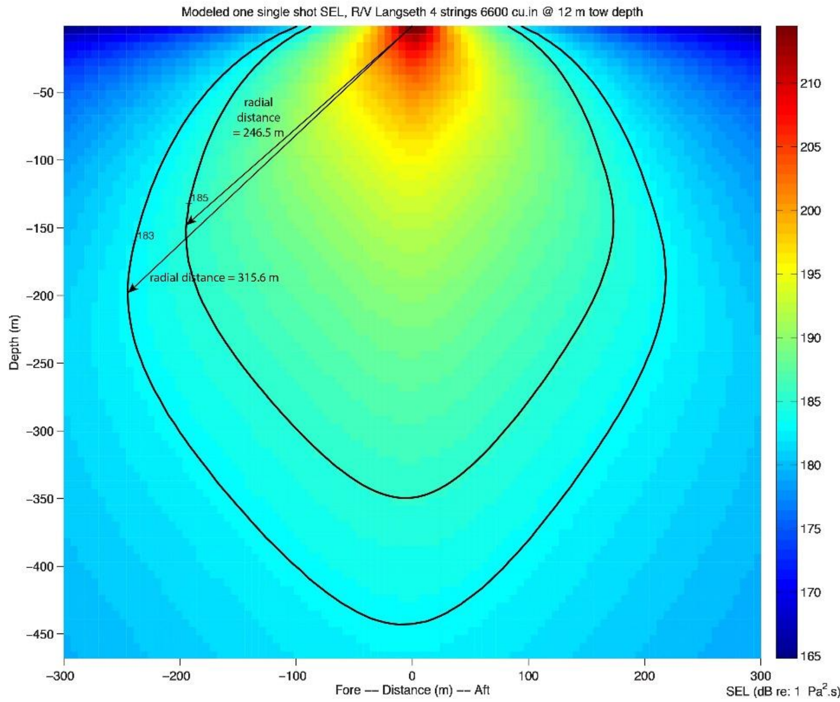


FIGURE A-7. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 183–185-dB SEL isopleths (315.6 and 246.5 m, respectively).

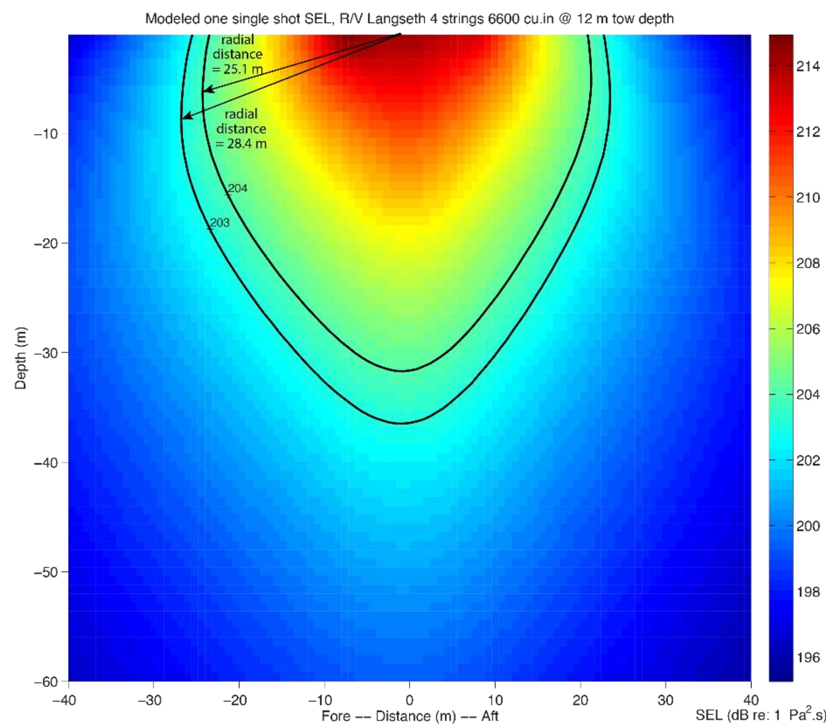


FIGURE A-8. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 203-dB and 204-dB SEL isopleth (28.4 m and 25.1 m, respectively).

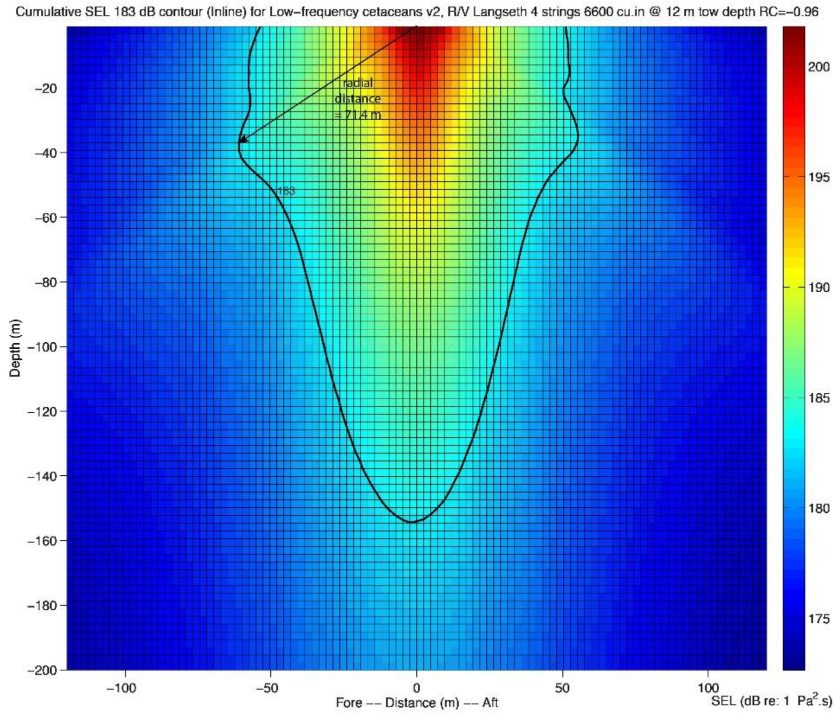


FIGURE A-9. Modeled received sound exposure levels (SELs) from the 36-airgun array at a 12-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one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

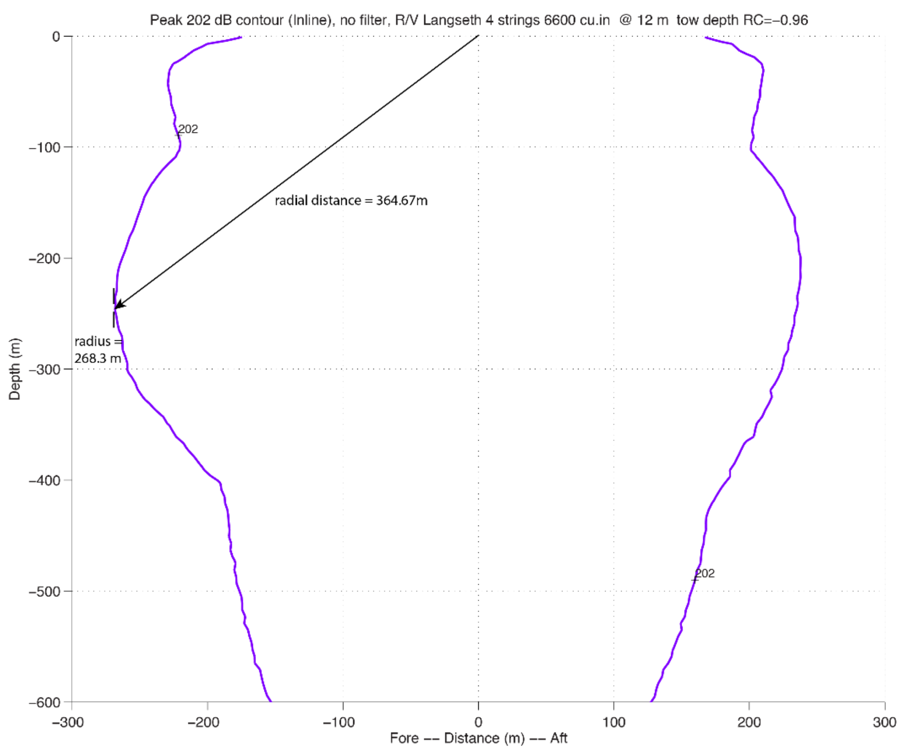


FIGURE A-10. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distance to the 202-dB Peak isopleth.

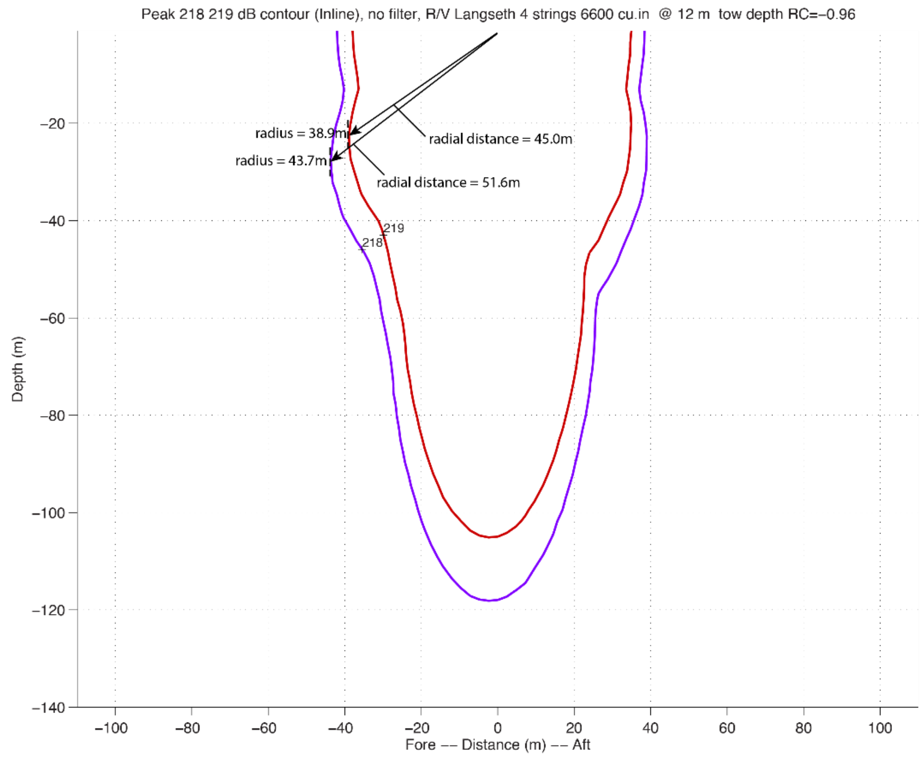


FIGURE A-11. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distances to the 218- and 219-dB Peak isopleths.

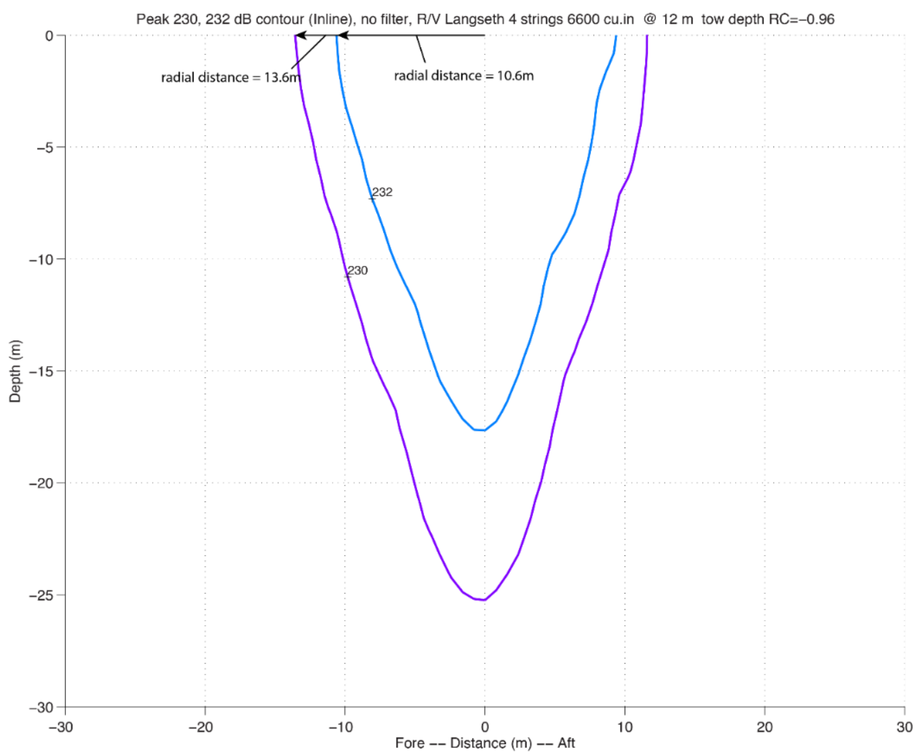


FIGURE A-12. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distances to the 230- and 232-dB Peak isopleths.

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	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. A propagation of 20 $\log_{10}$ (Radial distance) is used to estimate the modified farfield SEL.

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

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

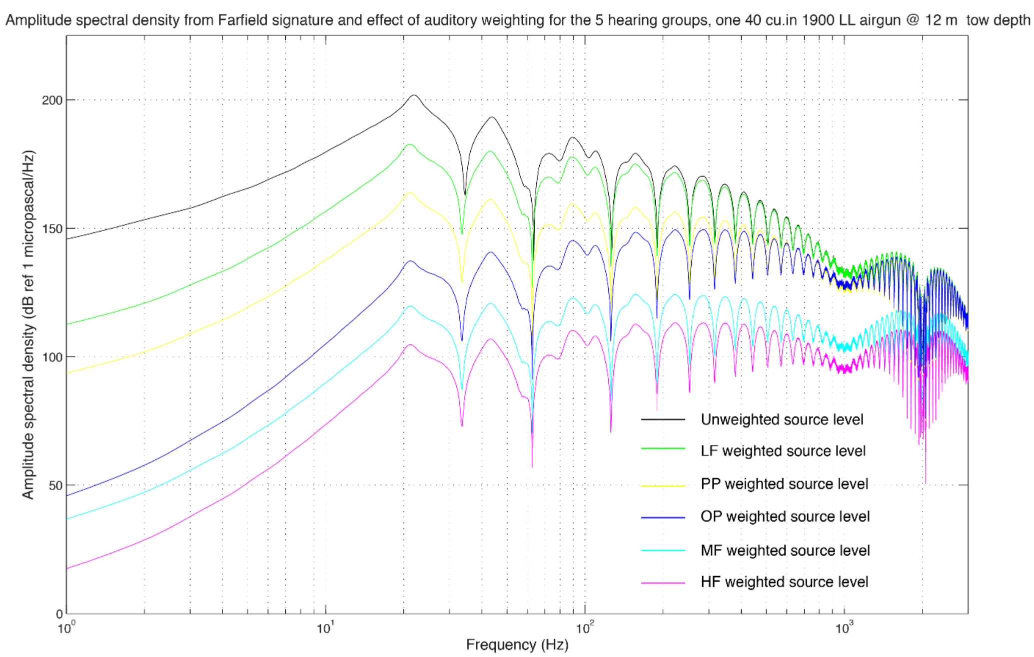


FIGURE A-13. Modeled amplitude spectral density of the 40-in^3 airgun farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral levels are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

TABLE A-7. Results for single shot SEL source level modeling for the single 40-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).

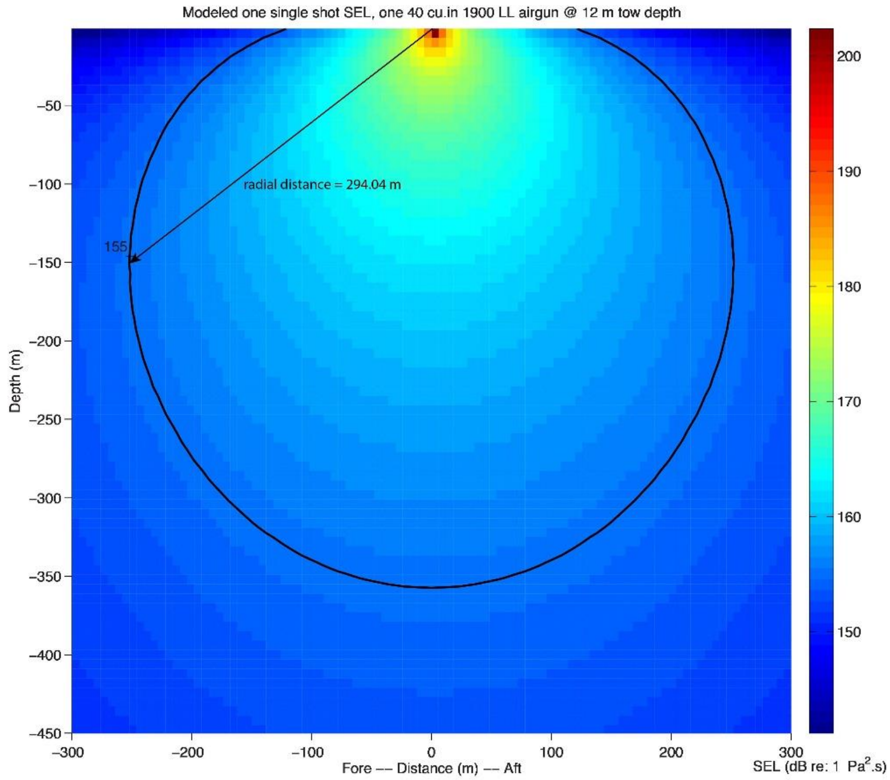


FIGURE A-14. Modeled received sound levels (SELs) in deep water from one 40-in^3 airgun at a 12-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (294.04 m).

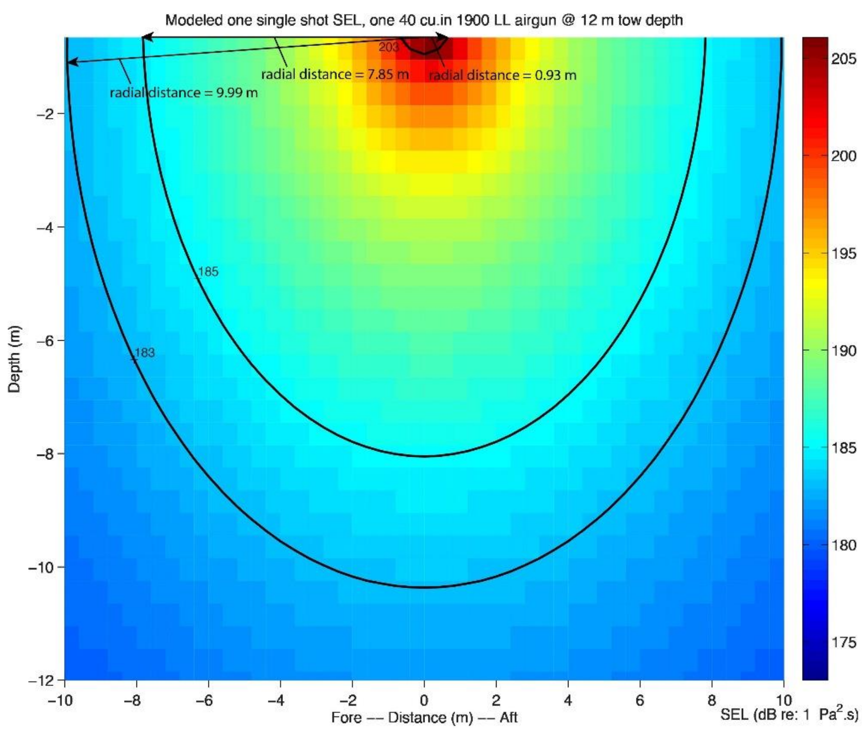


FIGURE A-15. Modeled received sound levels (SELs) in deep water from one 40-in^3 airgun at a 12-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183–185 dB and 203 dB SEL isopleths.

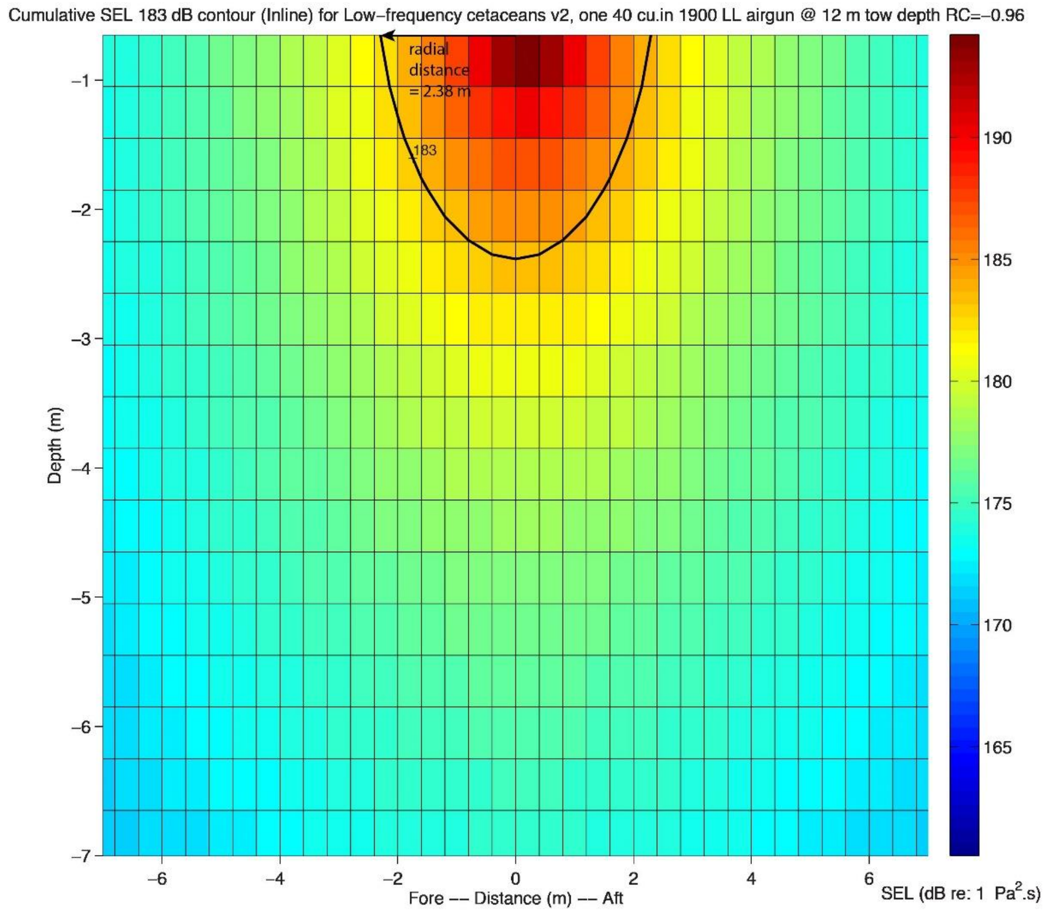


FIGURE A-16. Modeled received sound exposure levels (SELs) from one 40-in³ mitigation at a 12-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for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

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

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
Peak Threshold	**219**	**230**	**202**	**218**	**232**
Radial Distance to Threshold (m)	1.76	N.A.	12.47	1.98	N.A.
Modified Farfield Peak	223.93	224.09	223.92	223.95	223.95
PTS Peak Isopleth (Radius) to Threshold (m)	1.76	N.A.	12.5	1.98	N.A.

N.A. means not applicable or not available.

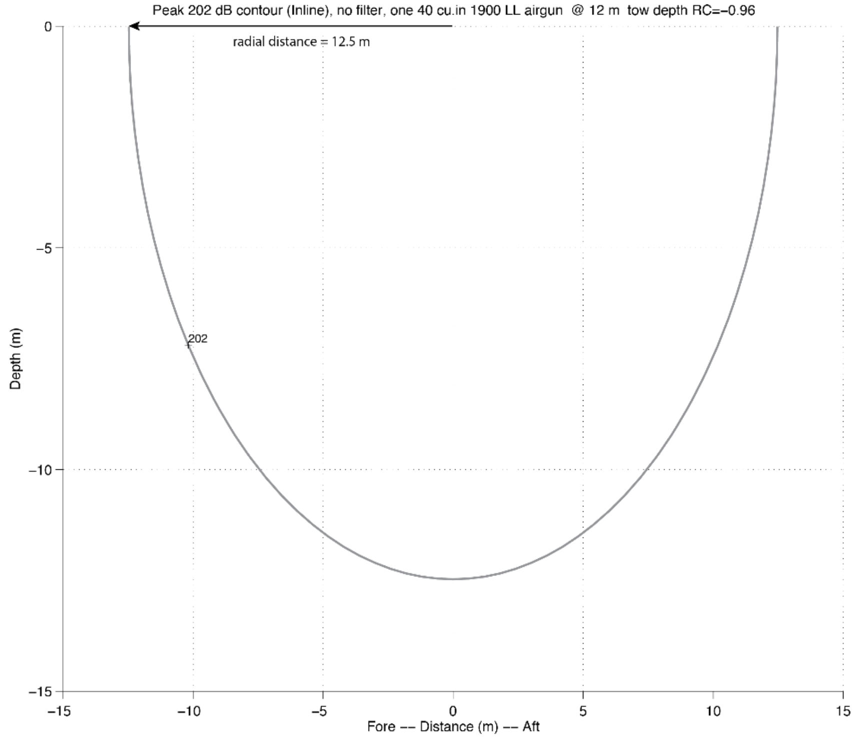


FIGURE A-17. Modeled deep-water received Peak SPL from one 40 in^3 airgun at a 12-m tow depth. The plot provides the radial distance from the source geometrical center to the 202-dB Peak isopleth.

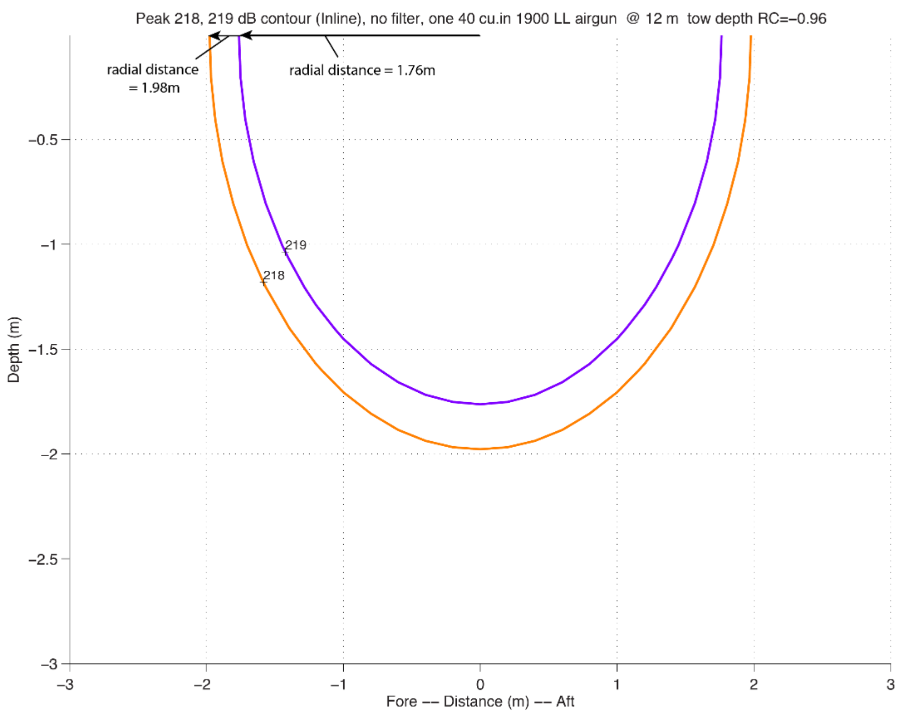


FIGURE A-18. Modeled deep-water received Peak SPL from one 40 in^3 airgun at a 12-m tow depth. The plot provides the radial distances from the source geometrical center to the 218 and 219-dB Peak isopleths.

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APPENDIX B: METHODS FOR MARINE MAMMAL DENSITIES AND TAKE CALCULATIONS

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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., 86 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 (74) 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). The requested takes were then assigned to various stocks as follows: as the southern resident killer whale population comprises 8.7% of all killer whales in the region, 8.7% (~8 individuals) of the requested take of 86 animals was allotted to this stock. This is equivalent to ~10% of that population. Following the same methods, the requested takes are 23, 26, and 29 individuals from the West Coast Transient, Northern Resident, and Offshore stocks, respectively.

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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 (#/km²)					
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	*0.011700*				USN (2019a)	Density for June (summer densities are lower)
	2: 70-130 km from shore	*0.139100*				USN (2019a)	Density for June (summer densities are lower)
	3: >130 km from shore	*0.010700*				USN (2019a)	Density for June (summer densities are lower)
Guadalupe fur seal							
	1: within 200-m isobath	*0.015300*				USN (2019a)	Density for summer (other densities lower)
	2: 200-m isobath to 300 km	*0.017100*				USN (2019a)	Density for summer (other densities lower)
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	0.267350				USN (2019a)	Average densities for OR/WA for summer
	2: 200-m isobath to 300 km	0.001900				USN (2019a)	Average densities for OR/WA for summer
Phocid Seals							
Northern elephant seal			0.031800	0.031800	0.031800	USN (2019a)	Density for spring (density during summer is less)
Harbor seal							
	1: within 30 km from shore	0.342400				USN (2019a)	Annual density within 30 km from WA/OR shore
Marine Fissiped							
Northern Sea Otter*							
	1: Washington	0.401240				See text	See text
	2: B.C.	0.517504				See text	See text
Turtle							
Leatherback Turtle			0.000114	0.000114	0.000114	USN (2019a)	Annual density

*****Densities were corrected for time spent underwater (see text above).

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

	Estimated Density (#/km²)				Level B 160 dB Ensonified Area (km²)			Level A Ensonified Area (km²)						
Species	Category 1	Category 2	Category 3	Regional Population Size	Category 1	Category 2	Category 3	Category 1	Category 2	Category 3	Just Level B Takes	Level A Takes	% of Pop. (Total Takes)	Requested Level A+B Take Authorization
LF Cetaceans														
North Pacific right whale	*0*	*0*	*0*	400	14,514	27,874	51,621	541	1,358	3,707	0	0	0.00	0
Sei whale	*0.0004000*	*0.0004000*	*0.0004000*	27,197	14,514	27,874	51,621	541	1,358	3,707	35	2	0.14	37
Minke whale	0.0013000	0.0013000	0.0013000	25,000	14,514	27,874	51,621	541	1,358	3,707	115	7	0.49	122
Gray whale	0.0155000	0.0010000		26,960	6,715	30,323		45	1,722		132	2	0.50	134
MF Cetaceans														
False killer whale	N.A.	N.A.	N.A.	N.A.	14,514	27,874	51,621	17	44	119	N.A.	N.A.	N.A.	**5**
Killer whale	0.0009200	0.0009200	0.0009200	881	14,514	27,874	51,621	17	44	119	86	0	9.82	86
Short-finned pilot whale	0.0002500	0.0002500	0.0002500	836	14,514	27,874	51,621	17	44	119	24	0	2.81	24
HF Cetaceans														
Pygmy/dwarf sperm whale	0.0016300	0.0016300	0.0016300	4,111	14,514	27,874	51,621	340	857	2,336	147	6	3.73	153
Harbor porpoise	0.6240000	0.4670000		65,347	19,139	10,141		495	301		16,230	449	25.52	16,679
Otariid Seals														
Northern fur seal	0.0117000	0.1391000	0.0107000	620,660	47,299	29,724	77,022	57	54	29	5,504	8	0.89	5,512
Guadalupe fur seal	*0.0153000*	*0.0171000*		20,000	29,280	64,729		32	109		1,553	2	7.77	1,555
California sea lion	0.0288000	0.0037000	0.0065000	257,606	31,988	15,312	46,711	40	17	83	1,280	2	0.50	1,282
Steller sea lion	0.2673500	0.0019000		45,675	29,280	64,729		32	109		7,942	9	17.41	7,951
Phocid Seal														
Northern elephant seal	0.0318000	0.0318000	0.0318000	179,000	14,514	27,874	51,621	55	140	382	2,971	18	1.67	2,989
Harbor seal	0.3424000			129,732	22,328			107			7,608	37	5.89	7,645
Marine Fissiped														
Northern Sea Otter	0.40124	0.52		2,058	1,236	1,155	0	0	0	0	496	0	24.10	496
Sea Turtle														
Leatherback Turtle	0.0001140	0.0001140	0.0001140		5,571.3	9,630.2	16,581.8	271.1			4	0		4

N.A. means not available. * Requested take for the false killer whale is based on mean group size (Mobley et al. 2000). 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 (#/km²)			Regional Population Size	Level B 160 dB Ensonified Area (km²)			Level A Ensonified Area (km²)			Level B Takes Only	Level A Takes	% of Pop. (Total Takes)	Requested Level A+B Take Authorization
	Shallow <100 m	Intermediate 100-1000 m	Deep >1000 m		Shallow <100 m	Intermediate 100-1000 m	Deep >1000 m	Shallow <100 m	Intermediate 100-1000 m	Deep >1000 m				
LF Cetaceans														
Humpback whale	*0.0052405*	*0.0040200*	*0.0004830*	10,103	14,514	27,874	51,621	541	1,358	3,707	203	10	2.11	213
Blue whale	*0.0020235*	*0.0010518*	*0.0003576*	1,647	14,514	27,874	51,621	541	1,358	3,707	73	4	4.68	77
Fin whale	*0.0002016*	*0.0009306*	*0.0013810*	18,680	14,514	27,874	51,621	541	1,358	3,707	94	6	0.54	100
MF Cetaceans														
Sperm whale	*0.0000586*	*0.0001560*	*0.0013023*	26,300	14,514	27,874	51,621	17	44	119	72	0	0.28	72
Baird's beaked whale	*0.0001142*	*0.0002998*	*0.0014680*	2,697	14,514	27,874	51,621	17	44	119	86	0	3.18	86
Small beaked whale	*0.0007878*	*0.0013562*	*0.0039516*	6,318	14,514	27,874	51,621	17	44	119	253	1	4.01	254
Bottlenose dolphin	*0.0000007*	*0.0000011*	*0.0000108*	1,924	14,514	27,874	51,621	17	44	119	1	0	0.03	1
Striped dolphin	*0.0000000*	*0.0000025*	*0.0001332*	29,211	14,514	27,874	51,621	17	44	119	7	0	0.02	7
Short-beaked common dolphin	*0.0005075*	*0.0010287*	*0.0016437*	969,861	14,514	27,874	51,621	17	44	119	121	0	0.01	121
Pacific white-sided dolphin	*0.0515230*	*0.0948355*	*0.0700595*	48,974	14,514	27,874	51,621	17	44	119	6,994	13	14.31	7,007
Northern right-whale dolphin	*0.0101779*	*0.0435350*	*0.0621242*	26,556	14,514	27,874	51,621	17	44	119	4,559	9	17.20	4,568
Risso's dolphin	*0.0306137*	*0.0308426*	*0.0158850*	6,336	14,514	27,874	51,621	17	44	119	2,120	4	33.52	2,124
HF Cetaceans														
Dall's porpoise	0.1450767	0.1610605	0.1131827	31,053	14,514	27,874	51,621	340	857	2,336	11,986	452	40.05	12,438

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	392.3	37	14,514.5	25,494
Intermediate 100-1000 m		160 dB	753.3	37	27,873.7	10,100
Deep >1000 m		160 dB	1395.2	37	51,621.2	6,733
	Overall	**160 dB**	**2540.8**	**37**	**94,009.5**	
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