Final Environmental Assessment of a Marine Geophysical Survey by R/V *Marcus G. Langseth* of the Aleutian Arc, September–October 2020

Prepared for

Lamont-Doherty Earth Observatory
61 Route 9W, P.O. Box 1000
Palisades, NY 10964-8000

and

National Science Foundation
Division of Ocean Sciences
4201 Wilson Blvd., Suite 725
Arlington, VA 22230

by

LGL Ltd., environmental research associates
22 Fisher St., POB 280
King City, Ont. L7B 1A6

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ABSTRACT

Researchers from Lamont-Doherty Earth Observatory (L-DEO) and Woods Hole Oceanographic Institute (WHOI), with funding from the U.S. National Science Foundation (NSF), propose to conduct a high-energy seismic survey from the Research Vessel (R/V) *Marcus G. Langseth* (*Langseth*) along and across the Aleutian Andreanof Arc in Alaska during September–October 2020. The NSF-owned *Langseth* is operated by Columbia University's L-DEO under an existing Cooperative Agreement. The proposed two-dimensional (2-D) seismic survey would use a towed array of up to 36 airguns with a discharge volume of up to ~6600 in^3. The survey would take place within the U.S. Exclusive Economic Zone (EEZ), in water ~35 to ~7100 m deep.

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 survey would collect data in support of research that would satisfy NSF program priorities. The primary goal of this survey is to image the basic architecture of oceanic-arc crust, to infer processes that control chemical fractionation and lead to the creation of continent-like compositions.

This Final Environmental Assessment (EA) addresses NSF's requirements under the National Environmental Policy Act (NEPA) for the proposed NSF federal action within the Alaskan EEZ. As operator of R/V *Langseth*, L-DEO, on behalf of itself, WHOI, and NSF, requested 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 survey. 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/threatened species was included, the Draft EA was 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 survey. 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 the PEIS. This document also tiers to an EA prepared for a similar seismic survey conducted by R/V *Langseth* in 2019 titled, "Environmental Assessment of a Marine Geophysical Survey by the R/V *Marcus G. Langseth* in the Gulf of Alaska, 2019".

Numerous species of marine mammals inhabit the Aleutian Islands study area. Several of these are listed as ***endangered*** under the ESA, including North Pacific right, sperm, sei, fin, and blue whales, the Western North Pacific Distinct Population Segment (DPS) of gray whales and humpback whales, and the Western DPS of Steller sea lions. Species that are listed as ***threatened*** under the ESA that could occur within the study area include the Mexico DPS of humpback whale and the Southwest Alaska DPS of sea otters. Critical habitat for the Steller sea lion and sea otter is found within the study area. Other ESA-listed species that could occur in the area are the ***endangered*** short-tailed albatross, the ***threatened*** Steller's eider, the ***threatened*** spectacled eider, and the ***endangered*** leatherback turtle. 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. After discussions with USFWS, the original survey design was adjusted to avoid take of sea otters.

Potential impacts of the proposed seismic survey 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 survey. 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 survey is a monitoring and mitigation program designed to minimize potential impacts of the proposed activities on marine animals present during the proposed survey, 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 be taken, and the planned monitoring and mitigation measures would reduce the possibility of any effects.

Proposed protection measures designed to mitigate the potential environmental impacts to marine mammals, sea turtles, and seabirds 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 maintaining a visual watch before and during ramp ups; no start ups during poor visibility or at night unless the exclusion zone (EZ) and passive acoustic monitoring (PAM) system have been monitored for 30 min with no detections; PAM via towed hydrophones during both day and night to complement visual monitoring; and shut downs when marine mammals or sea turtles are detected in or about to enter the designated EZs. The acoustic source would be shut down for North Pacific Right whales observed at any distance from the vessel. The acoustic source would also be powered down (or if necessary shut down) in the event an ESA-listed seabird were to be observed diving or foraging within the designated EZs. Observers would also watch for any impacts the acoustic sources may have on fish. L-DEO and its contractors would be 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 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 MMPA definition of “Level B Harassment” for those species managed by NMFS. No long-term or significant effects are expected on individual marine mammals, sea turtles, seabirds, or fish, the populations to which they belong, or their habitats. Consistent with past similar proposed actions, NSF has followed the National Oceanic and Atmospheric Administration (NOAA) *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* for estimating Level A takes. Although NMFS may issue Level A takes, based on the Proposed Action NSF believes Level A takes would be unlikely. No significant impacts are 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
ADFG	Alaska Department of Fish and Game
AEP	Auditory Evoked Potential
AMVER	Automated Mutual-Assistance Vessel Rescue
BIA	Biologically Important Areas
CA	California
CBD	Convention on Biological Diversity
CEBS	Central Eastern Bering Sea
CITES	Convention on International Trade in Endangered Species
dB	decibel
DoN	US Department of the Navy
DPS	Distinct Population Segment
EA	Environmental Analysis
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EO	Executive Order
ESA	(U.S.) Endangered Species Act
ESU	Evolutionarily Significant Unit
ETP	Eastern Tropical Pacific
EZ	Exclusion Zone
FM	Frequency Modulated
FMP	Fishery Management Plan
FONSI	Finding Of No Significant Impact
GeoPRISMS	Geodynamic Processes at Rifting and Subducting Margins program
GIS	Geographic Information System
GOA	Gulf of Alaska
GoM	Gulf of Mexico
GVP	Group Vocal Periods
h	hour
HAPC	Habitat Areas of Particular Concern
hp	horsepower
Hz	Hertz
IBA	Important Bird Area
ICR	(Japan) Institute of Cetacean Research
IHA	Incidental Harassment Authorization (under MMPA)
in	inch
IOC	Intergovernmental Oceanographic Commission of UNESCO
IODP	International Ocean Discovery Program
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
MMA	Marine Managed Areas
MMPA	(U.S.) Marine Mammal Protection Act
MPA	Marine Protected Area
ms	millisecond
MUS	Management Unit Species
NMFS	(U.S.) National Marine Fisheries Service
nmi	nautical mile
NOAA	National Oceanic and Atmospheric Administration
NPFMC	North Pacific Fishery Management Council
NPTZ	North Pacific Transition Zone
NRC	(U.S.) National Research Council
NSF	National Science Foundation
OAWRS	Ocean Acoustic Waveguide Remote Sensing
OBIS	Ocean Biogeographic Information System
OBS	Ocean Bottom Seismometer
OBSIP	Ocean Bottom Seismograph Instrument Pool
OEIS	Overseas Environmental Impact Statement
p or pk	peak
PEIS	Programmatic Environmental Impact Statement
PI	Principal Investigator
PTS	Permanent Threshold Shift
PSO	Protected Species Observer
rms	root-mean-square
R/V	research vessel
s	second
SBP	Sub-bottom Profiler
SEBS	South-Eastern Bering Sea
SEL	Sound Exposure Level (a measure of acoustic energy)
SIO	Scripps Institution of Oceanography
SPL	Sound Pressure Level
SOSUS	(U.S. Navy) Sound Surveillance System
t	tonnes
TTS	Temporary Threshold Shift
U.K.	United Kingdom
UNEP	United Nations Environment Programme
U.S.	United States of America
USGS	U.S. Geological Survey
USFWS	U.S. Fish and Wildlife Service
µPa	microPascal
vs.	versus
WCMC	World Conservation Monitoring Centre
WHOI	Woods Hole Oceanographic Institute
y	year

I PURPOSE AND NEED

This Final Environmental Assessment (EA) was prepared under the National Environmental Policy Act (NEPA). The Final 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 an EA prepared for a similar seismic survey conducted by R/V *Langseth* in 2019 titled, "Environmental Assessment of a Marine Geophysical Survey by the R/V *Marcus G. Langseth* in the Gulf of Alaska, 2019" and associated Finding of No Significant Impact (FONSI)[1]. This Final EA evaluates the specific geographic location and energy source level and configuration associated with the proposed survey. The purpose of this Final 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 survey.

The Final EA provides details of the Proposed Action at the site-specific level and addresses potential impacts of the proposed seismic survey on marine mammals, sea turtles, seabirds, fish, and invertebrates. The Draft EA was used in support of an application for an Incidental Harassment Authorization (IHA) from the National Marine Fisheries Service (NMFS) and Section 7 consultations under the Endangered Species Act (ESA). The IHA would allow the non-intentional, non-injurious "take by harassment" of small numbers of marine mammals[2] during the proposed seismic survey by Columbia University's Lamont-Doherty Earth Observatory (L-DEO) of the Aleutians Arc during 2020. Consistent with past similar proposed actions, NSF has followed the National Oceanic and Atmospheric Administration (NOAA) *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* for estimating Level A takes. Although NMFS may issue Level A takes for the remote possibility of low-level physiological effects, 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 would be unlikely. After discussions with the U.S. Fish and Wildlife Service (USFWS), the original survey design was adjusted to avoid take of sea otters and, accordingly, an IHA was not sought.

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 image the basic architecture of oceanic-arc crust, to infer processes that control chemical fractionation and lead to the creation of continent-like compositions. The proposed activities would collect data in support of a research proposal that has been reviewed through the NSF merit review

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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.

process and have been 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

- National Environmental Protection Act (NEPA);
- Marine Mammal Protection Act (MMPA);
- Endangered Species Act (ESA);
- Magnuson-Stevens Fishery Conservation and Management Act - Essential Fish Habitat (EFH).

II ALTERNATIVES INCLUDING PROPOSED ACTION

In this Final EA, two alternatives are evaluated: (1) the proposed seismic survey and 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.

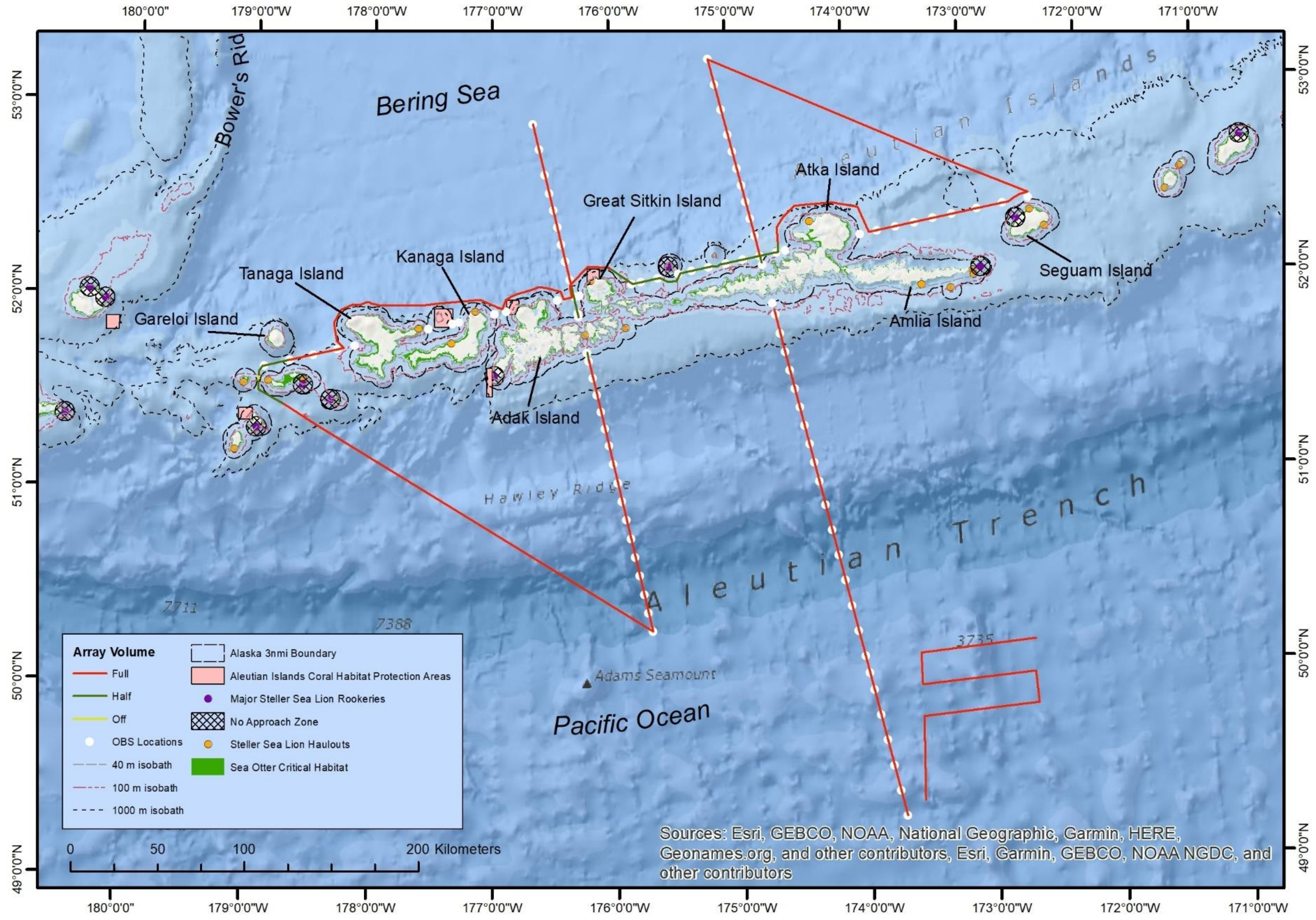
2.1 Proposed Action

The Proposed Action, including project objectives and context, activities, and monitoring/mitigation measures for the proposed seismic survey, is described in the following subsections.

2.1.1 Project Objectives and Context

Researchers from Woods Hole Oceanographic Institute (WHOI) and L-DEO have proposed to conduct a seismic survey using the Research Vessel (R/V) *Marcus G. Langseth* (*Langseth*) of the Aleutian Andreanof Arc in the Northeast Pacific Ocean (Fig. 1). The objectives of the proposed study are to seismically image the structure of the crust along and across the Andreanof segment of the Aleutian Arc, an intact arc segment with a simple and well known history. Existing geochemical analyses of igneous rocks from this segment suggest an along-segment trend in crustal-scale fractionation processes. Seismic velocity provides strong constraints on bulk composition, and so seismic images will reveal the constructional architecture, vertical fractionation patterns, and along-arc trends in both of those things. Together with existing observations from surface rocks (e.g., bulk composition, volatile content) and forcing parameters (e.g., slab geometry, sediment input, deformation-inferred stress regime), hypotheses related to controls on oceanic-arc crustal construction and fractionation can be tested and refined.

Crustal-scale imaging of an active volcanic arc is exceptionally challenging. In the along-arc (strike) direction, the underlying crust is locally hot and melt rich, resulting in an attenuating environment for seismic wave propagation. In the across-arc (dip) direction, the target of interest (i.e., the zone of accretion) is relatively narrow. The survey paths in both directions are disrupted by volcanoes and volcanic platforms. Large seismic sources are required to penetrate the crust, and large apertures are required to image both impedance contrasts and bulk velocity structure. The main objective of the proposed seismic program is to image the basic architecture of oceanic-arc crust along and across the Aleutian Arc using seismic airguns. To achieve the project goals, the Principal Investigator (PI) Dr. D. Lizarralde (WHOI) and Co-PI Dr. D. Shillington (L-DEO) propose to collect 2-D seismic reflection/refraction data along and across the Andreanof segment of the Aleutian Arc.



Sources: Esri, GEBCO, NOAA, National Geographic, Garmin, HERE, Geonames.org, and other contributors, Esri, Garmin, GEBCO, NOAA NGDC, and other contributors

FIGURE 1. Map of the proposed 2020 seismic survey of the Aleutian Arc showing representative survey lines.

2.1.2 Proposed Activities

2.1.2.1 Location of the Survey Activities

The proposed survey would occur within the area of ~49–53.5°N, ~172.5–179.5°W, in the EEZ of Alaska. All proposed activities would occur outside of 3 n.mi. from shore, in water depths ranging from ~35 to ~7100 m. Representative survey tracklines are shown in Figure 1. As described further in this document, however, deviation in actual track lines, including order of survey operations, could be necessary for reasons such as science drivers, poor data quality, inclement weather, safety, or mechanical issues with the research vessel and/or equipment. Thus, within the constraints of any federal authorizations issued for the activity, tracklines may shift from those shown and could occur anywhere within the coordinates noted above and illustrated by the box in the inset map on Figure 1.

2.1.2.2 Description of Activities

The procedures to be used for the proposed marine geophysical survey would be similar to those used during previous surveys by L-DEO and would use conventional seismic methodology. The survey would involve one source vessel, R/V *Langseth*. R/V *Langseth* would tow an array of up to 36 airguns at a depth of 9 m as an energy source with a volume of up to ~6600 in^3. The receiving system would consist of ocean bottom seismometers (OBSs) and a towed hydrophone streamer with a nominal length of 8 km. As the airgun array is towed along the survey lines, the OBSs would receive and store the returning acoustic signals internally for later analysis, and the hydrophone streamer would transfer the data to the on-board processing system. The airguns would fire at a shot interval of 22 s during multi-channel seismic (MCS) with the hydrophone streamer and at a 120-s interval during refraction surveying to OBSs.

The study consists of one east-west strike-line transect (~531 km), two north-south dip-line transects (~420 km and ~280 km), connecting MCS transects (~479 km), and survey of the Amlia Fracture Zone (~283 km). The representative tracklines are shown in Figure 1 have a total length of 1993 km. The strike- and dip-line transects would first be acquired using OBSs, which would be deployed along one line at a time, the line would then be surveyed, and the OBSs would then be recovered, before moving o not the next line. After all refraction data are acquired, the strike and dip lines would then be acquired a second time using MCS. The MCS transect lines and Amlia Fracture Zone transect lines would be acquired only once using MCS. Thus, the total line km to be acquired is expected to be ~3224 km. A total of 10% of this survey would use an 18-airgun array, and the remainder would employ the full 36-airgun array. There could be additional seismic operations associated with turns, airgun testing, and repeat coverage of any areas where initial data quality is sub-standard. In the calculations for our analysis (see § 4.1.1.5), 25% of effort has been added to the proposed line km to be surveyed. During the survey, ~1% of the line km would take place in shallow water (<100 m), 26% would occur in intermediate water depths (100–1000 m), and the rest (73%) would occur in deep water (>1000 m).

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

2.1.2.3 Schedule

The cruise is proposed for September–October 2020, but cruise dates have not been confirmed at the time of writing. The survey is expected to consist of ~16 days of seismic operations, 14 days of OBS and MCS equipment deployment/retrieval, 6 days of transits between seismic transects, 2 days of transiting to and from port, and 5 days of contingency (e.g., weather, etc.). R/V *Langseth* would leave from and return to port in Dutch Harbor.

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 timelines associated with the ESA Section 7 consultation and IHA processes, not all research projects or vessel logistics will have been identified at the time the consultation documents are submitted to federal regulators; typically, however, these types of details, such as port arrival/departure locations, are not a substantive component of the consultations. Seasonality of the proposed survey operations does not affect the ensuing analysis (including take estimates), because the best available species densities for any time of the year have been used.

2.1.2.4 Vessel Specifications

R/V *Langseth* is described in § 2.2.2.1 of the PEIS. The vessel speed during all seismic operations would be ~4.5 kts (~8.3 km/h).

2.1.2.5 Airgun Description

For the majority of the survey (90% of line km), R/V *Langseth* would tow the full array, consisting of four strings with 36 airguns (plus 4 spares) with a total volume of ~6600 in^3. In certain locations (Fig. 1), only half the array (18 airguns) would be operated, with a total volume of ~3300 in^3, in order to reduce sound exposure. The airgun arrays are described in § 2.2.3.1 of the PEIS, and the airgun configuration is illustrated in Figures 2-11 to 2-12 of the PEIS. The array would be towed at a depth of 9 m. The shot interval would be 50 m (~22 s) during MCS with the hydrophone streamer and 278 m (~120 s) during refraction surveying to OBSs.

2.1.2.6 OBS Description

The seismometers would consist of a total of 50 short-period OBSs from Scripps Institution of Oceanography (SIO). The SIO L-Cheapo OBSs have a height of ~0.9 m and a maximum diameter of 97 cm. The anchors are 36-kg iron grates with dimensions 7 × 91 × 91.5 cm. OBSs would be deployed and subsequently retrieved by R/V *Langseth* prior to MCS surveying. When an OBS is ready to be retrieved, an acoustic release transponder (pinger) interrogates the instrument at a frequency of ~12 kHz, and a response is received at the same frequency. The burn-wire release assembly is then activated, and the instrument is released from the anchor to float to the surface.

2.1.2.7 Additional Acoustical Data Acquisition Systems

Along with the airgun operations, three additional acoustical data acquisition systems (an MBES, SBP, and ADCP) would be operated from R/V *Langseth* during the proposed survey, but not during transits to/from the survey site and port. The ocean floor would be mapped with a Kongsberg EM 122 MBES and a Knudsen Chirp 3260 SBP. A Teledyne RDI 75 kHz Ocean Surveyor ADCP would be used to measure water current velocities. These sources are described in § 2.2.3.1 of the PEIS.

To retrieve the OBSs from the sea floor, an acoustic release transponder (pinger) transmits a signal to the instrument at a frequency of 12 kHz (±1 kHz) and a response is received at the same frequency to activate and release the instrument. The transmitting beam pattern is 55°, and the sound source level is ~93 dB referenced to one microbar at one yard. The pulse duration is 2 milliseconds (±10%) and the pulse repetition rate is one per second (±50 microseconds).

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 recently with recommendations on how to reduce anthropogenic sound in the ocean (e.g., Simmonds et al. 2014; Wright 2014; Dolman and Jasny 2015). Some of those recommendations have been taken into account here.

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 survey was to evaluate whether the research objectives could be met with a smaller energy source. The scientific objectives for the proposed survey could not be met using smaller sources in most of the survey area, as imaging active volcanic-arc crustal structure is challenging. The goal is to penetrate the crust, and large apertures are required to image both impedance contrasts and bulk velocity structure. The combination for 30-km thick crust, the presence of seismically attenuative melt, and wavefront expansion across the great water depths of deep-sea trenches together require the energy source level from the full 36-airgun array. However, after discussion with USFWS, a smaller airgun array (18 airguns) is proposed for use on several transect lines (Fig. 1) occurring near sea otter critical habitat in order to reduce sound exposure and avoid takes by harassment.

***Survey Timing and Location*.—**When considering potential times to carry out the proposed survey, key factors taken into consideration included environmental conditions (i.e., the seasonal presence of marine mammals, sea turtles, and seabirds), weather conditions, equipment, and optimal timing for other proposed seismic survey using R/V *Langseth*. Many marine mammal species occur in the area year-round; however, baleen whale presence in the area is highest on a seasonal basis and during the time of the proposed survey (September–October).

The Andreanof segment of the Aleutian Arc is the best location in the world to study the fundamental processes that form oceanic-arc crust. The crust at the survey location is not terribly old (~40 m.y.), it is intact (i.e., it has not been rifted, collided with, or subjected to discernable subduction erosion), the surface geochemistry is well studied, and an along-axis trend in fractionation is observed. There is no other place where this combination of attributes can be found.

***Mitigation Zones*.—**During the planning phase, mitigation zones for the proposed marine seismic survey were calculated based on both modeling by L-DEO for the Level A and Level B (160 dB re 1µPa$_{rms}$) threshold and using empirical measurements from Crone et al. (2014) from the Cascadia Margin. The background information and methodology for this are provided in Appendix A.

The proposed survey would acquire data with the airgun array at a maximum tow depth of 9 m. L-DEO model results are used to determine the 160-dB$_{rms}$ radius for the 18- and 36-airgun array at a 9-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). For the 36-airgun array, radii for intermediate water depths (100–1000 m) and shallow water (<100 m) are derived from empirical data from Crone et al. (2014) (see Appendix A). For the 18-airgun array, scaling factors from the empirical data collected by Crone et al. (2014) were used to determine the radii in intermediate and shallow water.

Table 1 shows the distances at which the 160-dB re 1µPa$_{rms}$ sound levels are expected to be received for the 18- and 36-airgun array and the 40 in^3 airgun to be used during power downs of the larger array (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 1µPa$_{rms}$ sound level is expected to be received for the 18- and 36-airgun array and a single airgun; this level is used by NMFS, as well as the U.S. DoN (2017), to determine behavioral disturbance for sea turtles. In this analysis, we have used the sound levels for the 36-airgun array for all take calculations, as the majority of the survey (90%) would employ the full airgun array for data acquisition.

The thresholds for permanent threshold shift (PTS) onset or Level A Harassment (injury) for marine mammals for impulsive sounds use dual metrics of cumulative sound exposure level (SEL$_{cum}$ over 24 hours) and peak sound pressure levels (SPL$_{flat}$) (NMFS 2016a, 2018). 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/sea otters underwater (OW). Consistent with the *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* (NMFS 2016a, 2018), the largest distance of the dual criteria (SEL$_{cum}$ or Peak SPL$_{flat}$) was used to calculate takes and Level A threshold distances. Here, SEL$_{cum}$ is used for LF cetaceans and turtles; Peak SPL is used for all other hearing groups (Table 2).

This document has been prepared in accordance with the current National Oceanic and Atmospheric Administration (NOAA) acoustic practices, and the monitoring and mitigation procedures are based on best practices noted by Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013a), Wright (2014), Wright and Cosentino (2015), and Acosta et al. (2017). For other recent high-energy seismic surveys conducted by L-DEO, NMFS required protected species observers (PSOs) to establish and monitor a 500-m exclusion zone (EZ) for power downs and to monitor an additional 500-m buffer zone beyond the EZ. A power down required the reduction of the full array to a single 40-in^3 airgun; a 100-m EZ was established and monitored for shut downs of the single airgun. However, based on recent direction from NMFS, power downs would not be allowable under the IHA; shut downs would be implemented for marine mammals within the designated EZ. However, a power down would be implemented for sea turtles or diving ESA-listed seabirds. Enforcement of mitigation zones via power and shut downs 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 is 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 for use 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 collection 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).

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 survey of the Aleutian Arc. 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	9	>1000 m	388[1]	66[1,4]
		100–1000 m	582[2]	99[2,4]
		<100 m	938[3]	145[3]
2 strings, 18 airguns, 3300 in^3	9	>1000 m	3,562[1]	775[1]
		100–1000 m	3,939[5]	1,057[5]
		<100 m	5,263[5]	1,633[5]
4 strings, 36 airguns, 6600 in^3	9	>1000 m	5,629[1]	1,618[1]
		100–1000 m	8,233[6]	2,210[6]
		<100 m	11,000[6]	3,412[6]

[1] Distance based on L-DEO model results. [2] Distance based on L-DEO model results with a 1.5 × correction factor between deep and intermediate water. [3] Distance based on empirically derived measurements in the Gulf of Mexico (GoM) with scaling applied to account for differences in tow depth. [4] An exclusion zone (EZ) of 100 m would be used as the shut-down distance for sea turtles in all water depths. [5] Based on empirical data from Crone et al. (2014) with scaling factor based on deep-water modeling applied to account for differences in array size; see Appendix A for details. [6] Based on empirical data from Crone et al. (2014); see Appendix A for details.

TABLE 2. Level A threshold distances for different hearing groups for the 18- and 36-airgun array and a shot interval of 50 m[1]. Consistent with NMFS (2016a, 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					
	LF Cetaceans	MF Cetaceans	HF Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds/Otters	Sea Turtles
18 airguns						
PTS SEL_{cum}	**54.8**	0	0.2	2.1	0	5.0
PTS Peak	23.3	**11.2**	**119.0**	**25.2**	**9.9**	**9.9**
36 airguns						
PTS SEL_{cum}	**376.0**	0	0.9	9.9	0	**12.8**
PTS Peak	38.8	**13.8**	**229.2**	**42.1**	**10.9**	10.9

[1] Using the 50-m shot interval provides more conservative distances than the 278-m shot interval. Also, Level A thresholds for the 36-airgun array are used here as a conservative measure for all airgun operations.

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 would be aboard 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. Concentrations of large whales may be encountered within the 160-dB isopleth if aggregations of food are present; if aggregations of feeding whales are encountered, they would be avoided. The airgun array would be shut down if a North Pacific right whale were to be observed at any distance from the vessel, and if a sea otter were to be seen within the 160-dB radius.

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, sea turtles, and seabirds, 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

The Andreanof segment of the Aleutian Arc is the best location in the world to study the fundamental processes that form oceanic-arc crust. The crust here is not terribly old (~40 m.y.), it is intact (i.e., it has not been rifted, collided with, or subjected to discernable subduction erosion), the surface geochemistry is well studied, and an along-axis trend in fractionation is observed. There is no other place where this combination of attributes can be found.

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).

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

Proposed Action	Description
Proposed Action: Conduct marine geophysical survey and associated activities	Under this action, research activities are proposed to study Earth processes and would involve a 2D seismic survey. Active seismic portions of the survey would be expected to take ~16 days. Additional operational days would be expected for transit; 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. 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 the fundamental processes that form oceanic-arc crust would not be collected. The crust created in volcanic arcs are the building blocks for continental crust. The growth and accretion of this crust replenishes the mass lost through weathering and erosion, maintaining both subaerial land mass and, consequently, robust biogeochemical cycles that enable a living planet. Despite the importance of these processes, we know surprisingly little about them. In addition, geological data adding to the comprehensive assessment of geohazards for the Alaska region would not be collected. The collection of new data, interpretation of these data, introduction of new results into the greater scientific community, and application 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	The Andreanof segment of the Aleutian Arc is the best location in the world to study the fundamental processes that form oceanic-arc crust. The crust in the location is not terribly old (~40 m.y.), it is intact (i.e., it has not been rifted, collided with, or subjected to discernable subduction erosion), the surface geochemistry is well studied, and an along-axis trend in fractionation is observed. There is no other place where this combination of attributes can be found. The data that would be collected would also add to the comprehensive assessment of geohazards for this region, and could not reasonably be collected elsewhere. The proposed science would meet NSF program priorities.
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.

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. Accordingly, 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 activities; 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 Proposed Action;
- *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 U.S. state and federal requirements;
- *Geological Resources (Topography, Geology and Soil)*—The Proposed Action would result in very minor disturbance to seafloor sediments from OBS deployments during the survey; small anchors would not be recovered. The Proposed Action 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 study area. Therefore, there would be no impacts to water resources resulting from the proposed activities;
- *Terrestrial Biological Resources*—The proposed Project Action 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 Proposed Action would involve a continually moving vessel and would be short-term; a large part of the activities would occur outside of the viewshed from the coast; and
- *Socioeconomic and Environmental Justice*—Implementation of the Proposed Action 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. Activities in the survey area could include commercial fishing, subsistence fishing and hunting, limited recreational diving, and other vessel traffic. These activities and potential impacts on them from the proposed survey are described in further detail in § III and § IV. No other socioeconomic impacts would be expected as a result of the proposed activities.

3.1 Oceanography

The Aleutian Islands are volcanic islands surrounded by the Bering Sea to the north and the Pacific Ocean to the south. The Aleutian Trench extends from the northernmost point in the GOA west to the Kamchatka Peninsula, south of the Aleutian Islands; it has water depths >7000 m. The Aleutian Basin is located north of the Aleutian Islands, with water depths up to 3600 m (Stabeno et al. 1999).

Oceanic conditions in the northwest Pacific are dynamic; the Kuroshio Current and Kuroshio Extension, flowing north and eastward from Japan, and the Oyashio Current, flowing south from the Bering Sea and the Sea of Okhotsk, converge there (Pickard and Emery 1990). Because of the complex topography (including steep slopes and seamounts) and currents in the area, frequent eddies are formed in this area (Bush et al. 1996). The Aleutian Low is a low-pressure system along the Aleutian Island chain (Stabeno et al. 1999). During the summer, with long daylight periods and high insolation, the Aleutian Low is weak (Stabeno et al. 1999). During winter, the Aleutian Low intensifies and dominates weather over the North Pacific and Bering Sea (Stabeno et al. 1999). During the winter, an average of 3–5 storms per month move eastward along the Aleutian Islands (Stabeno et al. 1999). The general climate is characterized by high winds, overcast skies, and frequent cyclonic storms (Armstrong 1971). Warm water from the Japanese current moderates the temperature.

The Bering Sea to the north is a deep basin with depths >1000 m. In the Bering Sea Basin, there is a cyclonic gyre, with the southward-flowing Kamchatka Current in the west and the northward-flowing Bering Slope Current in the east (Stabeno et al. 1999). Circulation in the Bering Sea is strongly influenced by the Alaska Stream, which enters the sea through the passes in the Aleutian Arc (Stabeno et al. 1999). The Alaska Stream flows west along the southern side of the Alaska Peninsula and Aleutian Islands and brings fresh surface water and warm sub-surface water into the Bering Sea (Stabeno et al. 1999). Water flowing through the Amchitka and Amukta passes is the source of the Aleutian North Slope Current (Reed and Stabeno 1999), which flows eastward along the northern arc (Stabeno et al. 1999).

There is extensive flow from the North Pacific through the 14 main passes in the Aleutian Arc into the Bering Sea (Stabeno et al. 1999). Samalga Pass appears to be a division between shallow shelf passes in the east and deeper passes to the west (Ladd et al. 2004, 2005). Unimak Pass is <80 m deep and ~30 km wide; it allows water from the Alaska Coastal Current (ACC) to flow into the Bering Sea (Stabeno et al. 1999). Akutan pass is <120 m deep, and Amukta, Seguam, and Tanaga passes are >120 m deep (Stabeno et al. 1999). Only three of the passes (Amchitka Pass, Near Strait, and Kamchatka Strait) are >700 m deep (Stabeno et al. 1999). The ACC extends 1000 km along the GOA, from southern Alaska to Unimak Pass (Stabeno et al. 1999). The Kamchatka Strait is the major area of outflow of the Bering Sea; it is >2000 m deep (Stabeno et al. 1999).

Strong tidal currents and the topography of the Aleutian passes result in frontal regions between vertically-mixed and stratified areas. The combination of nutrient-rich slope water and high summer solar radiation in the Bering and Chukchi seas create high productivity (Walsh et al. 1989). A bloom often starts on the shelf; the annual primary productivity varies from >200 g C/m^2 over the southeastern shelf to >800 g C/m^2 north of St. Lawrence Island (Arzhanova et al. 1995 *in* Stabeno et al. 1999). Ray et al. (2014) noted a productivity of 150–200 g C/m^2 per year along the Aleutian Islands. The post-bloom production appears to be higher in the eastern passes than in the central passes (Mordy et al. 2004). Because of strong currents, there is strong vertical mixing of nutrient-rich water in the passes, which in turn accounts for the high primary productivity in the Bering Sea (Stabeno et al. 2005). That productivity supports marine mammal, seabird, and fish populations.

Coyle et al. (1998) noted that a front divides the Bering Sea water mass from the mixed water in the pass and the Alaska Stream water to the south, and that chlorophyll concentrations and biomass were higher on the Bering Sea side of the front. Zeeman (2004) showed that there was a decline in productivity from the east to the west in the Aleutian Islands. In 2002, Unimak and Akutan passes had a primary production of 2.8 and 3.9 g $Cm^{-2}d^{-1}$, whereas passes to the west showed values ranging from 0.04 to 1.6 g $Cm^{-2}d^{-1}$ (Zeeman 2004). Surface waters were warmer and fresher, and nutrient concentrations were lower, to the east of Samalga Pass than those to the west of the pass (Ladd et al. 2004, 2005). The eastern Aleutian shelf is dominated by the euphausiid *Thysanoessa inermis* and shelf copepods (Coyle 2005). However, those species are rare or absent in the central Aleutians, where oceanic copepods and the euphausiid *Euphausia pacifica* dominate (Coyle 2005). Eddies and fronts generated by tides appear to be mechanisms through which zooplankton are concentrated in the passes, particularly in the middle Aleutian passes. Overall zooplankton densities are higher in the central Aleutians, but euphausiid species densities are lower there than in the east (Coyle 2005).

3.2 Protected Areas

3.2.1 Critical Habitat for ESA-listed Species

Several locations within or near the proposed survey area have been specifically identified as important to ESA-listed species, including critical habitat for three species of marine mammals (Fig. 1).

3.2.1.1 North Pacific Right Whale Critical Habitat

Critical feeding-season habitat has been designated by NMFS for the North Pacific right whale in the western GOA and in the southeastern Bering Sea (SEBS; 71 FR 38277, 6 July 2006). The bulk of the critical habitat lies in the Bering Sea with a small portion in the GOA located southeast of Kodiak Island. The closest critical habitat to the proposed survey area is located to the northeast in the Bering Sea more than 400 km away. None of the proposed transect lines enter the critical habitat, and the survey would occur far enough away from the critical habitat area that received sound levels within the habitat would not exceed 160 dB re 1 μPa_{rms}.

3.2.1.2 Steller Sea Lion Critical Habitat

Critical habitat for Steller sea lions is defined in detail in the Code of Federal Regulations (50 CFR 226.202). This species is divided into Western and Eastern DPSs with a boundary at 144°W. The survey area lies within the range of the ***endangered*** Western DPS and includes critical habitat (Fig. 1). The Eastern DPS was formerly listed as threatened but was delisted in 2013 (78 FR 66139, 4 November 2013). Designated critical habitat currently includes terrestrial, aquatic, and air zones that extend 3000 ft (0.9 km) landward, seaward, and above each major rookery and major haulout in Alaska. For the Western DPS, the aquatic zone extends further, out 20 n.mi. (37 km) seaward of major rookeries and haulouts west of 144ºW (50 CFR 226.202). In addition to major rookeries and haulouts, critical habitat foraging areas have been designated in Seguam Pass, Bogoslof area, and Shelikof Strait. Of the foraging areas, only Seguam Pass overlaps the proposed survey area (Fig. 1). The Bogoslof foraging area is located to the east of the survey area, and Shelikof Strait is in the western GOA. In addition, “no approach” buffer areas around rookery sites of the Western DPS of Steller sea lions are identified in the Code of Federal Regulations (50 CFR 223.202). “No approach” zones are restricted areas wherein no vessel may approach within 3 n.mi. (5.6 km) of listed rookeries; some of these are adjacent to the survey area (Fig. 1). The proposed transect lines were adjusted to avoid exposing the area within 3000 ft (0.9 km) of major rookeries and haulouts to sound levels ≥160 dB.

3.2.1.3 Sea Otter Critical Habitat

Critical habitat for the Southwest Alaska DPS of the northern sea otter was designated in November 2009 (74 FR 51988, 8 October 2009). The critical habitat primarily consists of shallow-water areas <20 m deep and nearshore water within 100 m of the mean tide line. As none of the proposed seismic transects would enter or ensonify sea otter critical habitat to sound levels >160-dB during seismic operations, no takes are being requested for sea otters. As noted earlier, some transect lines would be acquired using the 18-airgun array in order to avoid exposing sea otters and critical habitat to sound levels >160 dB. This approach was discussed with USFWS and an IHA application originally submitted for the proposed survey was withdrawn after adjustments were made to the survey design to avoid takes of sea otters and impacts to critical habitat.

3.2.2 Other Protected Areas

The Aleutian Islands and the surrounding waters (totaling 279,415 km^2) have been designated as a Habitat Conservation Area by the North Pacific Fishery Management Council (NPFMC) within which no bottom trawling can occur (Warrenchuk et al. 2017). Several areas near the proposed survey area have been designated as Habitat Areas of Particular Concern (HAPCs) within Alaska's essential fish habitat (EFH). However, there are no HAPCs in the proposed survey area; the nearest HAPC to the survey area is Bowers Ridge Habitat Conservation Zone ~100 km to the northwest (Fig. 1). HAPCs are considered high-priority areas for conservation because they are rare, sensitive, or provide important ecosystem functions. HAPCs are discussed further in Section 3.7 below.

The Aleutian Islands Coral Habitat Protection Areas, designated by NPFMC, include six areas totaling 111 km^2 that do not allow bottom contact gear or anchorage; these sites are located in Adak Canyon and off Great Sitkin Island, Bobrof Island, Cape Moffett Island, Semisopochnoi Island, and Ulak Island (Warrenchuk et al. 2017). Although some of these sites are located within the overall proposed survey area, no anchorage or bottom contact with gear would occur at these specific locations. No OBSs would be deployed in these areas, and none of the proposed transect lines would pass through these areas.

The nearshore portions of the proposed survey may take place within the Alaska Maritime National Wildlife Refuge, which includes "islands, islets, headlands, rocks, reefs, spires, and submerged lands" (Pippins 2012) and covers >4.8 million acres (19,425 km^2) extending from Forrester Island to the Aleutian Chain and northward along the coastline to near Barrow (USFWS 2019a). The Alaska Maritime Wildlife Refuge was established to "conserve marine mammals, seabirds and other migratory birds, and the marine resources upon which they rely" (USFWS 2019a). It provides essential habitat for ≥40 million seabirds (~80% of all breeding seabirds that migrate to Alaska), representing >30 species and including endemic subspecies and rare asiatic migrants (USFWS 2019a). It also protects the Steller sea lion, sea otter, fur seal, and salmon streams (USFWS 2019a). Permitted activities include wildlife and bird viewing, and sport fishing in accordance with Alaska Fish and Game regulations (USFWS 2019a). A conservation plan for the refuge provides direction for permitting subsistence use by residents and scientific research of marine resources (USFWS 2019b). The Aleutian Islands Wilderness which extends ~1100 nmi is part of this refuge and includes terrestrial areas from Amak Island on the east to Attu Island in the west (Pippins 2012).

Several important bird areas (IBAs) occur within the proposed study area and aim to protect and manage sites that are important for the long-term viability of bird populations (Birdlife International 2020a). They include sites for breeding, foraging, staging, molting, and migrating; to be designated as marine IBA, the site must support a high bird concentration, or provide habitat for rare, threatened species, or species with a restricted range (Smith 2017). In Alaska, most IBAs are globally significant, including all of those in the study area in the Aleutians, as they include at least 1% of the world population of seabirds or at least 1% of the North American population of waterfowl and shorebirds (Smith 2017). Over 10 million birds nest in the Aleutians during summer, including fulmars, puffins, auklets, cormorants, gulls, storm petrels, terns, kittiwakes, guillemots, murrres and murrelets (Pippins 2012). Marine IBAs within the study area include Seguam Island Marine, Fenimore Pass & Atka Island Marine, and Kuluk Bay; Gareloi Island Marine BIA is located just west of the proposed survey area (Smith 2017). Fenimore Pass & Atka Island

Marine typically supports 1.1 million nesting birds (Smith 2017). The Unimak and Akutan Passes BIA to the east of the survey area has the greatest abundance of birds, with an estimated 7 million birds (Smith 2017). Colony IBAs occur at Koniuji-Atka Island, within the study area, and to the west, at Gareloi Island (Smith 2017). Biologically important areas (BIA) for cetaceans also occur near the proposed study area. These are discussed below.

3.3 Marine Mammals

The marine mammals that occur in the proposed survey area belong to four taxonomic groups: odontocetes (toothed cetaceans, such as dolphins), mysticetes (baleen whales), pinnipeds (seals and sea lions), and fissipeds (sea otter). Eighteen cetacean species, six pinniped species, and the northern sea otter are known to or could occur in the proposed Aleutian Arc survey area (Table 4). Several of these species/populations are listed under the ESA as ***endangered***, including the North Pacific right, sperm, fin, sei, and blue whales, the Western North Pacific DPSs of humpback and gray whales, and the Western DPS of Steller sea lions. The ***threatened*** Mexico DPS of humpback whales and the Southwest Alaska DPS of sea otters could also occur in the region.

Several other North Pacific cetacean species are not included here because they do not typically occur as far north: Bryde's whale; pygmy and dwarf sperm whales; Blainville's, gingko-toothed, and Longman's beaked whales; pygmy and false killer whales; short-finned pilot whale; melon-headed whale; common, Fraser's, pantropical spotted, striped, spinner, rough-toothed, and common bottlenose dolphins. In addition, the bowhead whale, beluga whale, walrus, bearded seal, and ringed seal are typically found farther to the north, especially during the summer, and are not discussed further. Cetaceans and pinnipeds are the subject of the IHA application to NMFS; the sea otter is under USFWS jurisdiction. Adjustments were made to the survey design to avoid takes of sea otters and impacts to critical habitat.

General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of marine mammals are given in § 3.6.1, § 3.7.1, and § 3.8.1 of the NSF and USGS PEIS. The general distributions of marine mammals in the western North Pacific Ocean is discussed in § 3.6.2.4, § 3.7.2.4, § 3.8.2.4, and § 3.9.2.3 of the PEIS for the western GOA. The rest of this section deals specifically with marine mammal distribution within the proposed survey area. Information on the occurrence near the proposed survey area, habitat, population size, and conservation status for each of the marine mammal species that could occur in the area is presented in Table 4.

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 Bering Sea (Shelden et al. 2005; Wade et al. 2006). This species is divided into western and eastern North Pacific stocks. The eastern North Pacific stock that occurs in U.S. waters numbers only ~31 individuals (Wade et al. 2011b), and critical habitat has been designated in the SEBS and GOA, south of Kodiak Island (NOAA 2008). Wintering and breeding areas are unknown, but have been suggested to include the Hawaiian Islands, Ryukyu Islands, and Sea of Japan (Allen 1942; Banfield 1974; Gilmore 1978; Reeves et al. 1978; Herman et al. 1980; Omura 1986).

Since the 1960s, North Pacific right whale sightings have been relatively rare (e.g., Clapham et al. 2004; Shelden et al. 2005). Shelden et al. (2005) reported that the slope and abyssal plain in the western GOA were important areas for right whales until the late 1960s. In March 1979, a group of four right whales was seen in Yakutat Bay (Waite et al. 2003), but there were no further reports of right whale sightings in the GOA until July 1998, when a single whale was seen southeast of Kodiak Island (Waite et al. 2003). Right whale acoustic detections were made south of the Alaska Peninsula and to the east of

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

Species	**Habitat**	**Occurrence in Study Area***	**Abundance (Alaska)**	**Regional Abundance (North Pacific)**	**ESA[1]**	**IUCN[2]**	**CITES[3]**
Mysticetes							
North Pacific right whale	Coastal, shelf	Rare	28-31[4]	400-500[5]	EN	CR[49]	I
Gray whale	Mainly coastal	Rare	N.A.	26,960[6] 290[7]	EN/DL[8]	EN[50]	I
Humpback whale	Coastal, banks	Uncommon	1107[9] 10,103[10]	21,063[11]	EN/T/DL[12]	LC	I
Common minke whale	Coastal, shelf	Common	1233[13]	20,000[14]	NL	LC	I
Sei whale	Pelagic	Uncommon	N.A.	27,197[15]	EN	EN	I
Fin whale	Pelagic	Uncommon	1652[13]	13,620-18,680[16]	EN	VU	I
Blue whale	Pelagic, shelf, coastal	Uncommon	N.A.	1647[17]	EN	EN	I
Odontocetes							
Sperm whale	Pelagic	Common	159[18]	26,300[19]	EN	VU	I
Cuvier's beaked whale	Pelagic	Uncommon	N.A.	3274[20]	NL	LC	II
Baird's beaked whale	Pelagic	Uncommon	N.A.	2697[20] 5029[21] 10,190[22]	NL	DD	I
Sato's beaked whale	Pelagic	Rare	N.A.	N.A.	NL	NL	I
Stejneger's beaked whale	Likely pelagic	Uncommon	N.A	3044[20,23]	NL	DD	II
Pacific white-sided dolphin	Pelagic, shelf, coastal	Uncommon	26,880[24]	988,333[25]	NL	LC	II
Northern right whale dolphin	Slope, pelagic	Rare	N.A	26,556[20]	NL	LC	II
Risso's dolphin	Pelagic, shelf, coastal	Rare	N.A.	838,000[26]	NL	LC	II
Killer whale	Pelagic, shelf, coastal	Common	2347[27] 587[28] 300[29]	5000[30]	NL[31]	DD	II
Harbor porpoise	Coastal	Common	48,215[32] 31,046[33]	N.A.	NL	LC	II
Dall's porpoise	Pelagic, shelf	Common	83,400[34]	1,186,000[35]	NL	LC	II
Pinnipeds							
Northern fur seal	Pelagic, breeds coastally	Common	620,660[36]	1.1 million[37]	NL	VU	NL
Steller sea lion	Coastal, offshore	Common	43,201[38] 53,624[39]	N.A.	EN/DL[40]	EN[51]	NL
Harbor seal	Coastal	Common	5588[41]	205,090[42]	NL	LC	NL
Northern elephant seal	Coastal, offshore	Uncommon	N.A.	210,000-239,000[43]	NL	LC	NL
Ribbon seal	Mostly pelagic, ice-associated	Uncommon	184,697[44]	N.A.	NL	LC	NL
Spotted seal	Pelagic, coastal, ice-associated	Rare	461,625[44]	N.A.	NL	LC	NL
Fissipeds							
Northern Sea Otter	Coastal	Common	54,771[45] 25,712[46] 18,297[47]	N.A.	T[48]	EN	II

N.A. = not available. NL = Not listed.

* Occurrence in area at the time of the survey; based on LGL professional opinion and available data.

[1] U.S. Endangered Species Act (ESA): EN = Endangered; T = Threatened; DL = Delisted;

[2] 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; NT = Near Threatened; DD = Data Deficient.

[3] 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.

[4] Bering Sea/Aleutian Islands (Wade et al. 2011b).

[5] North Pacific (Jefferson et al. 2015).

[6] Eastern North Pacific stock (Carretta et al. 2019).

[7] Western North Pacific stock (Carretta et al. 2019).

[8] Western stock is endangered; eastern stock was delisted (Carretta et al. 2019).

[9] Western North Pacific stock (Muto et al. 2019a).

[10] Central North Pacific stock (Muto et al. 2019a).

[11] North Pacific, 2004–2006 (Barlow et al. 2011).

[12] Western North Pacific DPS is listed as endangered and Mexico DPS is threatened; the Hawaii DPS was delisted in 2016.

[13] Western GOA and eastern Aleutians (Zerbini et al. 2006).

[14] Northwest Pacific and Okhotsk Sea (IWC 2019).

[15] Central and Eastern North Pacific (Hakamada and Matsuoka 2015).

[16] North Pacific (Ohsumi and Wada 1974).

[17] Eastern North Pacific stock (Calambokidis and Barlow 2013).

[18] Northern GOA and Aleutians (Zerbini et al. 2004).

[19] Northeast Temperate Pacific; estimate based on visual sightings (Barlow and Taylor 2005).

[20] California/Oregon/Washington stock (Carretta et al. 2019).

[21] Pacific coast of Japan (Thewissen 2018).

[22] Western Pacific Ocean (Okamura et al. 2012).

[23] All mesoplodont whales (Carretta et al. 2019).

[24] U.S. North Pacific stock (Muto et al. 2019a).

[25] North Pacific Ocean (Miyashita 1993b).

[26] Western North Pacific Ocean (Miyashita 1993a).

[27] Eastern North Pacific Alaska Resident stock (Muto et al. 2019a).

[28] Eastern North Pacific Gulf of Alaska, Aleutian Islands, and Bering Sea Transient stock (Muto et al. 2019a).

[29] Eastern North Pacific Offshore stock (Carretta et al. 2019).

[30] Northeastern Pacific Ocean, from Aleutians to California (Ford 2018).

[31] Only the southern resident DPS is listed as endangered, but it does not occur in the Aleutian Islands.

[32] Bering Sea stock (Muto et al. 2019a).

[33] GOA stock (Muto et al. 2019a).

[34] Alaska stock, but estimate more than 8 years old (Muto et al. 2019a).

[35] North Pacific Ocean and Bering Sea (Houck and Jefferson 1999).

[36] Eastern Pacific stock (Muto et al. 2019a).

[37] North Pacific (Jefferson et al. 2015).

[38] Eastern U.S. stock (Muto et al. 2019a).

[39] Western U.S. stock (Muto et al. 2019a).

[40] The Western DPS is listed as endangered; the Eastern DPS was delisted in 2013.

[41] Aleutian Island stock (Muto et al. 2019a).

[42] Alaska statewide (Muto et al. 2019a).

[43] U.S. and Mexico (Lowry et al. 2014).

[44] Alaska (Muto et al. 2019a).

[45] Southwest Alaska DPS (Muto et al. 2019b).

[46] Southeast Alaska DPS (Muto et al. 2019b).

[47] Southcentral Alaska DPS (Muto et al. 2019b).

[48] Southwest Alaska DPS is threatened; others are not listed.

[49] Northeast Pacific subpopulation is critically endangered; globally, the North Pacific right whale is considered endangered.

[50] Globally considered as least concern; western population listed as endangered.

[51] Globally considered as near threatened; western population listed as endangered.

Kodiak Island in 2000 during August and September (Waite et al. 2003; Mellinger et al. 2004b), but no acoustic detections were made from April to August 2003 (Munger et al. 2008) or in April 2009 (Rone et al. 2010). Three sightings and one acoustic detection of right whales were made in Barnabas Trough south of Kodiak Island during NOAA surveys in 2004 to 2006 in areas with high densities of zooplankton (Wade et al. 2011a). Those authors also report a fourth opportunistic sighting by a commercial fisher during that time in the same area. Another three right whales were acoustically detected in the Barnabas Trench area during a towed-PAM survey of the U.S. Navy training area east of Kodiak in the summer of 2013, but none were observed visually (Rone et al. 2014). Right whales were not detected acoustically in any year (2011–2015) of the fixed PAM monitoring east of Kodiak Island (Baumann-Pickering et al. 2012; Debich et al. 2013; Rice et al. 2015), and no right whales were visually observed during three years of surveys (2009, 2013, and 2015) to the east and south of Kodiak Island (Rone et al. 2017). However, a right whale was detected acoustically on a recorder in the GOA (56.3°N, 145.2°W) during summer 2013 (Širović et al. 2015). A single North Pacific right whale was seen during L-DEO's seismic survey in the western GOA in summer 2011 (RPS 2011). A feeding BIA has been identified east of the Kodiak Archipelago, encompassing the GOA critical habitat and extending south of 56°N and north of 58°N and beyond the shelf edge (Ferguson et al. 2015a).

In the eastern North Pacific, south of 50ºN, only 29 reliable sightings were recorded from 1900 to 1994 (Scarff 1986, 1991; Carretta et al. 1994). Starting in 1996, right whales have been sighted regularly in the SEBS, including calves in some years (Goddard and Rugh 1998; LeDuc et al. 2001; Moore et al. 2000, 2002b; Wade et al. 2006; Zerbini et al. 2009; Friday et al. 2012); they have also been detected acoustically when sonobuoys were deployed (McDonald and Moore 2002; Munger et al. 2003; 2005, 2008; Berchok et al. 2009; Crance et al. 2017; Wright et al. 2017). Right whales are known to occur in the SEBS from May to December (e.g., Tynan et al. 2001; Hildebrand and Munger 2005; Munger et al. 2005, 2008). Call frequencies tend to be higher in July–October than from May–June or November–December (Munger et al. 2008). Right whales seem to pass through the middle-shelf areas, without remaining there longer than a few days (Munger et al. 2008). Besides being a critical habitat area, this region has also been identified as a BIA for right whale feeding (Ferguson et al. 2015b). In addition, calls have also been detected north of St. Matthew Island (61.6°N) during summer 2016 and within Unimak Pass in the eastern Aleutian Islands during all months of the year (Wright et al. 2018, 2019). Single sightings have also been reported just north of Unimak Pass (Zerbini et al. 2015) and in the northern Bering Sea, at Chukotka (Filatova et al. 2019). One right whale was sighted in the Aleutian Islands south of Unimak Pass in September 2004 (Wade et al. 2011b). Matsuoka et al. (2018) also reported a sighting to the south of the Aleutian Islands (~42°N, 180°), along with numerous other sightings to the southwest of the Aleutian Islands and in the Sea of Okhotsk during 1982–2016, likely from the western stock. It is possible although unlikely that a right whale could be seen during the proposed survey.

3.3.1.2 Gray Whale (*Eschrichtius robustus*)

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

Gray whale populations were severely reduced by whaling, but the eastern North Pacific population is considered to have recovered. In 2009, Punt and Wade (2012) estimated the eastern North Pacific population to be at 85% of its carrying capacity. The eastern North Pacific gray whale breeds and winters in Baja, CA, and migrates north to summer feeding grounds in the northern Bering, Chukchi, and western

Beaufort seas (Rice and Wolman 1971; Rice 1998; Jefferson et al. 2015). Most of the eastern Pacific population makes a round-trip annual migration of >18,000 km. From late May to early October, the majority of the population concentrates in the northern and western Bering and Chukchi seas. However, some individuals spend the summer months scattered along the coasts of southeast Alaska, B.C., Washington, Oregon, and northern California (Rice and Wolman 1971; Nerini 1984; Darling et al. 1998; Dunham and Duffus 2001, 2002; Calambokidis et al. 2002). Gray whales are found primarily in shallow water (Braham 1984).

It is difficult to determine precisely when the southbound migration begins; whales near Barrow were moving predominantly south in August (Maher 1960; Braham 1984). Gray whales leave the Bering Sea through Unimak Pass from late October through January (Braham 1984). From October to January, the main part of the population moves down the west coast of North America. Rugh et al. (2001) analyzed data collected from two sites in California to estimate the timing of the gray whale southward migration; the median date for the migration was 1 December in the central Bering Sea (a nominal starting point), 12 December at Unimak Pass, 18 December at Kodiak Island, and 5 January for Washington.

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

In summer, gray whales are seen in the Bering Sea (Moore et al. 2002b; Friday et al. 2012, 2013) and in the GOA, including around Kodiak Island (e.g., Wade et al. 2003; Calambokidis et al. 2004; Calambokidis 2007; Moore et al. 2007). In fact, gray whales have been seen feeding off southeast Kodiak Island, in particular near Ugak Bay, year-round (Moore et al. 2007). One feeding aggregation in July consisted of 350–400 animals, clustered in groups of 10–20 animals, from the mouth of Ugak Bay to 100 km southeast of Ugak Island (Moore et al. 2007). Rone et al. (2017) sighted gray whales off Ugak Island, Kodiak, in all three years (2009, 2013, and 2015) of surveys east of Kodiak Island. Gray whales were detected acoustically throughout the summer and fall at fixed hydrophones on the shelf off Kenai Peninsula and near Kodiak Island in the military training area in a 2014–2015 study (Rice et al. 2015). During aerial surveys in the northwestern GOA and SEBS in 1985, Brueggeman et al. (1987) sighted most gray whales during the migration periods in April and November–December; only a few whales were seen in the area during summer.

BIAs for feeding for gray whales have been identified in the waters east of the Kodiak Archipelago (greatest densities from June through August; Ferguson et a. 2015a), and along the northern Alaska Peninsula, where the greatest densities occur from April to July (Ferguson et al. 2015b). Additionally, migratory corridor BIAs have been identified: (1) from Unimak Pass in the western GOA to the Canadian border in the eastern GOA, as gray whales occur in this area in high densities during November through January (southbound) and March through May (northbound); (2) from Unimak Pass to Nunivak Island for the northbound migration; and (3) Unimak Pass during the southbound migration (Ferguson et al. 2015a,b). Gray whales are considered common in the nearshore waters of the eastern Aleutian Islands, but are not likely to occur in the study area farther to the west. Twenty-two gray whale sightings of 123 individuals were seen during summer (July–August) surveys in 2001–2003 from the Kenai Peninsula to the central Aleutian Islands (Wade et al. 2003). In June 2001, a group of ~30 killer whales was seen feeding on a gray whale carcass in Unimak Pass (Wade et al. 2003). However, gray whales are unlikely to occur in the proposed Aleutian Arc study area.

3.3.1.3 Humpback Whale (*Megaptera novaeangliae*)

The humpback whale is found in all ocean basins (Clapham 2018), with genetic evidence suggesting three separate subspecies: North Pacific, North Atlantic, and Southern Hemisphere (Jackson et al. 2014). Nonetheless, genetic analyses suggest some gene flow (either past or present) between the North and South Pacific (e.g., Jackson et al. 2014; Bettridge et al. 2015). Although considered to be mainly a coastal species, the humpback whale often traverses deep pelagic areas while migrating (e.g., Mate et al. 1999; Garrigue et al. 2015). North Pacific humpback whales migrate between summer feeding grounds along the Pacific Rim and the Bering and Okhotsk seas and winter calving and breeding areas in subtropical and tropical waters (Pike and MacAskie 1969; Rice 1978; Winn and Reichley 1985; Calambokidis et al. 2000, 2001, 2008).

In the North Pacific, humpbacks winter in four different breeding areas: (1) along the coast of Mexico; (2) along the coast of Central America; (3) around the Main Hawaiian Islands; and (4) in the western Pacific, particularly around the Ogasawara and Ryukyu islands in southern Japan and the northern Philippines (Calambokidis et al. 2008; Fleming and Jackson 2011; Bettridge et al. 2015). These breeding areas are recognized as the Mexico, Central America, Hawaii, and Western North Pacific DPSs, respectively (NMFS 2016b). Hawaii is the primary wintering area for whales from summer feeding areas in the GOA (Calambokidis et al. 2008). However, individuals from the Hawaii, Western North Pacific, and Mexico DPSs could occur in the proposed Aleutian Arc survey area to feed (e.g., Calambokidis et al. 2008; Titova et al. 2018).

There is potential for mixing of the western and eastern North Pacific humpback stocks on their summer feeding grounds (Muto et al. 2019a,b). NMFS is currently reviewing the global humpback whale stock structure in light of the revision to their ESA listing and identification of 14 DPSs (NMFS 2016b). NMFS recognizes two stocks of humpback whales in Alaskan waters – the Central North Pacific stock occurs from southeast Alaska to the Alaska Peninsula, and the Western North Pacific stock occurs from the Aleutians to the Bering Sea and Russia. These two stocks overlap on feeding grounds in the eastern Bering Sea and the western GOA (Muto et al. 2019a,b). Given the stock boundaries, only the Western North Pacific stock is likely to occur within the proposed Aleutian Arc study area. BIAs for humpback whale feeding have been identified: (1) along the eastern Aleutian Islands and Bristol Bay (highest densities June through September); (2) Shumagin Islands (highest densities from July through August); (3) around Kodiak Island (highest densities from July through September); and (4) PWS (high densities from September to December) (Ferguson et al. 2015a,b).

Waite et al. (1999) identified 127 individuals in the western GOA and eastern Aleutian Islands from 1991 to 1994; most sightings occurred around Kodiak Island, but sightings were also made in the Shumagin Islands, off Akutan Island, and ~280 km south of the Shumagin Islands. During July 2003, two killer whales were seen harassing a humpback whale mother and calf east of the Shumagin Islands (Wade et al. 2003). Waite (2003) reported that 117 humpbacks were seen in 41 groups during their surveys in the western GOA in 2003, with aggregations off northeast Kodiak Island. Sightings of humpbacks around Kodiak Island were made most frequently in the fall, and aggregations were seen off Shuyak and Sitkalidak islands (Wynne and Witteveen 2005), as well as in Marmot and Chiniak bays (Baraff et al. 2005). Sightings have been reported south and east of Kodiak Island during surveys by Rone et al. (2017), and peak acoustic detections were made in the U.S. Navy training area in the GOA during late fall through early winter, with detections at all shelf, slope, and seamount sites (Baumann-Pickering et al. 2012; Debich et al. 2013; Rice et al. 2015). In the western GOA, humpback whales were the most frequently sighted cetacean during

L-DEO's seismic survey in summer 2011 (RPS 2011), but only two sightings were made during L-DEO's seismic survey in June 2019 (RPS 2019a).

Humpback whales are considered common in nearshore waters of the eastern Aleutian Islands. Forney and Brownell (1996) made 57 sightings during their surveys south of the eastern Aleutian Islands and western GOA in 1994; they were the second-most frequently-encountered cetacean and the most commonly-seen large whale. In the eastern Aleutians, they were mostly seen in offshore waters over the Aleutian Trench or the Aleutian Abyssal Plain (Forney and Brownell 1996). Waite et al. (1999) identified seven whales near Akutan Island in 1991. During summer surveys from the Kenai Fjord to Amchitka Pass in the central Aleutian Islands in 2001–2003, 407 sightings of 773 humpbacks were made (Wade et al. 2003). They were most abundant near Kodiak Island, Shumagin Islands, and Unimak Pass, with the most westerly sighting at Umnak Island; abundance in the area was estimated at 2644, with a density of 0.0012 whales/km^2 (Zerbini et al. 2006). Humpbacks that were tagged near Unalaska Bay during the summer spent the majority of time on the Bering Sea shelf and slope; one individual traveled as far west as the Island of Four Mountains, just west of Samalga Pass, and another humpback traveled all the way to Chukotka, Russia, before traveling east again to Navarin Canyon (Kennedy et al. 2014).

During surveys in the central eastern Bering Sea (CEBS) and SEBS, humpbacks have been primarily sighted southwest of St. Lawrence Island, in Bristol Bay, and along the Alaska Peninsula (Moore et al. 2002b; Friday et al. 2012, 2013). The abundance estimate for 2010 for the U.S. portion of the Bering Sea was 675, with a density of 0.0006/km^2 (Friday et al. 2013). Sightings were also made in the eastern Aleutian Islands, including north of Unimak and Unalaska Islands, and in Unimak Pass (Moore et al. 2002b; Friday et al. 2012, 2013). During the Splash 2004 Cruise from 12 to 25 August, nine humpback whales were seen in the Aleutian Islands (Barlow 2004a,b). During an L-DEO cruise along the Aleutian Islands during summer 2005, humpback whales were only seen along northern Unalaska Island (Ireland et al. 2005). This species could be encountered during the proposed survey.

3.3.1.4 Common Minke Whale (*Balaenoptera acutorostrata*)

The common minke whale has a cosmopolitan distribution ranging from the tropics and subtropics to the ice edge in both hemispheres (Jefferson et al. 2015). In the Northern Hemisphere, minke whales are usually seen in coastal areas, but can also occur in pelagic waters during northward migrations in spring and summer, and southward migration in autumn (Stewart and Leatherwood 1985). In the North Pacific, the summer range extends to the Chukchi Sea; in the winter, minke whales move further south to within 2º of the Equator (Perrin et al. 2018). The International Whaling Commission (IWC) recognizes three stocks in the North Pacific: the Sea of Japan/East China Sea, the rest of the western Pacific west of 180º, and the remainder of the Pacific (Donovan 1991). Minke whales are relatively common in the Bering and Chukchi seas and in the inshore waters of the GOA (Mizroch 1992). They are also considered common in the Aleutian Islands, but they are not abundant in any other part of the eastern Pacific (Brueggeman et al. 1990).

Sightings in the GOA, near Kodiak Island, were made by Rone et al. (2017) as well as by RPS (2011) during the L-DEO seismic survey conducted in the summer of 2011. Additionally, Waite (2003) sighted four minke whales in three groups during surveys in the western GOA in 2003, south of the Kenai Peninsula and south of PWS. Baraff et al. (2005) reported a single sighting near Kodiak Island in July 2002. Moore et al. (2002b) reported a minke whale sighting south of the Sanak Islands. In 2001, three killer whales were observed attacking a minke whale near the Shumagin Islands (Wade et al. 2003).

Minke whales have been seen throughout the Bering Sea (Moore et al. 2002b; Friday et al. 2012, 2013). The abundance estimate for the U.S. portion of the Bering Sea for 2010 was 2020 whales, with a density of 0.0019/km^2 (Friday et al. 2013). Sightings were also made in the eastern Aleutian Islands, including north of Unimak and Unalaska islands (Moore et al. 2002b; Friday et al. 2012, 2013). Moore

(2001) noted the occurrence of resident minke whales in Akutan Pass. A total of 96 sightings of single minke whales were made during surveys in summer 2001–2003 extending from the Kenai Fjord to the central Aleutian Islands (Wade et al. 2003). Minke whales occurred primarily in the Aleutians, with numerous sightings in the proposed survey area, including in Seguam Pass, and off Amlia, Atka, Adak, Kanaga, and Tanaga islands; abundance in the survey region was estimated at 1233 animals, with a density of 0.006 whales/km^2 (Zerbini et al. 2006).

During the Splash 2004 Cruise from 12 to 25 August, five minke whales were seen in the Aleutian Islands (Barlow 2004a). Forney and Brownell (1996) also noted five sightings of minke whales during surveys south of the Aleutian Islands. During an L-DEO cruise along the Aleutian Islands during summer 2005, minke whales were sighted just east of the proposed survey area northeast of Seguam Island (~52.7°N, 171.7°W; one whale), north of Seguam Island (~53.6°N, 172.4°W; two sightings of three whales), north of Amlia Island (~53.5°N, 173.2°W; three individuals), and one individual southwest of Kiska Island (Ireland et al. 2005). Thus, minke whales are likely to be common 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).

In the U.S. Pacific, an Eastern North Pacific and a Hawaii stock are recognized (Carretta et al. 2019). During summer in the North Pacific, the sei whale can be found from the Bering Sea to the northern GOA and south to California, and in the western Pacific from Japan to Korea. Its winter distribution is concentrated at ~20°N, and sightings have been made between southern Baja California and Islas Revilla Gigedo (Rice 1998). No breeding grounds have been identified for sei whales; however, calving is thought to occur from September to March.

Sei whales are considered uncommon in the Aleutian Islands (Sobolevsky and Mathisen 1996). Sightings during summer have been reported for the eastern Bering Sea and south of the Alaska Peninsula during surveys from 1999 through 2010 (Moore et al. 2002b; Friday et al. 2012), and in the eastern Aleutians (Friday et al. 2013). Rone et al. (2017) reported a single sei whale in 2015 south of Kodiak Island. One sighting of two sei whales was reported during L-DEO's seismic survey in the western GOA in summer 2011 (RPS 2011). Sei whales are likely to be uncommon in the proposed survey area.

3.3.1.6 Fin Whale (*Balaenoptera physalus*)

The fin whale is widely distributed in all the world's oceans (Gambell 1985), although it is most abundant in temperate and cold waters (Aguilar and García-Vernet 2018). Nonetheless, its overall range and distribution is not well known (Jefferson et al. 2015). 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 the summer; they are known to use the shelf edge as a migration route (Evans 1987). However, some animals may remain at high latitudes in winter or low latitudes in summer (Edwards et al. 2015).

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 and not all populations follow this simple pattern (Jefferson 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).

North Pacific fin whales summer from the Chukchi Sea to California and winter from California southwards (Gambell 1985). In the U.S., three stocks are recognized in the North Pacific: California/ Oregon/Washington, Hawaii, and Alaska (Northeast Pacific) (Carretta et al. 2019). 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, GOA, and Aleutian Islands, call rates peak during summer and fall (Moore et al. 1998, 2006; Watkins et al. 2000a,b; Stafford et al. 2009). Stafford et al. (2009) noted that sea-surface temperature is a good predictor variable for fin whale call detections in the North Pacific.

A BIA for fin whale feeding has been identified in the GOA, south of the Kenai Peninsula, inshore of the Kodiak Archipelago, and along the Alaska Peninsula, including the Semidi Islands and Shelikof Strait (Ferguson et al. 2015a). Fin whales have been sighted around Kodiak Island year-round, but most sightings were made in the spring and summer (Wynne and Witteveeen 2005). Numerous sightings of fin whales were made between the Semidi Islands and Kodiak Island during surveys by Waite (2003), and Moore (2001) reported fin whale sightings near Semidi Island and Shumagin Islands during June 2001. Rone et al. (2017) reported numerous fin whale sightings south and east of Kodiak Island; fin whales were also frequently detected acoustically throughout the year in the central GOA (Baumann-Pickering et al. 2012; Debich et al. 2013; Rice et al. 2015). Fin whales were the most frequently sighted cetacean during L-DEO's seismic survey in the western GOA during spring 2019 (RPS 2019a), and the second most frequently sighted cetacean during L-DEO's seismic survey in the region in summer 2011 (RPS 2011).

Another BIA for fin whale feeding have been identified in the eastern Bering Sea. Numerous sightings have been reported during surveys in the CEBS and SEBS from 1999 through 2010 (Moore et al. 2002b; Friday et al. 2012, 2013). Fin whale abundance for the U.S. portion of the Bering Sea was estimated at 1061 whales in 2010, with a density of 0.0010/km^2 (Friday et al. 2013). Moore et al. (2002b) noted that sighting rates were more than twice as high in water >100 m deep than in water 50–100 m deep; no sightings occurred in water <50 m deep. Sightings were also made in the eastern Aleutian Islands, including north of Unalaska Island (Moore et al. 2002b; Friday et al. 2012, 2013).

Sightings have been reported in the eastern Aleutian Islands year-round, but sightings in the proposed survey area appear to be restricted to summer (June–August) (Edwards et al. 2015). During summer surveys from the Kenai Fjord to Amchitka Pass in the central Aleutian Islands in 2001–2003, 276 sightings totaling 580 fin whales were made (Wade et al. 2003). Sightings were concentrated along the Alaska Peninsula, with additional sightings around Kodiak Island and the eastern Aleutian Islands; the western-most sightings were north of the Islands of Four Mountains, east of the proposed survey area; abundance in the survey region was estimated at 1652, with a density of 0.007 whales/km^2 (Zerbini et al. 2006).

Forney and Brownell (1996) reported four sightings of fin whales in slope and shelf waters south of the Aleutian Islands. During the Splash 2004 Cruise from 12 to 25 August in the Aleutian Islands, four fin whales were seen (Barlow 2004b). During an L-DEO cruise along the Aleutian Islands during summer 2005, sightings of fin whales were made near the proposed survey area, including north of Atka Island (~53.4°N, 174.5°W; one individual) and north of Amlia Island (~53.5°N, 173.0°W; three individuals)

(Ireland et al. 2005). During an L-DEO cruise at the Emperor Seamount chain south of the western Aleutian Islands during spring, two fin whale sightings were made (RPS 2019b). Fin whales could 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). Blue whale migration is less well defined than for some other rorquals, and its movements tend to be more closely linked to areas of high primary productivity, and hence prey, to meet its high energetic demands (Branch et al. 2007). Generally, blue whales are seasonal migrants between high latitudes in the summer, where they feed, and low latitudes in the winter, where they mate and give birth (Lockyer and Brown 1981). Some individuals may stay in low or high latitudes throughout the year (Reilly and Thayer 1990; Watkins et al. 2000b).

Although it has been suggested that there are at least five subpopulations in the North Pacific (Reeves et al. 1998), analysis of calls monitored from the U.S. Navy Sound Surveillance System (SOSUS) and other offshore hydrophones (e.g., Stafford et al. 1999, 2001, 2007; Watkins et al. 2000a; Stafford 2003) suggests that there are two separate populations: one in the eastern and one in the central North Pacific (Carretta et al. 2019). The Eastern North Pacific stock includes whales that feed primarily off California from June–November and winter off Central America (Calambokidis et al. 1990; Mate et al. 1999). The Central North Pacific Stock feeds off Kamchatka, south of the Aleutians and in the GOA during summer (Stafford 2003; Watkins et al. 2000b) and migrates to the western and central Pacific (including Hawaii) to breed in winter (Stafford et al. 2001; Carretta et al. 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).

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

In July 2004, three blue whales were sighted in the GOA; the first blue whale was seen on 14 July ~185 km southeast of PWS. Two more blue whales were seen ~275 km southeast of PWS (NOAA 2004a; Calambokidis et al. 2009). These whales were thought to be part of the California feeding population (Calambokidis et al. 2009). Three blue whales were seen in mid July 2004 at a location 200–250 km southeast of PWS at a water depth of ~3000 m, and 15 were seen from R/V *Maurice Ewing* in August 2004 near Dixon Entrance (MacLean and Koski 2005). Western blue whales are more likely to occur in the western portion of the GOA, southwest of Kodiak, where their calls have been detected (Stafford 2003). Rone et al. (2017) reported blue whale sightings east of Kodiak Island. Sightings of blue whales were made within the study area (south of the Aleutian Islands) and in the GOA during surveys conducted in 2010–2014 (Branch et al. 2016).

Blue whale distribution in the Northwest Pacific appears to be associated with the Emperor Seamounts (south of the Aleutian Islands) and the steep continental slope off the Kamchatka Peninsula, and the western Aleutian Islands (Moore et al. 2002a). In the summer, concentrations of blue whale calls were evident in the waters between the seamounts and the western Aleutian Islands; in the spring, blue whale locations were associated with high chlorophyll *a* concentrations (Moore et al. 2002a). During the Splash 2004 Cruise from 12 to 25 August, two blue whales were seen in the Aleutian Islands; one was seen at the far western end of the Aleutian archipelago, and the other ~130 km south-southeast of Tanaga Island (Barlow 2004b). Two blue whale sightings were also made in the Aleutians in August 2004; one of these was made just to the west of the proposed survey area (Rankin et al. 2006; Calambokidis et al. 2009). In addition, blue whales were detected acoustically along the southern Aleutian Islands during August 2004 (Rankin et al. 2006), including within the proposed survey area. Thus, blue whales could be encountered during the proposed survey.

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). Males may migrate north in the summer to feed in the GOA, Bering Sea, and waters around the Aleutian Islands (Muto et al. 2019a,b); an unusual sighting of a group of female and immature sperm whales was seen in the central Aleutian Islands during winter (February) 2008 (Fearnbach et al. 2012).

Sperm whales are commonly sighted and detected acoustically in the Aleutians and the central and western GOA (e.g., Forney and Brownell 1996; Moore 2001; Waite 2003; Wade et al. 2003; Zerbini et al. 2004; Barlow and Henry 2005; Ireland et al. 2005; Straley et al. 2005; Moore et al. 2006; Rone et al. 2010, 2014, 2017; Baumann-Pickering et al. 2012; Debich et al. 2013; Rice et al. 2015). There are fewer reports on the occurrence of sperm whales in the eastern GOA (e.g., Rice and Wolman 1982; Mellinger et al. 2004a; MacLean and Koski 2005). During surveys south of the Aleutian Islands in 1996, the sperm whale was the second most commonly sighted large whale; 12 sightings were made, most in deep (4000–5000 m) water over the Aleutian Abyssal Plain and Aleutian Trench (Forney and Brownell 1996). During summer surveys extending from the Kenai Fjord to the central Aleutian Islands in 2001–2003, 37 sightings of 44 sperm whales were made (Wade et al. 2003). During a survey in the eastern Aleutian Islands in June 2001, Moore (2001) noted that sperm whales were common north of Seguam Island and in Seguam Pass. During the Splash 2004 Cruise from 12 to 25 August, 18 sperm whales were seen throughout the Aleutian Islands (Barlow 2004a,b). Zerbini et al. (2004) estimated the abundance of sperm whales in the northern GOA and eastern Aleutian Islands at 159. During an L-DEO cruise along the Aleutian Islands during summer 2005, 72 groups totaling 78 individuals were seen, including sightings just west (~51.7°N, 179.3°W), northeast of Seguam Island (~52.6°N, 172.1°W), and within (52.6°N, 172.6°W) the proposed survey area north of Seguam Island, as well as in the western Aleutian (Ireland et al. 2005). During an L-DEO cruise at the Emperor Seamount chain south of the western Aleutian Islands during spring, one sperm whale was sighted (RPS 2019b). Sperm whales could be encountered during the proposed survey.

3.3.2.2 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 2018). 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 (Baird 2018).

Cuvier's beaked whale ranges as far north as Alaska and the Commander Islands (Rice 1986, 1998). Most reported sightings have been in the Aleutian Islands (e.g., Leatherwood et al. 1983; Forney and Brownell 1996; Brueggeman et al. 1987). Leatherwood et al. (1983) noted the occurrence of Cuvier's beaked whales in the eastern Aleutian Islands and summarized sightings there. One sighting was made during surveys south of the Aleutians in 1994 in deep (4000–5000 m) water (Forney and Brownell 1996). They have been detected acoustically near Kiska Island during summer (Baumann-Pickering et al. 2013, 2014). They have also been sighted (Brueggeman et al. 1987; Waite 2003; Rone et al. 2017) and detected acoustically (Rone et al. 2014; Rice et al. 2015) in the GOA near Kodiak Island. Cuvier's beaked whale could be encountered during the proposed survey.

3.3.2.3 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). Leatherwood et al. (1983) summarized sightings in the eastern Aleutians. Baumann-Pickering et al. (2013) reported that a mass stranding occurs in the Aleutian Islands every three years, most of which have occurred on Adak Island. In the past, groups of 3–15 Stejneger's beaked whales have been sighted on occasion near the central Aleutian Islands (Rice 1986). A sighting of two unidentified beaked whales, possibly Stejeneger's beaked whales, was made on the south side of Unalaska Island during surveys in 2002 (Wade et al. 2003). Muto et al. (2019b) reported one sighting within the western-most portion of the proposed survey area. More recently, they have been detected acoustically in the Aleutian Islands during summer, fall, and winter (Baumann-Pickering et al. 2014), and they were detected year-round at deep-water sites east of Kodiak Island (Baumann-Pickering et al. 2012; Debich et al. 2013; Rone et al. 2014; Rice et al. 2015). Stejneger's beaked whale 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 were recognized until recently – the common slate-gray form and a smaller, rare black form (Morin et al. 2017). The gray form is seen off Japan, 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 have now shown that the black form is a separate species, *B. mimimus* (Yamada et al. 2019).

Baird's beaked whale is currently divided into three distinct stocks: Sea of Japan, Okhotsk Sea, and Bering Sea/eastern North Pacific (Balcomb 1989; Reyes 1991). Baird's beaked whales sometimes are seen close to shore, but their primary habitat is over or near the continental slope and oceanic seamounts in waters 1000–3000 m deep (Jefferson et al. 1993; Kasuya and Ohsumi 1984; Thewissen 2018). Baird's beaked whale is migratory, arriving in the Bering Sea in the spring, and remaining there throughout the summer; the winter distribution is unknown. There are numerous sighting records from the central GOA to the Aleutian Islands and the southern Bering Sea (Leatherwood et al. 1983; Kasuya and Ohsumi 1984; Forney and Brownell 1996; Brueggeman et al. 1987; Moore et al. 2002b; Waite 2003; Wade et al. 2003; Friday et al. 2012, 2013). In the GOA, Baird's beaked whales have been sighted (Rone et al. 2014, 2017) and detected acoustically (Baumann-Pickering et al. 2012; Debich et al. 2013; Rice et al. 2015) east of Kodiak Island. Brueggeman et al. (1987) noted the occurrence of Baird's beaked whales during aerial surveys in 1985 in the northwestern GOA.

Leatherwood et al. (1983) reported a sighting of a Baird's beaked whale by Umnak Island and summarized previous sightings in the area. A total of eight sightings of 86 Baird's beaked whales were made during summer surveys extending from the Kenai Fjord to the central Aleutian Islands in 2001–2003; one group was seen on the north side of Tanaga Island (Wade et al. 2003). Forney and Brownell (1996) made one sighting of Baird's beaked whale during surveys along the south side of the Aleutians in 1994 in deep (4000–5000 m) water. Baumann-Pickering et al. (2014) reported acoustic detections at a recorder deployed at Buldir Island. According to Muto et al. (2019b), there have been several sightings within the proposed survey area, extending from Seguam Pass to Amchitka Pass. Thus, Baird's beaked whale could be encountered during the proposed survey.

3.3.2.5 Sato's Beaked Whale (*Berardius minimus*)

Sato's beaked whale was recently described as a new species by Yamada et al. (2019), who distinguished it from *B. bairdii* as being smaller and darker in color. This species (unnamed at the time) was previously described by Morin et al. (2017). It occurs in the North Pacific, where individuals have been reported for Hokkaido, Japan and the eastern Aleutian Islands (Morin et al. 2017; Yamada et al. 2019). In the eastern Aleutian Islands, all five specimens were reported between 162° and 170°W, with one record near St. George Island, two near the Fox Islands, one north of the Fox Islands, and one near Izembek Lagoon at the southern end of Alaska Peninsula (Morin et al. 2017). Sato's beaked whale is thought to be rare or at least not to frequent continental slopes or canyons, where it might be observed more readily (Morin et al. 2017). Although there are no records within the central Aleutian survey area, Sato's beaked whale could be encountered during the proposed survey.

3.3.2.6 Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*)

The Pacific white-sided dolphin is found throughout the temperate North Pacific between 20°N and 61°N (Waite and Shelden 2018). It is common both on the high seas and along the continental margins (Leatherwood et al. 1984; Dahlheim and Towell 1994; Ferrero and Walker 1996). Pacific white-sided dolphins were seen throughout the North Pacific during surveys conducted during 1983–1990 (Buckland et al. 1993; Miyashita 1993b). During winter, this species is most abundant in California slope and offshore areas; as northern marine waters begin to warm in the spring, it appears to move north to slope and offshore waters off Oregon/Washington (Green et al. 1992, 1993; Forney 1994; Forney et al. 1995; Buchanan et al. 2001; Barlow 2003). During the summer, Pacific white-sided dolphins occur north into the GOA and west to Amchitka in the Aleutian Islands, as well as into the Bering Sea (Muto et al. 2019b).

Sightings have been reported in the western GOA (Waite 2003; Rone et al. 2010, 2017), as well as in the Bering Sea along the Alaska Peninsula (Moore et al. 2002b; Friday et al. 2012; Waite and Shelden 2018), and the Aleutians (Friday et al. 2013; Waite and Shelden 2018). They have also been detected acoustically in the Bering and Chukchi seas between 2007 and 2017 (Seger and Miksis-Olds 2019). Neither Buckland et al. (1993) nor Miyashita (1993b) reported sightings near the Aleutian Islands. Wade et al. (2003) reported one sighting of eight individuals during summer (July–August) surveys in 2001–2003 from the Kenai Peninsula to the central Aleutian Islands. Waite and Shelden (2018) reported several sightings within the proposed survey area (off Atka Island and north of Amlia Island), during summer, autumn, and winter. Pacific white-sided dolphins could be encountered during the proposed survey.

3.3.2.7 Northern Right Whale Dolphin (*Lissodelphis borealis*)

The northern right whale dolphin is found in cool temperate and sub-arctic waters of the North Pacific, ranging from ~30°N to 50°N (Jefferson et al. 2015). In the eastern North Pacific Ocean, it 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 (Jefferson et al. 2015). Northern right whale dolphins typically do not occur as far north as Alaska, but there have been acoustic detections north of 55°N (Seger and Miksis-Olds 2019), extralimital sightings along the Aleutian Islands and GOA (Jefferson et al. 2015), and several sightings north of 50°N in Canadian waters (Baird and Stacey 1991). Northern right whale dolphins are unlikely to be encountered in the proposed survey area.

3.3.2.8 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). In the Northeast Pacific, from California to Washington, the distribution and abundance of Risso's dolphins are highly variable, presumably in response to changing oceanographic conditions on both annual and seasonal time scales (Forney and Barlow 1998; Buchanan et al. 2001; Becker 2007). Water temperature appears to be an important factor affecting their distribution (Kruse et al. 1999; see also Becker 2007). Risso's dolphin is believed to make seasonal north-south movements related to water temperature, spending colder winter months off California and moving north to waters off Oregon/Washington during the spring and summer as northern waters begin to warm (Green et al. 1992, 1993; Buchanan et al. 2001; Barlow 2003; Becker 2007). Risso's dolphins are uncommon to rare in Alaska, but they have been sighted near Chirikof Island (southwest of Kodiak Island) and offshore in the GOA (Consiglieri et al. 1980; Braham 1983). They were detected acoustically once, in January 2013, near Pratt Seamount during fixed-PAM studies from 2011–2015 in the U.S. Navy training area (Debich et al. 2013). They have also been detected acoustically in the Bering and Chukchi seas between 2007 and 2017 (Seger and Miksis-Olds 2019). It is possible although unlikely, that Risso's dolphin would be encountered during the proposed survey.

3.3.2.9 Killer Whale (*Orcinus orca*)

The killer whale is cosmopolitan and globally abundant; it has been observed in all oceans of the world (Ford 2018). It is very common in temperate waters but also occurs in tropical waters (Heyning and Dahlheim 1988) and inhabits coastal and offshore regions (Budylenko 1981). High densities of the species occur in high latitudes, especially in areas where prey is abundant. Killer whale movements generally appear to follow the distribution of its prey, which includes marine mammals, fish, and squid.

Of eight killer whale stocks currently recognized in the Pacific U.S., six occur in Alaskan waters: (1) the Eastern North Pacific Alaska Resident Stock, from southeast Alaska to the Aleutians and Bering Sea, (2) the Eastern North Pacific Northern Resident Stock, from B.C. through parts of southeast Alaska, (3) the Eastern North Pacific Gulf of Alaska, Aleutian Islands, and Bering Sea Transient Stock, from PWS through to the Aleutians and Bering Sea, (4) the AT1 Transient Stock, from PWS through the Kenai Fjords, (5) the West Coast Transient Stock, from California through southeast Alaska, and (6) the Offshore Stock, from California through Alaska. Movements of resident groups between different geographic areas have also been documented (e.g., Leatherwood et al. 1990; Dahlheim et al. 1997). Killer whales occur throughout Alaska, including the Aleutian Islands (Wade et al. 2003; Durban et al. 2010), Bering Sea (Moore et al. 2002b; Friday et al. 2012, 2013), western GOA (RPS 2011, 2019a,b; Rone et al. 2017), and central GOA (Baumann-Pickering et al. 2012; Debich et al. 2013; Rone et al. 2014, 2017).

All three ecotypes of killer whales have been seen in the Aleutian Islands (Wade et al. 2003). In the proposed study area, individuals from the Eastern North Pacific Alaska Resident; North Pacific Offshore; and Eastern North Pacific Gulf of Alaska, Aleutian Islands, and Bering Sea Transient stocks could be encountered during the surveys. During surveys from the Kenai Fjords to Amchitka Pass in the central Aleutian Islands, 59 groups totaling 1038 individuals were seen, including 39 (66%) residents, 14 (24%) transients, 2 (3%) offshore, and 4 (7%) unknown (Wade et al. 2003). Transient killer whale densities were higher south of the Alaska Peninsula between the Shumagin Islands and the eastern Aleutians than in other areas (Wade et al. 2003; Zerbini et al. 2007). Resident killer whales were most abundant near Kodiak Island, around Umnak and Unalaska islands in the eastern Aleutians, and in Seguam Pass in the central Aleutians (Wade et al. 2003; Zerbini et al. 2007). Transient and resident killer whales were sighted as far west as Amchitka Pass (Wade et al. 2003). Durban et al. (2010) also reported transients in the western and eastern portions of the proposed survey area during 2001 to 2003. Only two sightings of offshore killer whales were made, one northeast of Unalaska Island and another one south of Kodiak Island near the Trinity Islands (Wade et al. 2003; Zerbini et al. 2007). As the groups sighted were large, it suggests the number of offshore killer whales in the area is relatively high (Zerbini et al. 2007). Wade et al. (2003) noted that offshore killer whales had the greatest mean group size (50), followed by residents (22), and transients (5). Dahlheim et al. (2008b) encountered groups of 20–60 killer whales in western Alaska; offshore killer whales encountered near Kodiak Island and the eastern Aleutians were also sighted in southeast Alaska and California. A group of at least 54 offshore killer whales was sighted in July 2003 during a survey in the eastern Aleutian Islands (Matkin et al. 2007).

Moore (2001) noted concentrations of killer whales southwest of Unimak Pass and north of Seguam Island. During the Splash 2004 cruise from 12 to 25 August, a total of 18 killer whales were seen in the Aleutian Islands; the majority were thought to be resident whales, and a small percentage were assumed to be transients (Barlow 2004a,b). Three of the killer whales were seen harassing and killing a Dall's porpoise (Barlow 2004b). Forney and Brownell (1996) also made sightings (16) of killer whales during surveys just south of the Aleutian Islands in 1994; they were mainly seen in deep waters over the Aleutian Trench and Aleutian Abyssal Plain. Zerbini et al. (2007) estimated the abundance of killer whales in the northern GOA, from the Kenai Peninsula, to Amchitka Pass in the Aleutian Islands at 991.

During an L-DEO cruise along the Aleutian Islands during summer 2005, a group of two killer whales was sighted just east of the proposed survey area northeast of Seguam Island (~52.7°N, 172.0°W), one individual was seen just north of Atka Island (~52.2°N, 175.1°W), a group of 11 was seen just north of Adak Island (~52.2°N, 176.2°W), two individuals were seen farther north of Adak Island (~53.4°N, 175.2°W), and a group of five was seen north of Unalaska Island (Ireland et al. 2005). A white killer whale, likely a resident type, was sighted off northern Adak Island during August 2000 (Renner and Bell 2008). During an L-DEO cruise at the Emperor Seamount chain south of the western Aleutian Islands during spring, one killer whale was seen (RPS 2019b). Killer whales are expected to be common in the proposed survey area.

3.3.2.10 Dall's Porpoise (*Phocoenoides dalli*)

Dall's porpoise is only found in the North Pacific and adjacent seas. It is widely distributed across the North Pacific over the continental shelf and slope waters and over deep (>2500 m) oceanic waters (Hall 1979), ranging from ~30–62ºN (Jefferson et al. 2015). In general, this species is common throughout its range (Buckland et al. 1993). Dall's porpoise occurs throughout Alaska; the only apparent gaps in distribution in Alaskan waters south of the Bering Strait are for upper Cook Inlet and the Bering Sea shelf.

Numerous studies have documented the occurrence of Dall's porpoise in the Aleutian Islands and western GOA (Forney and Brownell 1996; Moore 2001; Moore et al. 2002b; Wade et al. 2003; Waite 2003; Baraff et al. 2005; Ireland et al. 2005) as well as in the Bering Sea (Moore et al. 2002b; Friday et al. 2012, 2013). Dall's porpoise was one of the most frequently sighted species during summer seismic surveys in the GOA (RPS 2011, 2019a,b) and southeast Alaska (MacLean and Koski 2005; Hauser and Holst 2009). Rone et al. (2014) also reported sightings and acoustic detections in the central GOA, and Rone et al. (2017) reported sightings south and east of Kodiak Island. The abundance for the U.S. portion of the Bering Sea in 2010 was estimated at 11,143, with a density of 0.0103/km^2 (Friday et al. 2013). Zerbini et al. (2004)

provided an abundance estimate in the northern GOA and Aleutian Islands of 30,248. However, Turnock and Quinn (1991) suggested that the tendency of this species to approach vessels has resulted in inflated abundance estimates, perhaps by as much as five times.

Dall's porpoises are considered common in the nearshore waters of the Aleutian Islands and were the most frequently encountered cetacean during surveys just south of the Aleutians in 1994, with 151 sightings (Forney and Brownell 1996). During summer surveys extending from the Kenai Fjord to the central Aleutian Islands in 2001–2003, 592 sightings of 2072 Dall's porpoises were made (Wade et al. 2003). During surveys of the central Aleutian Islands, Moore (2001) noted that they were particularly common near Samalga Pass. During an L-DEO cruise along the Aleutian Islands during summer 2005, 19 groups totaling 99 individuals were seen, including sightings within the proposed survey area northwest of Seguam Island, north of Amlia Island, and just to the west (~51.7°N, 179.6°W) of the survey area, as well as in the western Aleutian Islands (Ireland et al. 2005). Dall's porpoise are expected to be common in the proposed survey area.

3.3.2.11 Harbor Porpoise (*Phocoena phocoena*)

The harbor porpoise inhabits temperate, subarctic, and arctic waters. It is typically found in shallow water (<100 m) nearshore but is occasionally sighted in deeper offshore water (Jefferson et al. 2015); abundance declines linearly as depth increases (Barlow 1988). In the eastern North Pacific, its range extends from Point Barrow, Alaska, to Point Conception, California. In Alaska, there are three stocks of harbor porpoise: Southeast Alaska, GOA, and Bering Sea. The Southeast Alaska Stock occurs from northern B.C. to Cape Suckling, the GOA Stock ranges from Cape Suckling to Unimak Pass, and the Bering Sea stock occurs in the Bering Sea and Aleutian Islands. Only the Bering Sea stock is likely to occur in the proposed survey area.

Harbor porpoise are also seen regularly in the western GOA and Aleutian Islands (e.g., Wade et al. 2003; Waite 2003; Baraff et al. 2005; Ireland et al. 2005) and Bering Sea (Moore et al. 2002b; Friday et al. 2012, 2013). The abundance in the U.S. portion of the Bering Sea was estimated at 833 in 2010, with a density of 0.0008/km^2 (Friday et al. 2013). Harbor porpoises have also been sighted in the eastern and central GOA and southeast Alaska (Dahlheim et al. 2000, 2008a; MacLean and Koski 2005; Rone et al. 2010, 2017). During summer surveys extending from the Kenai Fjord to the central Aleutian Islands in 2001–2003, 19 sightings of 34 harbor porpoises were made (Wade et al. 2003). During an L-DEO cruise along the Aleutian Islands during summer 2005, two groups of harbor porpoise (14 individuals) were seen within the proposed survey area north of Adak Island, and one individual was seen southwest of Kiska Island during August (Ireland et al. 2005). The harbor porpoise is expected to be common in the nearshore waters of the proposed survey area.

3.3.3 Pinnipeds

3.3.3.1 Northern Fur Seal (*Callorhinus ursinus*)

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

When not on rookery islands, northern fur seals are primarily pelagic but occasionally haul out on rocky shorelines (Muto et al. 2019a,b). During the breeding season, adult males usually come ashore in May–August and may sometimes be present until November; adult females are found ashore from June–November (Carretta et al. 2019; Muto et al. 2019a,b). After reproduction, northern fur seals spend the next 7–8 months feeding at sea (Roppel 1984). Pups and juveniles travel through the Aleutian passes and spend the first two to three years at sea before returning to their islands of origin. Animals may migrate to the GOA, off Japan, and the west coast of the U.S. (Muto et al. 2019a,b).

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

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

Northern fur seals were seen throughout the North Pacific during surveys conducted during 1987–1990 (Buckland et al. 1993). Tracked adult male fur seals that were tagged on St. Paul Island in the Bering Sea in October 2009, wintered in the Bering Sea or northern North Pacific Ocean; females migrated to the GOA and the California Current (Sterling et al. 2014). A total of 42 northern fur seals was seen during 3767 km of shipboard surveys in the northwestern GOA during June–July 1987 (Brueggeman et al. 1988). Rone et al. (2014) reported 78 northern fur seal sightings (83 animals) in 2013 east of Kodiak. There were seven sightings during the L-DEO seismic survey in the western GOA conducted in the summer of 2011 (RPS 2011), and one sighting during summer 2019 (RPS 2019a).

Leatherwood et al. (1983) reported 14 sightings of 34 northern fur seals away from the breeding islands in the southeast Bering Sea during aerial surveys in 1982, mostly during July and August. None of the 42 female northern fur seals tagged on St. Paul Island between August–October 2007 and 2008 traveled south of the Aleutian Islands (Kuhn et al. 2010). During an L-DEO cruise along the Aleutian Islands during summer 2005, five fur seal sightings totaling nine individuals were made of and west of Umnak Island, east of the survey area (Ireland et al. 2005). During an L-DEO cruise at the Emperor Seamount chain south of the western Aleutian Islands during spring, one northern fur seal was sighted (RPS 2019b). Fin whales could be encountered in the proposed survey area. Northern fur seals are expected to be common in the proposed survey area.

3.3.3.2 Steller Sea Lion (*Eumetopias jubatus*)

Steller sea lions occur along the North Pacific Rim from northern Japan to California (Loughlin et al. 1984). They are distributed around the coasts to the outer shelf from northern Japan south to California, including the Aleutian Islands, Bering Sea, and southern Alaska (Muto et al. 2019a,b). There are two stocks, or DPSs, of Steller sea lions – the Western and Eastern DPSs, which are divided at 144°W longitude (Muto et al. 2019a,b). The Western DPS is listed as ***endangered*** and includes animals that occur in Japan and Russia (Muto et al. 2019a,b); the Eastern DPS was delisted from *threatened* in 2013 (NMFS 2013a). Critical habitat for Steller sea lions has been identified in the Code of Federal Regulations (50 CFR 226.202) and described above. In the Aleutian Islands, the critical habitat includes 66 sites (26 rookeries and 40 haulout sites) and foraging areas in Seguam Pass (within the proposed survey area) and the Bogoslof area (east of the survey area; Fig. 1).

Rookeries of Steller sea lions from the Western DPS are located on the Aleutian Islands and along the GOA, as well as the east coast of Kamchatka, Commander Islands, and Kuril Islands (Burkanov and Loughlin 2005; Fritz et al. 2016; Muto et al. 2019a,b). Breeding adults occupy rookeries from late-May to early-July (NMFS 2008). Non-breeding adults use haulouts or occupy sites at the periphery of rookeries during the breeding season (NMFS 2008). Pupping occurs from mid-May to mid-July (Pitcher and Calkins 1981) and peaks in June (Pitcher et al. 2002; Kuhn et al. 2017). Territorial males fast and remain on land during the breeding season (NMFS 2008). Females with pups generally stay within 30 km of the rookeries in shallow (30–120 m) water when feeding (NMFS 2008). Tagged juvenile sea lions showed localized movements near shore (Briggs et al. 2005). Loughlin et al. (2003) reported that most (88%) at-sea movements of juvenile Steller sea lions in the Aleutian Islands were short (<15 km) foraging trips. The mean distance of juvenile sea lion trips at sea was 16.6 km, and the maximum trip distance recorded was 447 km. Long-range trips represented 6% of all trips at sea, and trip distance and duration increase with age (Loughlin et al. 2003; Call et al. 2007). Although Steller sea lions are not considered migratory, foraging animals can travel long distances outside of the breeding season (Loughlin et al. 2003; Raum-Suryan et al. 2002). Steller sea lions are present in Alaska year round. Telemetry studies showed that during summer, 90.5% of Steller sea lion locations occurred within critical habitat; and most locations occurred on the shelf in water <200 m (Lander et al. 2013).

Only individuals from the Western DPS are expected to occur in the proposed survey area at the time of the survey. However, individuals from the Eastern DPS have also been sighted in the eastern Aleutian Islands (e.g., Jemison et al. 2013, 2018); one individual was recorded as far west as Seguam Island. The population size of the Western DPS drastically declined from the late 1970s to 2000, but the abundance has been increasing since 2003, with great regional variation in the trend (Burkanov and Loughlin 2005; Fritz et al. 2013, 2016). In the central and western Aleutian Islands, the decline may have slowed in the 1990s (Trites and Larkin 1996), but according to current counts of Steller sea lions, numbers have continued to decline west of Samalga Pass (Sweeney et al. 2018; Rand et al. 2019). During aerial surveys of the central Aleutian Islands in June–July 2018, the highest number of sea lions for the islands surveyed occurred on, Seguam Island, Kasatochi, and Amlia islands (Sweeney et al. 2018). Population trends in the eastern Aleutians appear to have stabilized (Muto et al. 2019a,b; Rand et al. 2019). It is possible that the variability in distribution and availability of fish prey sources within the Aleutian Islands affect population trends (Fritz et al. 2019; Rand et al. 2019); however, Hui et al. (2015) suggested that availability of primary prey items such as pollock, cod, and Atka mackerel was unlikely to have limited sea lion populations from 2000 to 2008. Similarly, Maschner et al. (2014) noted that availability of fish alone does not explain population trends in Steller sea lions. Steller sea lions are expected to be common in the proposed survey area.

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. Most elephant seals return to their natal rookeries when they start breeding (Huber et al. 1991). When not breeding, elephant seals 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). Males may feed as far north as the eastern Aleutian Islands and the GOA, whereas females feed south of 45ºN (Le Boeuf et al. 1993; Stewart and Huber 1993).

Rone et al. (2014) reported 16 sightings (16 animals) in a June–July 2013 survey east of Kodiak Island in the GOA. Some seals that were satellite-tagged in California and tracked for no more than 224 days traveled distances >10,000 km (Le Beouf et al. 2000). Northern elephant seals that were satellite-tagged at a California rookery traveled as far west as ~166.5–172.5°E and as far north as the Aleutian Islands (Le Boeuf et al. 2000; Robinson et al. 2012; Robinson 2016 *in* OBIS 2020; Costa 2017, 2018 *in* OBIS 2020). Post-molting seals traveled longer and farther than post-breeding seals (Robinson et al. 2012). They occurred in the Aleutian Islands from spring through fall (Le Boeuf et al. 2000; Robinson et al. 2012) and were recorded within the proposed survey area during August and November (OBIS 2020). Several focal foraging areas were used by male elephant seals within the proposed study area during spring and fall (Le Boeuf et al. 2000). Thus, northern elephant seals could be encountered in the proposed survey area.

3.3.3.4 Harbor Seal (*Phoca vitulina richardsi*)

The harbor seal is distributed in the North Atlantic and North Pacific. Two subspecies occur in the Pacific: *P.v. stejnegeri* in the northwest Pacific Ocean and *P.v. richardii* in the eastern Pacific Ocean. Eastern Pacific harbor seals occur in nearshore, coastal, and estuarine areas ranging from Baja California, Mexico, north to the Pribilof Islands in Alaska, including the Aleutian Islands (Muto et al. 2019a,b). Harbor seals inhabit estuarine and coastal waters, hauling out on rocks, reefs, beaches, and glacial ice flows. They are generally non-migratory, but move locally with the tides, weather, season, food availability, and reproduction (Scheffer and Slipp 1944; Fisher 1952; Bigg 1969, 1981). Twelve stocks of harbor seals are recognized in Alaska (Muto et al. 2019a,b); the proposed survey would take place within the range of the Aleutian Islands stock. This stock decreased from the late 1970s to late 1990s (Small et al. 2008) and is still thought to be decreasing (Muto et al. 2019a,b).

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

During surveys of the Anreanof Islands in the central Aleutians in 1977–1982, the greatest number of seals were counted at Adak Island (639), Tanaga Islands (521), Tagalak Island (187), Kanaga Island (171), and Amlia Island (110). In 1999, the highest counts were again made at Kanaga Island (212), Amlia Island (206 seals), Adak Island (107), and Tanaga Island (98), but counts were much lower than during the initial surveys (Small et al. 2008). Harbor seals that were tagged at Adak Island during September 2014 made localized movements to the north and east of the island during the year (Dahle et al. 2015). Harbor seals are expected to be common in nearshore waters of the proposed survey area.

3.3.3.5 Ribbon Seal (*Histriophoca fasciata*)

Ribbon seals occur in the North Pacific and adjacent Arctic Ocean. In Alaska, ribbon seals generally are found in the open sea and on pack ice (Kelly 1988). They range from Bristol Bay into the Chukchi and western Beaufort seas. Ribbon seals inhabit the Bering Sea ice front from late March to early May and are abundant in the northern parts of the ice front in the central and western parts of the Bering Sea (Burns 1970; Burns 1981b). In May to mid July, when the ice recedes, some of the seals move farther north (Burns 1970; Burns. 1981c) to the Chukchi Sea (Kelly 1988c). However, most likely remain in the Bering Sea during the open-water season, and some occur on the Pacific Ocean side of the Aleutian Islands (Burns 1994). Boveng et al. (2013) reported that 10 ribbon seals tagged off Kamchatka during spring 2005 spent the summer and fall within the Bering Sea and the Aleutian Islands, including the proposed study area. When 72 seals were tagged in the central Bering Sea during 2007–2010, 29% moved northward with the receding ice, but others moved throughout the Bering Sea and Aleutian Islands (Boveng et al. 2013). Moore et al. (2012) reported acoustic detections of ribbon seals in the Chukchi Sea during fall. Leatherwood et al. (1983) reported a ribbon seal just north of Unalaska Island during aerial surveys in 1982. This species could be encountered in the proposed survey area.

3.3.3.6 Spotted Seal (*Phoca largha*)

Spotted seals occur in the Beaufort, Chukchi, Bering and Okhotsk seas, and south to the northern Yellow Sea and western Sea of Japan (Shaughnessy and Fay 1977). The breeding stocks are grouped into DPSs: Bering Sea DPS, Okhotsk Sea DPS, and Southern DPS in the Yellow Sea and Sea of Japan (Boveng et al. 2013). The Alaska stock consists of the Bering Sea DPS that occurs in U.S. waters (Muto et al. 2019b). Spotted seals migrate south from the Chukchi Sea and through the Bering Sea in October (Lowry et al. 1998). They overwinter in the Bering Sea and inhabit the southern margin of the ice during spring (Shaughnessy and Fay 1977). In the summer and fall, spotted seals are known to occur around the Pribilof Islands, Bristol Bay, and eastern Aleutian Islands (Muto et al. 2019b). Satellite telemetry evidence suggests that they may range much more widely in summer than suspected from conventional observations (Lowry et al. 1998, 2000).

3.3.4 Marine Fissiped

3.3.4.1 Northern Sea Otter (*Enhydra lutris*)

There are two subspecies of sea otters in U.S. waters. The southern sea otter (*E. l. nereis*) is found in California, and the northern sea otter (*E. l. kenyoni*) can be found in Washington and Alaska. 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 in Alaska are generally not migratory and do not disperse over long distances. However, individual sea otters are capable of long-distance movements 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), but then deceased to as low as 2000 (Kenyon 1969). Sea otters occupied coastal areas from Hokkaido, Japan, around the North Pacific Rim to central Baja California (Rotterman and Simon-Jackson 1988). In 1911, sea otters received protection under the North Pacific Fur Seal Convention, and populations recovered quickly (Kenyon 1969).

Three stocks (DPSs) of sea otters are recognized in Alaska: Southeast Alaska, from Dixon Entrance to Cape Yakataga; Southcentral Alaska, from Cape Yakataga to Cook Inlet, including PWS, Kenai Peninsula, and Kachemak Bay; and Southwest Alaska, from the Alaska Peninsula and Bristol Bay coasts, and the Aleutian, Barren, Kodiak, and Pribilof islands (USFWS 2014). The Southwest Alaska DPS occurs in the proposed study area. This DPS had declined by more than 50% since the mid-1980s when it was listed as ***threatened*** in 2005 (USFWS 2013). In the Aleutian Islands, the population has declined by >90% which can likely be attributed to killer whale predation (Davis et al. 2019). The population now appears to be stable (i.e., growth rate ~0); populations numbers in the Kodiak Archipelago, the Alaska Peninsula, and Kamishak Bay also appear to be stable and may be increasing (USFWS 2014). However, densities in the western Aleutians are still extremely low (Davis et al. 2019). Sea otters show restricted habitat utilization in the Aleutian Islands, which is likely based on physical habitat requirements to afford protection against killer whale predation (Stewart et al. 2015). Critical habitat for the Southwest Alaska DPS was designated in November 2009 (USFWS 2009). The critical habitat primarily consists of shallow-water areas <20 m deep and nearshore water within 100 m of the mean tide line. None of the proposed survey lines encroach on sea otter critical habitat (Fig. 1). In the Aleutian Islands, the highest sea otter aerial survey counts in 2000 were around Attu (282 animals), Tanaga (187), Adak (470), Atka (171), and Unalaska (including its very small neighbor, Sedanka) (374) islands (Doroff et al. 2003). Densities of otters calculated from aerial surveys in 2000 ranged from 0.2/km surveyed at Kagalaska Island (east of Adak) to 1.72/km at Adak Island. During vessel-based sea otter surveys in the Aleutian Islands in 2000, sea otter encounter rates were 0.61–5.19/km (Doroff et al. 2003). Koltun (2014) reported on sea otter hotspots in the Aleutian Islands. Sea otters are likely to be common in the nearshore waters of the Aleutian Islands. Adjustments were made to the survey design, to avoid takes of sea otters and impacts to critical habitat.

3.4 Sea Turtles

Only one species of sea turtle, the ***endangered*** leatherback turtle, could occur within the proposed Aleutian Islands study area. The olive ridley turtle (*Lepidochelys olivacea*), loggerhead turtle (*Caretta caretta*), and green turtle (*Chelonia mydas*) have also been recorded in Alaska waters, but they are considered extralimital and are not discussed further. Any sea turtles occurring in Alaska would be non-nesting individuals. 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 in the GOA is discussed in § 3.4.2.4 of the PEIS. The rest of this section deals specifically with their distribution within the proposed survey area.

3.4.1 Leatherback Turtle (*Dermochelys coriacea*)

The leatherback turtle is the most widely distributed sea turtle, ranging far from its tropical and subtropical breeding grounds to feed (Plotkin 2003). It is found from 71°N to 47°S, and nesting occurs from 38°N to 34°S (Eckert et al. 2012). In the eastern Pacific, leatherbacks nest along the west coast of Mexico and Central America (Marquez 1990); critical habitat has been designated off the U.S. west coast (NOAA 2020a). After nesting, female leatherbacks typically migrate from tropical waters to temperate areas, to feed on jellyfish (Eckert et al. 2012). Leatherbacks tend to feed in areas of high productivity, such as current fronts and upwelling areas, along continental margins, and in archipelagic waters (Morreale et al. 1994; Lutcavage 1996).

Hatchling leatherbacks are pelagic, but nothing is known about their distribution for the first four years (Musick and Limpus 1997). Leatherbacks are highly pelagic and are known to swim more than 11,000 km each year (Eckert 1998). They are one of the deepest divers in the ocean, with dives deeper than 4000 m (Spotila 2004). The leatherback dives continually and spends short periods of time on the surface between dives (Eckert et al. 1986). During migrations or long distance movements, leatherbacks maximize swimming efficiency by traveling within 5 m of the surface (Eckert 2002). Adult leatherbacks appear to migrate along bathymetric contours from 200–3500 m (Morreale et al. 1994). They appear to use the Kuroshio Extension during migrations from Indonesia to the high seas and the eastern Pacific (Benson et al. 2008). It is not known whether most leatherbacks in the central Pacific Ocean come from eastern or western Pacific nesting sites, but individuals from both nesting areas occur in Hawaiian waters (Dutton et al. 1998; 2000a,b).

After analyzing some 363 records of sea turtles sighted along the Pacific coast of North America, Stinson (1984) concluded that the leatherback was the most common sea turtle in U.S. waters north of Mexico; six sightings were made in Alaska. According to the Alaska Department of Fish and Game (ADFG 2020a), 19 sightings have been reported in Alaska between 1960 and 2007. Sightings and incidental capture data indicate that leatherbacks are found in Alaska as far north as 60°N, 145°W, and as far west as the Aleutian Islands, and documented encounters extend southward through the waters of B.C., Washington, Oregon, and California (NMFS and USFWS 1998). Some aerial surveys of California, Oregon, and Washington waters suggest that most leatherbacks occur in continental slope waters and fewer occur over the continental shelf. Leatherbacks occur north of central California during the summer and fall, when sea surface temperatures are highest (Dohl et al. 1983; Brueggeman 1991).

3.5 Seabirds

Three ESA-listed seabird species could occur in the proposed survey area. The Steller's and spectacled eiders are listed as ***threatened*** and could occur in the area in very low densities during September/October. The ***endangered*** short-tailed albatross may occur as a seasonal visitor to the project area during September/October. The IUCN (2019) lists the albatross and Steller's eider as *vulnerable* and the spectacled eider as *near threatened*. General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of seabird families is given in § 3.5.1 of the PEIS.

3.5.1 Short-tailed Albatross (*Phoebastria albatrus*)

Historically, millions of short-tailed albatrosses bred in the western North Pacific Ocean on islands off the coast of Japan. Historically, this species was the most abundant albatross in the North Pacific. However, the entire population was nearly extirpated during the last century by feather hunters at Japanese breeding colonies. In addition, the breeding grounds of the remaining birds were threatened by volcanic eruptions in the 1930s; this species was believed to be extinct in 1949 until it was rediscovered in 1951 (BirdLife International 2020b). However, this population is increasing, and the most recent population estimate is 4200 individuals (Birdlife International 2020b). Its marine range occurs throughout the North Pacific Ocean, but the highest densities are found in upwelling areas off Japan, eastern Russia, and Alaska, including the Aleutians (Piatt et al. 2006; Suryan et al. 2007). Its range has been expanding in recent decades and now includes the northeastern Bering Sea (Kuletz et al. 2020). Current threats to this population include volcanic activity on Torishima, commercial fisheries, and pollutants (USFWS 2008).

Currently, nearly all short-tailed albatrosses breed on two islands off the coast of Japan: Torishima and Minami-kojima (UWFWS 2008; BirdLife International 2020b). 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 2020b). Parents forage primarily off the east coast of Honshu Island, where the warm Kuroshio and the cold Oyashio currents meet (USFWS 2008). However, albatrosses have been seen as far south (23°N) as the Northwestern Hawaiian Islands between November and April (USFWS 2008).

After the breeding season, short-tailed albatrosses roam much of the North Pacific Ocean; females spend more time offshore from Japan and Russia, while males and juveniles spend more time around the Aleutian Islands and Bering Sea (Suryan et al. 2007; Suryan and Kuletz 2018). A tracking study suggests that a large proportion of fledglings reach the Bering Sea during the summer of their fledging year (Orben et al. 2018). Post-breeding dispersal occurs from April through November (Suryan et al. 2007; USWFS 2008; Orben et al. 2018). Short-tailed albatross are considered a continental shelf-edge specialist (Piatt et al. 2006);

they occur in the highest densities along the shelf-slope region, which is nearshore in the Aleutian Arc (Suryan and Kuletz 2018). However, Suryan et al. (2007) reported that short-tailed albatrosses occasionally transit the northern boundary of the Kuroshio Extension in May while en route to the Aleutians and Bering Sea, but that they do not spend much time in the area. Short-trailed albatrosses, particularly juveniles, start appearing in the Aleutian Islands as early as June (USFWS 2008), but most birds travel to the Aleutians in late summer and early fall (Suryan et al. 2006, 2007; USWFS 2008b; Suryan and Kuletz 2018; Orben et al. 2018). However, O'Connor (2013) reported that immature birds occur within the survey area throughout the year, and that they sometimes occur in association with fishing vessels in the Aleutian Islands. Warnock et al. (2017) reported the proposed survey area to have concentrated albatross use.

3.5.2 Steller's Eider (*Polysticta stelleri*)

There are three breeding populations of Steller's eiders worldwide: two in Arctic Russia and one in Alaska. The largest population breeds across coastal eastern Siberia and may number >128,000 (Hodges and Eldridge 2001). Smaller numbers breed in western Russia and on the Arctic Coastal Plain of Alaska. Steller's eider was listed as ***threatened*** under the ESA in July 1997 because of a reduction in the number of breeding birds and suspected reduction in the breeding range in Alaska (USFWS 1997). The USFWS has established Steller's eider critical habitat in the Y-K Delta nesting area, the Kuskokwim Shoals, and at the Seal Island, Nelson Lagoon, and Izembek Lagoon units on the Alaska Peninsula (USFWS 2004), but none of these areas occur within the proposed survey area. Strategies for recovery of the Alaska breeding population of Steller's eiders are discussed in detail in the Steller's Eider Recovery Plan (USFWS 2002).

Although Steller's eiders were formerly common breeders in the Yukon-Kuskokwim (Y-K) Delta, numbers there declined drastically, and only a small subpopulation breeds there now (Kertell 1991; Flint and Herzog 1999; MMS 2006; Birdlife International 2020c). Steller's eider density on the Arctic Coastal Plain is low, with the highest densities reported near Barrow (Ritchie and King 2001, 2002 *in* USFWS 2002). Mallek et al. (2006) reported lower than average population indices for Steller's eiders on the North Slope of Alaska for the period 2000–2005. Larned et al. (2009) also reported a decreasing population growth rate for Steller's eiders during breeding pair surveys on the North Slope. Based on comparisons of historical and recent data, Quakenbush et al. (2002) suggested that a reduction in both occurrence and breeding frequency of Steller's eiders had occurred on the Arctic Coastal Plain with the exception of the Barrow area. Larned (2005) also reported a declining trend during annual spring surveys for Steller's eiders in the Bristol Bay area during migration.

Causes for the decline of the Steller's eider population in Alaska are unknown but may include increased predation pressure on the North Slope and Y-K Delta breeding grounds, subsistence harvest, ingestion of lead shot, and contaminants (Quakenbush and Snyder-Conn 1993). Flint et al. (2000) suggested that a decrease in adult survival may have brought on the long-term decline in the population. Bustnes and Systad (2001) also suggested that Steller's eiders may have specialized feeding behavior that may limit the availability of winter foraging habitat. Steller's eiders could be affected by global climate regime shifts that cause changes in prey communities.

In the spring, the majority of the world population migrates along the Bristol Bay coast of the Alaska Peninsula, crosses Bristol Bay toward Cape Pierce, and continues northward along the Bering Sea coast (Larned 2003). In Alaska, Steller's eiders nest on tundra habitats often associated with polygonal ground both near the coast and at inland locations (e.g., Quakenbush et al. 2004); nests have been found as far inland as 90 km (USFWS 2002). The young Steller's eiders hatch in late June. After breeding, Steller's eiders move to nearshore marine habitats (Fredrickson 2001), using lagoon systems and coastal bays from Barrow to Cape Lisburne, the northeast Chukotka coast, and numerous locations in southwest Alaska (USFWS 2002). Steller's eiders are known to occur in shallow marine habitats of Kodiak Island, the south side of the Alaska Peninsula, and the eastern Aleutian Islands to lower Cook Inlet, with stragglers occurring south to B.C. during the non-breeding season.

Male departure from the breeding grounds begins in late June or early July. Females that fail in breeding attempts may remain in the Barrow area into late summer. Females and fledged young depart the breeding grounds in early to mid-September. The molting period occurs from late July to late October (USFWS 2002). Molting occurs throughout southwest Alaska, but is concentrated at four areas along the north side of the Alaska Peninsula and Kuskokwim Shoals; molting areas tend to be shallow with eelgrass beds and intertidal sand flats and mudflats (USFWS 2002; Martin et al. 2015). Following the molt, Steller's eiders disperse to wintering sites throughout the Aleutian Islands, Alaskan Peninsula, and western GOA (USFWS 2019b). During the molt, winter, and spring migration, the Alaska breeding population mixes with the Russian-Pacific population in the waters of southwest Alaska (USFWS 2002).

There are four locations along the north coast of the Alaska Peninsula that are particularly important for molting and staging Steller's eiders: the Izembek Lagoon, Nelson Lagoon, Port Heiden, and Seal Islands (e.g., Larned 2012; Williams et al. 2016). Steller's eiders begin to arrive in the GOA in late August or September; however, they are most common in the area during winter and spring; they are considered uncommon during the fall (MacIntosh 1998). It is possible although unlikely that Steller's eiders would occur in the study area during September/October. Distributional maps in Goldman et al. (2017) do not show the range to include the proposed survey area; in the eastern Aleutian, the range is depicted as occurring as far west as Umnak Island.

3.5.3 Spectacled Eider (*Somateria fischeri*)

The spectacled eider is a medium-sized sea duck that breeds along coastal areas of western and northern Alaska and eastern Russia, and winters in the Bering Sea (Petersen et al. 2000). Three breeding populations have been described: one in the Yukon-Kuskokwim (Y-K) delta in western Alaska, a second on the North Slope of Alaska, and the third in arctic Russia. The spectacled eider was listed as a ***threatened*** species because of declines in the breeding population in the Y-K delta (Stehn et al. 1993; Ely et al. 1994). The North Slope spectacled eider population seems to be stable (Larned et al. 2003). The largest breeding population is located in arctic Russia; the population there has been estimated at >140,000 (Petersen et al. 2000; Hodges and Eldridge 2001). The majority of the spectacled eider world population winters in the Bering Sea south of St. Lawrence Island (Petersen et al. 1999). Based on counts and photography from aerial surveys, this population may number ~360,000–375,000 (Larned and Tiplady 1999). There are a few scattered winter records for spectacled eiders at Izembek Lagoon, Katchemak Bay, and Kodiak Island (Petersen et al. 2000), and a few records from Attu Island during birding tours. The spectacled eider probably occurs only as a straggler in the study area.

The reasons behind declines in spectacled eider breeding populations are unknown but may be related to a combination of factors including ingestion of lead shot (Franson et al. 1995; Flint et al. 1997; Flint and Grand 1997; Franson et al. 1998; Grand et al. 1998; Flint 1998; Flint et al. 2000), predation (Eberhardt et al. 1982; Day 1998), subsistence harvest, exposure to contaminants (Stout 1998; Stout et al. 2002; Trust et al. 2000), and the potential effects of global climate change that may affect food chains (Merrick 1997; Mantua et al. 1997; Benson and Trites 2002; Lovvorn et al. 2003). A recovery plan for spectacled eiders was published to delineate reasonable actions that are believed to be required to provide for recovery and/or protection of the species (USFWS 1996). Critical habitat has been designated in molting areas in Norton Sound and Ledyard Bay, breeding areas in central and southern Y-K Delta, and the wintering area in waters south of St. Lawrence Island. A total of ~101,000 km^2 is designated as critical habitat for spectacled eiders; none of this occurs in the proposed study area. Goldman et al. (2017) did not include the proposed survey area as part of this species' distributional range.

3.6 Corals

There are 137 distinct taxa of corals that occur throughout Alaskan waters, including octocorals (89 taxa), hydrocorals (24 taxa), antipatharians (12 taxa), and scleractinian corals (12 taxa) (Stone and Cairns 2017). The Aleutian Islands region supports the highest abundance and diversity of corals in Alaska with 96 taxa recorded (Heifetz 2000; Stone and Cairns 2017). Coral diversity is lower in deep water, although corals may be found at depths >4700 m (Alaska Science Outreach 2004; Stone and Shotwell 2007). The most diverse communities occur at 300–350 m and continue to a lesser degree down to 800 m (Alaska Science Outreach 2004). These ecologically important coral communities provide structure and refuge for fish and invertebrates, especially juveniles (Stone and Shotwell 2007); in the central Aleutian Islands, 84.7% of commercial fish and crab species were associated with corals and other epibenthic invertebrate structures (Stone 2006). Several areas in the GOA with coral communities have been designated as HAPC for fish; however, none occur within the survey area.

3.7 Fish, Essential Fish Habitat, and Habitat Areas of Particular Concern

3.7.1 ESA-Listed Fish Species

There are no ESA-listed fish species in Alaska. However, there are several ESA-listed fish species that spawn on the West Coast of the Lower 48 United States and may occur in Alaskan waters during the marine phases of their life cycles. Species listed as ***endangered*** include the sockeye salmon (*Oncorhynchus nerka*; Snake River Evolutionarily Significant Unit [ESU]) and chinook salmon (*Oncorhynchus tshawytscha*; Upper Columbia River spring-run ESU). Species listed as ***threatened*** include the green sturgeon (*Acipenser medirostris*; Southern DPS), chum salmon (*Oncorhynchus keta*; Hood Canal summer-run ESU), coho salmon (*Oncorhynchus kisutch*; Lower Columbia River ESU), steelhead trout (*Oncorhynchus mykiss*; Snake River Basin DPS, Upper Willamette River DPS, and Lower, Middle, Upper Columbia River DPSs), and chinook salmon (*Oncorhynchus tshawytscha*; Lower Columbia River ESU, Upper Willamette River ESU, Puget Sound ESU, Snake River fall-run ESU, Snake River spring/summer-run ESU) (NOAA 2020b). The Alaskan populations of these species, which are more likely to be encountered near the proposed survey area, are not listed under the ESA.

3.7.2 Important Fish Resources

Alaska supports substantial finfish resources, including groundfish, forage fish, rockfish, and salmonids, that are important to the area both biologically and economically. Additionally, there are important shellfish and invertebrate resources.

3.7.2.1 Groundfish

Walleye pollock (*Theragra chalcogramma*) is the most abundant species of groundfish targeted in the commercial fisheries of the North Pacific Ocean. Pollock is a target species in the Bering Sea, although some are caught incidentally in the Aleutian Islands. Walleye pollock occupy demersal habitats along the outer continental shelf (OCS) and slope during winter. They migrate into shallower waters and aggregate for spawning in late winter and spring along the Aleutian Basin, Bering Sea, and GOA. Pollock usually grow to commercial size within three years (Dorn et al. 2007).

Pacific cod (*Gadus macrocephalus*) has been an important commercial species in Alaska since 1882 (Rigby 1984). Pacific cod inhabit waters of the continental shelf and upper continental slope waters (100–250 m deep) in the winter (Hart 1973) and move to water <100 m deep in the summer (NOAA 2004b). They are moderately fast growing and short lived compared to many other Alaskan groundfish. Spawning generally occurs from January to April in waters 40–120 m deep (Klovach et al. 1995). Eggs and winter concentrations of adults have been found to be associated with coarse sand and cobble bottom types, and it has been inferred that this is optimal spawning habitat (Palsson 1990). Larvae and juveniles are pelagic, and there is some evidence that both larvae and juveniles are transported to nursery habitats by currents (Garrison and Miller 1982). Nursery habitats are associated with shallow water and intertidal areas with a sandy bottom and kelp or eel grass (Miller et. al. 1976). It has been suggested that, with increasing size and age, juveniles move into deeper water (Brodeur et al. 1995). Spawning areas are located within the study area, including around Tanaga, Adak, Atka, and Amlia islands (Zaleski and Mecum 2017).

Atka mackerel (*Pleurogrammus monopterygius*) is a semi-demersal species, mainly fished with bottom trawl gear at depths <200 m. The center of Atka mackerel's abundance is in the Aleutian Islands, particularly from Buldir Island to Seguam Pass. The eastern Aleutians show localized dense aggregations of Atka mackerel (Rand et al. 2019); it is also prominent in the Delarof Islands at the western edge of the survey area (Bryan et al. 2019). Atka mackerel migrate from the shelf edge to shallow coastal waters (5–30 m deep) to spawn. Spawning begins in late spring in the Aleutian Islands and males guard the egg nests through late fall. Spawning sites are located within nearshore waters of the proposed survey area (Zaleski and Mecum 2017).

Sablefish (*Anoplopoma fimbria*) inhabit the northeastern Pacific Ocean from northern Mexico to the GOA, westward to the Aleutian Islands, and into the Bering Sea (Wolotira et al. 1993). Adult sablefish occur along the continental slope, shelf gullies, and in deep fjords, generally at depths >200 m. Sablefish observed from a manned submersible were found on or within 1 m of the bottom (Krieger 1997). In contrast to their adult distribution, juvenile sablefish (<40 cm long) spend their first two to three years on the continental shelf. Sablefish are highly migratory for at least part of their life (Heifetz and Fujioka 1991; Maloney and Heifetz 1997; Kimura et al. 1998) and are assessed as a single population in Alaskan waters (Hanselman et al. 2007a).

The arrowtooth flounder (*Atheresthes stomias*) ranges from central California to the Bering Sea in water 20 to 800 m deep; it is the most abundant groundfish species in the GOA. Although its stock structure and migratory patterns are poorly understood, it does appear to move to deeper water as they grow (Zimmerman and Goddard 1996), but recent research suggests juveniles may be more ubiquitous across depths than previously thought (Doyle et al. 2018).

Pacific halibut (*Hippoglossus stenolepis*) spawn during the winter, primarily from December through February, off the edge of the continental shelf in waters 350–550 m deep (IPHC 1998). Males reach maturity at ~7 years of age and females at ~8 years. Females are highly fecund, laying two to three million eggs annually. Younger halibut, <10 years of age, are highly migratory. Older halibut tend to be much less migratory; they often use both shallow and deep waters over the annual cycle, but they do not travel as much as the younger fish (IPHC 1998).

Alaska plaice (*Pleuronectes quadrituberculatus*) is a shallow-water flatfish that occurs in water <200 m deep (Matta 2012). In the eastern Pacific Ocean, it inhabits the northern GOA, Bering Sea, and Chukchi Sea, but is primarily found on the Eastern Bering Sea shelf; only small numbers occur in the Aleutian Islands (Wilderbuer and Nichol 2019).

Other groundfish that are found in the waters of the survey area include lingcod (*Ophiodon elongatus*), yellowfin sole (*Limanda aspera*), starry flounder (*Platichthys stellatus*), and other flatfish, greenlings, sculpins, poachers, and pricklebacks, which inhabit the Kodiak and southern Aleutian Peninsula region (NPFMC 2015; Mecklenburg et al. 2002). These species generally are in the same habitats as the previously discussed groundfish species and are often food sources for other fish, birds, and mammals.

3.7.2.4 Forage Fish

Pacific herring (*Clupea pallasi*) is an abundant and widespread forage fish in Alaska. They are critical prey for a variety of fishes, mammals, and birds. Herring migrate in large schools and generally spawn in the spring. After spawning, most adults leave inshore waters and move seaward to feed primarily on zooplankton such as copepods and other crustaceans. They are seasonal feeders and accumulate fat reserves for periods of relative inactivity. Herring schools often demonstrate a diel vertical migration, spending daylight hours near the seafloor and moving upward during the evening to feed (ADF&G 2015). Other forage fish that are critical food sources to marine mammals, seabirds, and larger fish species include eulachon (*Thaleichthys pacificus*), capelin (*Mallotus villosus*), and Pacific sandlance (*Ammodytes hexapterus*) (Ormseth and Vollenweider 2018). There are capelin spawning areas within the survey area around Atka Island; spawning areas from May to August (Zaleski and Mecum 2017).

3.7.2.5 Salmonids

Pacific salmon (*Oncorhynchus* spp.) rear in the GOA and are managed in three regions based on freshwater drainage areas: southeast, central (Cook Inlet, PWS, and Bristol Bay), and westward (Alaska Peninsula, Chignik, and Kodiak). Although some Pacific salmon species are listed under the ESA in parts of their range, they are not listed in Alaska. All salmon except chinook generally spend the majority of their ocean life in offshore pelagic waters, bounded by brief periods of migration through coastal areas as juveniles and returning adults. Chinook salmon migrate through coastal areas as juveniles and returning adults, whereas adult chinook salmon undergo extensive migrations and can be found inshore and offshore throughout the North Pacific (Morrow 1980). Staging areas are located in nearshore waters of the survey area (Zaleski and Mecum 2017). Salmon are not targeted in high seas fisheries, but are targeted in nearshore waters with troll, gillnet, and seine gear.

3.7.2.6 Rockfish

Rockfishes (*Sebastes* spp.) range from southern California to the Bering Sea, and are prominent in the Aleutian Islands (Bryan et al. 2019). At least 30 rockfish species inhabit Alaskan waters, with Pacific ocean perch (*S. alutus*) being the most common. Pacific ocean perch are slow growing, bear live young, and reach a maximum age of ~30 years (Hart 1973). Males grow more slowly and have shorter life spans than do females. Rockfishes are internal fertilizers, with females releasing larvae. Pacific ocean perch release their larvae in winter. Larvae and juveniles are pelagic until joining adults in demersal habitats after two or three years. Adults are found primarily on the OCS and the upper continental slope in depths 150–420 m. In the summer, adults inhabit shallower depths, especially 150–300 m; in the fall, they migrate farther offshore to depths of ~300–420 m. They stay at these deeper depths until about May, when they return to their shallower summer depths (Love et al. 2002; Hanselman et al. 2007b).

3.7.2.7 Shellfish

Crab, shrimp, other crustaceans, and mollusks are harvested from Alaskan waters. All these species, grouped in this document as shellfish, inhabit benthic regions as adults, but can occupy pelagic waters as larvae. Three species of king crab (red, *Paralithodes camtschaticus*; blue, *P. platypus*; golden, *Lithodes aequispinus*), Tanner crab (*Chionoecetes bairdi*), and snow crab (*C. opilio*) occur in Alaska. Geoduck clam (*Panopea generosa*) and Weathervane scallop (*Patinopecten caurinus*) are important shellfish resources in the Aleutian islands.

3.7.3 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 2018a).

EFH is identified for only those species managed under a federal Fishery Management Plan (FMP), which in the GOA includes groundfish, Pacific cod, sablefish, rockfish, scallops, and Pacific salmon. As the entire GOA has been designated as EFH, the proposed survey would be conducted in areas designated as EFH. The *Magnuson-Stevens Fishery Conservation and Management Act* (16 U.S.C. §1801-1882) established Regional Fishery Management Councils and mandated that 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; this mandate was intended to minimize, to the extent practicable, any adverse effects on habitat caused by fishing or non-fishing activities, and to identify other actions to encourage the conservation and enhancement of such habitat. EFH has been designated for groundfish species or species assemblages, salmonids, and invertebrates in different development stages surrounding the Aleutian Islands (Table 5).

3.7.4 Habitat Areas of Particular Concern

A Habitat Area of Particular Concern (HAPC) is a subset of EFH that provides important ecological functions, is especially vulnerable to degradation, or includes habitat that is rare (NOAA 2018b). There are several HAPCs near the Aleutian Islands, including Bowers Ridge Habitat Conservation Zone and Areas of Skate Egg Concentration Monitoring in the Bering Sea, and the GOA Slope Habitat Conservation Areas. However, none occur within the proposed survey area. Bowers Ridge is the closest HAPC to the study area; it covers an area of 5286 nmi^2 and is located ~100 km to the northwest (Fig. 1). Bottom trawling and dredging are prohibited in this HAPC (Witherell and Woodby 2005).

3.8 Fisheries

3.8.1 Commercial Fisheries

Commercial fisheries for the Aleutian Islands are managed as a component of Alaska's Westward Region, which also includes the Kodiak Archipelago and portions of the Alaska Peninsula (ADFG 2020b). The eastern portion of the proposed survey area is also within the Aleutian Pribilof Island Community Development Association Community Development Quota (CDQ) Region (NOAA 2019a). The CDQ Program provides residents of western Alaska villages with investment opportunities for fisheries in the Bering Sea/Aleutian Islands Management Area and is a means of supporting local economic and social development (NOAA 2019a). Under the Program, a portion of all groundfish, prohibited species, halibut, and crab from the Bering Sea/Aleutian Island quotas are allocated to eligible communities (NOAA 2019a).

In terms of catch weight, the country's premier fishing port is Dutch Harbor, located in the Aleutian Islands northeast of the proposed survey area (ADFG 2020b). Excluding salmon harvests, which included all Alaskan catches combined, the total commercial fisheries catch for the Aleutian Islands and/or Aleutian Islands/Bering Sea area during 2017 and 2018 was over 1.25 million tons per year (Table 6). During 2017 and 2018, most of the commercial fisheries catch weight in the Bering Sea/Aleutian Islands was comprised of halibut and yellowfin sole, followed by Atka mackerel, herring, Pacific ocean perch, rock sole, Alaska plaice, and Pacific cod (Table 6).

In subarctic Alaskan waters, Pacific halibut are harvested using longlines and caught as bycatch in bottom trawl, pot, jig, and other hook-and-line fisheries (SAU 2016; NOAA 2019b). The proposed survey area is within the International Pacific Halibut Commission (IPHC) Regulatory Area 4B (NOAA 2020c). The IPHC manages the Pacific halibut stock in accordance with the Canada-U.S. Pacific Halibut Treaty, with quota allocations and regulation development/enforcement determined in the U.S. by the North Pacific Fishery Management Council (NPFMC) and NMFS, respectively (ADFG 2020d). The Alaskan commercial halibut fishery is managed under an Individual Fisheries Quota (IFQ) system, which includes

TABLE 5. Species with Essential Fish Habitat (EFH) for the Aleutian Islands.

Species	**Eggs**	**Larvae**	**Early Juvenile**	**Late Juvenile**	**Adult**
Walleye pollock	✓	✓	✓	✓	✓
Pacific cod	-	✓	-	✓	✓
Greenland halibut (turbot)	-	-	✓	✓	✓
Arrowtooth flounder	-	✓	✓	✓	✓
Kamchatka flounder	-	-	✓	✓	✓
Northern rock sole	-	✓	✓	✓	✓
Southern rock sole	-	-	✓	✓	✓
Rex sole	✓	-	✓	✓	✓
Dover sole	-	-	✓	✓	✓
Flathead sole	✓	-	✓	✓	✓
Sablefish	-	-	-	✓	✓
Pacific ocean perch	-	✓	✓	✓	✓
Shortraker rockfish	-	-	✓	✓	✓
Blackspotted rockfish	-	-	✓	✓	✓
Rougheye rockfish	-	-	✓	✓	✓
Northern rockfish	-	-	✓	✓	✓
Shortspine thornyhead rockfish	-	-	✓	✓	✓
Dusky rockfish	-	-	✓	✓	✓
Atka mackerel	✓	-	-	✓	✓
Bigmouth sculpin	-	-	-	✓	✓
Great sculpin	-	-	-	✓	✓
Yellow Irish lord	-	-	-	✓	✓
Alaska skate	-	-	✓	✓	✓
Aleutian skate	-	-	✓	✓	✓
Bering skate	-	-	✓	✓	✓
Mud skate	-	-	✓	✓	✓
Octopus	-	-	-	-	✓
Chinook salmon*	-	-	✓	✓	✓
Chum salmon*	-	-	✓	✓	✓
Coho salmon*	-	-	✓	✓	✓
Pink salmon*	-	-	✓	✓	✓
Sockeye salmon*	-	-	✓	✓	✓
Weathervane scallop	-	-	-	✓	✓
Blue king crab	✓	-	-	✓	✓
Golden king crab	✓	-	-	✓	✓
Red king crab	✓	-	-	✓	✓
Snow crab	✓	-	-	✓	✓
Tanner crab	✓	-	-	✓	✓

- Information currently unavailable.
* Salmon egg and larval life stages not included because they occur in freshwater.
Source: NPFMC (2011, 2014, 2018a,b).

TABLE 6. Total commercial catches for the Aleutian Islands in 2017 and 2018.

	Commercial Catch (t)	
Species	**2017**	**2018**
Pacific cod	15,204	19,558
Alaska plaice	16,491 [a]	23,343 [a]
Arrowtooth flounder	6,519 [a]	7,003 [a]
Kamchatka flounder	4,504 [a]	3,108 [a]
Atka mackerel	64,451 [a]	70,393 [a]
Herring	68,416 [b]	45,707 [b]
Rougheye rockfish	205 [a]	237 [a]
Flathead sole	9,146 [a]	11,061 [a]
Yellowfin sole	132,297 [a]	146,500 [a]
Rock sole	35,272 [a]	28,276 [a]
Bering flounder	3 [a]	5 [a]
Greenland halibut (turbot)	2,834 [a]	1,834 [a]
Halibut	833,417 [c]	826,707 [c]
Northern rockfish	4,699 [a]	5,766 [a]
Octopus	35	142
Dusky rockfish	404	463
Shortspine thornyhead rockfish	101	91
Harlequin rockfish	48	92
Yelloweye rockfish	0.2	~1
Redbanded rockfish	2	~1
Redstripe rockfish	5	0
Black rockfish	~1	0.3
Silvergray rockfish	0.1	0
Shortraker rockfish	161 [a]	250 [a]
Unspecified thornyheads	~1	0.5
Unspecified rockfish	10	15
Pacific ocean perch	32,543 [a]	34,750 [a]
Pollock	1,507	1,778
Sablefish	590	474
Sculpin	5,340 [a]	5,109 [a]
Chinook salmon	3,154 [b]	2,794 [b]
Chum salmon	191,662 [b]	158,659 [b]
Coho salmon	32,811 [b]	27,365 [b]
Pink salmon	515,241 [b]	149,534 [b]
Sockeye salmon	290,907 [b]	259,375 [b]
Shark	142	94
Skate	1,420	1,657
Squid	43	35
Golden king crab	2,829	2,942
Red king crab	<1	<1
	Commercial Catch (t)	
	2014	**2015**
"Other" flatfish [d]	13,936	17,978

- Data unavailable.

[a] Total catch for the Bering Sea and Aleutian Islands combined.

[b] Total catch for Alaska combined.

[c] Total catch for International Pacific Halibut Commission regulatory area 4B.

[d] "Other" flatfish includes dover sole, longhead dab, rex sole, Sakhalin sole, starry flounder, deepsea sole, and butter sole.

Sources: AFSC (2019); ADFG (2020c); NOAA (2020f); NPFMC (2020a).

annual, daily bag, and possession limits (ADFG 2020d). The commercial fishery for halibut in Area 4B occurs during mid-March to mid-November and had a total allowable catch (TAC) of ~549 t during 2019 (IPHC 2019). Directed longline halibut fishing may occur within the proposed survey area during September and October.

Yellowfin sole are targeted in bottom trawl fisheries in the Bering Sea/Aleutian Islands and taken as bycatch in hand line, pelagic trawl, and pot/trap fisheries in subarctic Alaskan waters (SAU 2016; NPFMC 2018a). The majority of the Bering Sea/Aleutian Islands stock inhabits the continental shelf; a relatively negligible portion of its abundance is in the Aleutian Islands (NPFMC 2018a). Overall, the stock has been in decline since the mid-1980s; recent total catch weights from the Aleutian Islands have been ~100,000 t per year (NPFMC 2018a). The TAC for the Bering Sea/Aleutian Islands is 166,425 t for 2020 (NPFMC 2018c). As the directed yellowfin sole fishery generally occurs from winter through fall in the Bering Sea/Aleutian Islands (AFSC 2019), a relatively limited commercial fishery for yellowfin sole may occur within the proposed survey area during September and October, although it is anticipated that most of the fishery would occur in the Bering Sea, north of the survey area.

In the Aleutian Islands region, Atka mackerel spawn from late-July to mid-October, with peak spawning during early-September (AFSC 2019). Territorial, mature males brood the eggs until they hatch between October and January, although most hatching occurs in late-November (AFSC 2019). Prior to 2011, the Atka mackerel fishery was closed during mid-April to early-September to avoid the spawning and early- to mid-brooding seasons; this avoidance period was removed as of 2011, and the Atka mackerel trawl fishery has been open in the Aleutian Islands from late-January to the end of December since 2014 (AFSC 2019). Some bycatch occurs in the Bering Sea/Aleutian Islands Pacific cod and rockfish fisheries (AFSC 2019). The proposed survey area is within the Eastern Aleutian Islands fishery management region. Atka mackerel TACs within the region increased from 2013 to 2018 but decreased thereafter, with a limit of 36,500 t and 24,535 t during 2018 and 2020, respectively (AFSC 2019; NOAA 2020d). The fishery may occur within the proposed survey area during September and October.

The nearest active statewide commercial herring fishery port to the proposed survey area is Dutch Harbor, for sac roe and food and bait use (ADFG 2020c). In the Adak District of the Alaska Peninsula-Aleutian Islands Area, the herring sac roe fishery may occur from mid-April to late-June, and the food and bait fishery by gillnet from late-June to late-February and by purse seines from early-July to late-February (ADFG 2019a). During 2019–2021, up to 500 t per year may be harvested using seines or gillnets in the Adak District (ADFG 2019a). Purse seines and gillnets are the only lawful gear permitted for commercial herring fisheries in the area, although herring are incidentally taken in bottom and pelagic trawls (SAU 2016; ADFG 2019a). Food and bait herring fisheries may occur within the proposed survey area during September and October.

The Aleutians Islands stock is one of four Pacific ocean perch stocks, which also include the eastern Pacific (British Columbia), Gulf of Alaska, and Bering Sea stocks (AFSC 2019). Aleutian Island Pacific ocean perch are targeted using bottom trawls, but they have also been caught in pelagic trawls, hand lines, pots/traps, and longlines in subarctic Alaskan waters (SAU 2016). The TAC for the Eastern Aleutian Islands increased from 9000 t in 2018 to 11,146 t in 2020 (AFSC 2019; NOAA 2020e). During 2019, Pacific ocean perch harvests occurred in the Eastern Aleutian Islands during April–November and could occur within the proposed survey area during September and October (NOAA 2020f).

Rock sole are harvested using trawls and have been incidentally caught using hand lines or pots/traps in subarctic Alaskan waters (SAU 2016). They are commonly caught as bycatch in the targeted yellowfin sole, pollock, flathead sole, and Pacific cod fisheries in the Bering Sea/Aleutian Islands area (AFSC 2019). The TAC for rock sole in the Bering Sea/Aleutian Islands increased from 47,100 t in 2019 to 57,100 t in 2020 (NOAA 2020e). Rock sole were harvested all year within the Bering Sea/Aleutian Islands area during

2019; the fishery may occur within or near the proposed survey area during September and October (NOAA 2020f).

Alaska plaice are harvested using bottom trawls primarily in the eastern Bering Sea, but have been caught as bycatch using pelagic trawls and hand lines within subarctic Alaskan waters (SAU 2016). The TAC for Alaska plaice in the Bering Sea/Aleutian Islands has remained at 18,000 t since 2019 (NOAA 2020e). Alaska plaice were caught throughout the year in 2019 in the Bering Sea/Aleutian Islands; this trawl fishery may occur within the proposed survey area during summer and fall (NOAA 2020f).

Pacific cod in the Bering Sea/Aleutian Islands are caught in targeted fisheries using bottom and pelagic trawls, handlines/longlines, and pots/traps, and are occasionally caught incidentally by purse seines or shrimp trawls in subarctic Alaskan waters (SAU 2016). The Bering Sea/Aleutian Islands catcher-processor and catcher-vessel hook-and-line and trawl Pacific cod fisheries occurred year-round during 2019, except for December for trawl fisheries (NOAA 2020f). The 2019 catcher-processor/catcher-vessel pot fishery occurred during January and September, and mixed hook-and-line/pot fisheries during January-February and April-December within the Bering Sea/Aleutian Islands (NOAA 2020f). All Bering Sea/ Aleutian Island Pacific cod fisheries would be active during the proposed survey months of September and October, and the fishery is likely to occur within and/or near the proposed survey area. The TAC for Pacific cod in the Aleutian Islands has been set at 14,214 t for 2019 and 2020 (NOAA 2020e).

King crab are only permitted to be retained using king crab pots; any taken incidentally by other fishing gear must be returned to the water unharmed (ADFG 2017). King Crab Registration Area O consists of the Aleutian Islands area, including the proposed survey area which is in the king crab Adak District (ADFG 2017). Due to low stock abundance, the commercial fishery for red king crab in the Aleutian Islands area was closed during the 2015–2016 season, although it has since reopened (Leon et al. 2017). The Aleutian Islands golden king crab fishery is unique for western Alaskan king crab fisheries, in that it has never been closed due to low stock abundance and is the only such fishery for which longline pot gear is the sole lawful gear type (Leon et al. 2017). During the 2007–2015 seasons, five vessels participated in the Aleutian Islands golden king crab fishery, for a combined average annual catch weight of 0.002 t (Leon et al. 2017). During the 2019/2020 season, the Aleutian Islands IFQ and Adak Community Allocation (ACA) TACs west of 174ºW for golden king crab are ~1172 t and 130 t, respectively (Vincent-Lang and Rabung 2019). During 2017–2019, unless otherwise specified by emergency order, male red king crab were set to be harvested by vessels <60’ in the Adak District from August to mid-February, and the male golden king crab season was set to open from mid-August to mid-May in Area O (ADFG 2017). King crab pot fisheries may occur within or near the proposed survey area during September and October.

In the Aleutian Islands, the 2019–2021 commercial salmon fishery season is open from 10 July to 30 September; gear types may include purse, hand purse, and beach seines (ADFG 2019b). During 2018, the combined commercial salmon harvest in the Alaska Peninsula, Aleutian Islands, and Atka-Amlia Islands management areas included ~20,000 Chinook, 3,696,000 sockeye, 368,000 Coho, 794,000 pink, and 1,154,000 chum salmon (Brenner et al. 2019). Harvests of all five species were reported for the South Peninsula and Aleutian Islands during 2018, with catches mainly consisting of sockeye, chum, and pink salmon (Brennar et al. 2019). Commercial fisheries for salmon may occur within the proposed survey area from July through September but the season would be closed during the October portion of the survey. Commercial diving fishing activities are not anticipated to occur within the survey area.

3.8.2 Recreational Fisheries

Recreational fisheries in Alaska are world-renowned and economically important, with the charter sector generating >$165 million annually in Southern Alaska during recent years (NOAA 2019c). Recreational fisheries for all five Pacific salmon species, dolly varden and steelhead/rainbow trout are popular in freshwaters of the Alaska Peninsula and Aleutian Islands, while halibut, lingcod, and rockfishes are commonly caught recreationally in marine waters (ADFG 2020e). The State of Alaska is responsible for monitoring recreational fisheries and collect harvest data via mail surveys, logbooks from charter vessels, and on-site sampling (ADFG 2020d). Alaska Peninsula and Aleutian Islands recreational fisheries are open year-round for salmon, rainbow/steelhead trout, dolly varden, Arctic grayling, and other finfish, with the exception of a January–July season for king salmon (ADFG 2020f). During 2018, 1586 anglers fished a total of 8668 angler-days in saltwater and 8355 anglers fished 33,597 angler-days in freshwater in the Alaska Peninsula/Aleutian Islands Area (ADFG 2020g). In order of decreasing catch numbers, species caught in the Area's marine recreational fisheries during 2018 included rockfish (1970), sea-run Coho salmon (1335), Pacific halibut (1148), Pacific cod (1141), pink salmon (978), sockeye salmon (801), sea-run Chinook salmon (359), dolly varden/Arctic char (212), sablefish/black cod (101), lingcod (40), and chum salmon (14) (ADFC 2020h). Species caught recreationally in freshwater during 2018 included sea-run Coho salmon (14,835), pink salmon (3031), sea-run Chinook salmon (2736), varden/Arctic char (1736), sockeye salmon (801), Arctic grayling (98), chum salmon (96), dolly rainbow trout (89), lake trout (25), and northern pike (9) (ADFG 2020f). No shellfish have been reported in the recreational fishery in Southcentral Alaska since at least 2009 (ADFG 2020g).

3.9 SCUBA Dive Sites and Shipwrecks

Shipwreck and obstruction site locations are maintained in NOAA's Office of Coast Survey Wrecks and Obstructions database, including the Electronic Navigational Chart (ENC) and Automated Wreck and Obstructions Information System (AWOIS) datasets (NOAA 2018c). There are ~15 shipwreck sites within or near the proposed survey area, including near proposed survey lines (Fig. 2; NOAA 2018c). At least 12 of the shipwrecks are nearshore and may be recreational SCUBA diving sites in the proposed survey area. Charter vessels operating out of Dutch Harbor, such as the *Miss Alyssa*, offer guided SCUBA dives within the Aleutian Islands, and may host recreational diving activities within or near the proposed survey area (TMA 2019).

In September 2019, U.S. Navy divers cleared and removed a sunken, abandoned fishing vessel, F/V *Heritage*, from Adak's harbor because it blocked access to the harbor's primary private and commercial boat ramp (Handley 2019). It is not clear whether this vessel was included in the ENC or AWOIS datasets. The U.S. Navy divers also conducted a cold-weather training exercise off Adak Island during September 2019, the "Arctic Expeditionary Capabilities Exercise 2019" (Woody 2019). Because of its strategic location and deep-water port, the U.S. Navy may continue to periodically conduct diving exercises off Adak, re-using facilities at the naval military base on northern Adak Island that was abandoned in 1997 (Woody 2019). SCUBA diving may also occur for benthic ecological data collection within the Aleutian Islands, including the proposed survey area, as part of the Alaska Monitoring and Assessment Program (AKMAP) which has been ongoing since 2002 (Jewett et al. 2008; SOA 2020).

There are two sites with documented obstructions in the proposed survey area, located ~40 km north of Atka Island and in Kuluk Bay, Adak Island (Fig. 2; NOAA 2018c). The obstructions site north of Atka Island may contain unexploded munitions and submerged ruins of a pier. Obstructions within Kuluk Bay include pier ruins (4) and piles (3) that are "visible at high water", and submerged items including pier ruins (4), pilings (5), breakwater ruins (1), an open metal frame, a concrete block, and a large rock (NOAA 2018c).

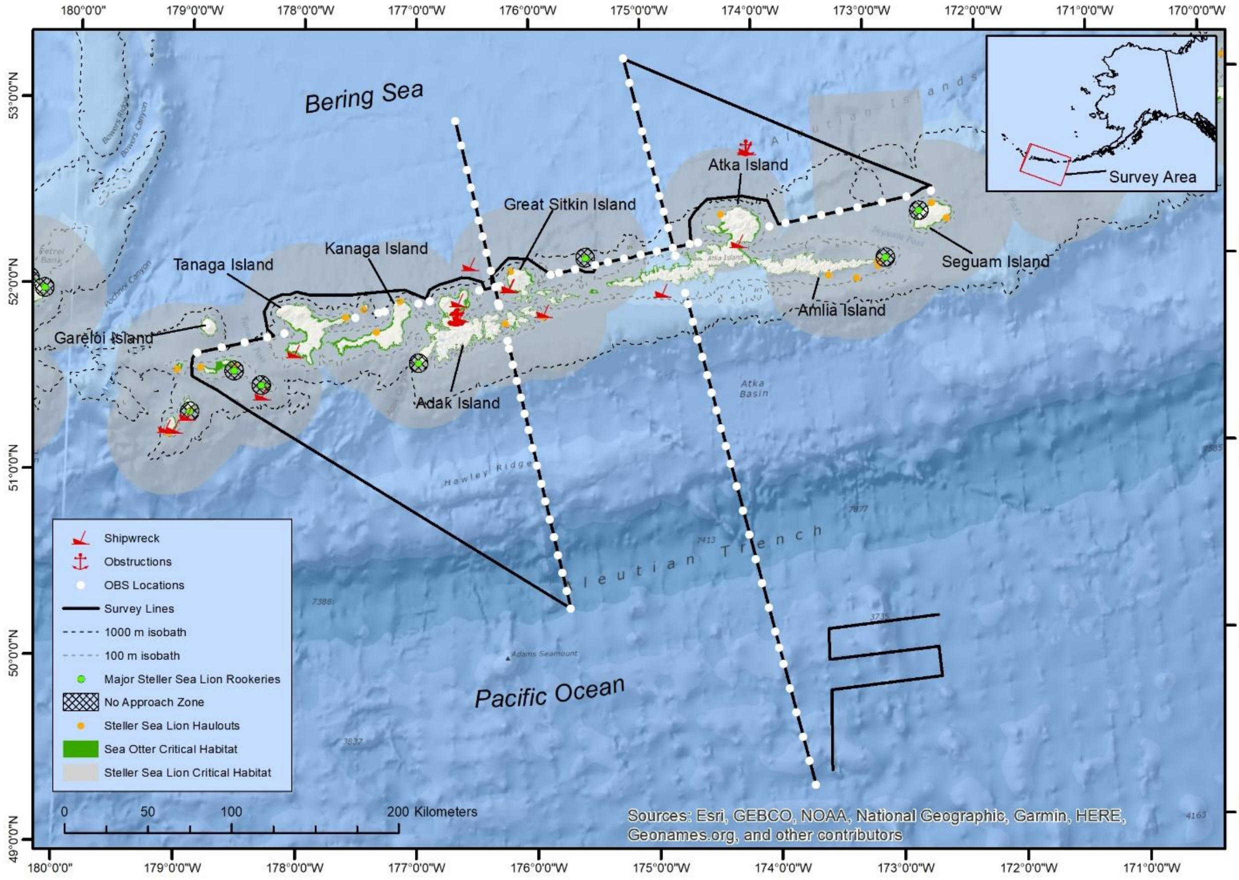


FIGURE 2. Map of the proposed 2020 seismic survey of the Aleutian Arc showing representative survey lines, critical habitat, shipwrecks, and obstructions.

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 survey. 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.

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, 2019; Kunc et al. 2016; National Academies of Sciences, Engineering, and Medicine 2017; Weilgart 2017; Bröker 2019). 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 (permanent threshold shift [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). Although Hastie et al. (2019) reported that the impulsive nature of sound is range-dependent, becoming less harmful over distance from the source, Martin et al. (2020) noted that sound retains its impulsive character at SPLs above the effective quiet threshold, and therefore this is not relevant for assessing hearing damage. Temporary threshold shift (TTS) is not considered an injury by some authors (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 2016). These findings have raised some doubts as to whether TTS should continue to be considered a non-injurious effect (Weilgart 2014; Tougaard et al. 2015, 2016). Although the possibility cannot be entirely excluded, it is unlikely that the proposed survey would result in any cases of temporary or permanent hearing impairment, or any significant non-auditory physical or physiological effects. If marine mammals encounter a survey while it is underway, some behavioral disturbance could result, but this would be localized and short-term.

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

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

Some baleen and toothed whales are known to continue calling in the presence of seismic pulses, and their calls usually can be heard between the pulses (e.g., Nieukirk et al. 2012; Thode et al. 2012; Bröker et al. 2013; Sciacca et al. 2016). Cerchio et al. (2014) suggested that the breeding display of humpback whales off Angola could be disrupted by seismic sounds, as singing activity declined with increasing received levels. In addition, some cetaceans are known to change their calling rates, shift their peak frequencies, or otherwise modify their vocal behavior in response to airgun sounds (e.g., Di Iorio and Clark 2010; Castellote et al. 2012; Blackwell et al. 2013, 2015). The hearing systems of baleen whales are undoubtedly more sensitive to low-frequency sounds than are the ears of the small odontocetes that have been studied directly (e.g., MacGillivray et al. 2014). The sounds important to small odontocetes are predominantly at much higher frequencies than are the dominant components of airgun sounds, thus limiting the potential for masking. Ghoul and Reichmuth (2014) reported that sea otter hearing sensitivity is greatly reduced underwater compared to pinnipeds and that they are primarily adapted to hear air-borne sounds. Their best underwater hearing occurs at frequencies of 2 to 26 kHz; these frequencies are outside the mainly low frequencies produced by airguns. In general, masking effects of seismic pulses are expected to be minor, given the normally intermittent nature of seismic pulses.

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

Behavioral reactions of marine mammals to sound are difficult to predict in the absence of site- and context-specific data (Ellison et al. 2018). Reactions to sound, if any, 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, 2016; Harding et al. 2019; Rako-Gospić and Picciulin 2019). 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, numerous data gaps remain regarding the consequences of behavioral responses (Elliott et al. 2019). 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). Kastelein et al. (2019a) reported that if disturbance by noise would displace harbor porpoises from a feeding area or otherwise impair foraging ability for a short period of time (e.g., 1 day), they would be able to compensate by increasing their food consumption following the disturbance.

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. 2018). Various authors have noted that some marine mammals that show no obvious avoidance or behavioral changes may still be adversely affected by sound (e.g., Weilgart 2007; Wright et al. 2011; Gomez et al. 2016).

Given the many uncertainties in predicting the quantity and types of impacts of noise on marine mammals, it is common practice to estimate how many marine mammals would be present within a particular distance of industrial activities and/or exposed to a particular level of industrial sound. In most cases, this approach likely overestimates the numbers of marine mammals that would be affected in some biologically important manner. The sound criteria used to estimate how many marine mammals could be disturbed to some biologically important degree by a seismic program are based primarily on behavioral observations of a few species. Detailed studies have been done on humpback, gray, bowhead, and sperm whales. Less detailed data are available for some other species of baleen whales and small toothed whales, but for many species, there are no data on responses to marine seismic surveys.

Baleen Whales

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

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

Dunlop et al. (2015) reported that migrating humpback whales in 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 $\mu\mathrm{Pa}^2 \cdot \mathrm{s}$ (Dunlop et al. 2017a). Responses to ramp up and use of a large 3130 in^3 array elicited greater behavioral changes in humpbacks when compared with small arrays (Dunlop et al. 2016c). Humpbacks reduced their southbound migration, or deviated from their path thereby avoiding the active array, when they were within 4 km of the active large airgun source, where received levels were >130 dB re 1 $\mu\mathrm{Pa}^2 \cdot \mathrm{s}$ (Dunlop et al. 2017b, 2018). These results are consistent with earlier studies (e.g., McCauley et al. 2000). However, some individuals did not show avoidance behaviors even at levels as high as 160 to 170 dB re 1 $\mu\mathrm{Pa}^2 \cdot \mathrm{s}$ (Dunlop et al. 2018). Dunlop et al. (2020) found that humpback whales were significantly less likely to interact socially (e.g., joining a group) in the presence of a vessel, whether it was towing an active airgun array or not, at greater ranges and received sound levels lower than the recommended thresholds.

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 $\mathrm{CSEL}_{10\text{-min}}$ (cumulative SEL over a 10-min period) of ~94 dB re 1 $\mu\mathrm{Pa}^2 \cdot \mathrm{s}$, decreased at $\mathrm{CSEL}_{10\text{-min}}$ >127 dB re 1 $\mu\mathrm{Pa}^2 \cdot \mathrm{s}$, and whales were nearly silent at $\mathrm{CSEL}_{10\text{-min}}$ >160 dB re 1 $\mu\mathrm{Pa}^2 \cdot \mathrm{s}$. Thus, bowhead whales in the Beaufort Sea apparently decreased their calling rates in response to seismic operations, although movement out of the area could also have contributed to the lower call detection rate (Blackwell et al. 2013, 2015).

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

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

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

Various species of *Balaenoptera* (blue, sei, fin, and minke whales) have occasionally been seen in areas ensonified by airgun pulses. Sightings by observers on seismic vessels using large arrays off the U.K. from 1994–2010 showed that the detection rate for minke whales was significantly higher when airguns were not operating; however, during surveys with small arrays, the detection rates for minke whales were similar during seismic and non-seismic periods (Stone 2015). Sighting rates for fin and sei whales were similar when large arrays of airguns were operating vs. silent (Stone 2015). All baleen whales combined tended to exhibit localized avoidance, remaining significantly farther (on average) from large arrays (median closest point of approach [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).

Kavanagh et al. (2019) analyzed more than 8000 hr of cetacean survey data in the northeastern Atlantic Ocean to determine the effects of the seismic surveys on cetaceans. They found that sighting rates of baleen whales were significantly lower during seismic surveys compared with control surveys. Sighting rates of baleen whales were also significantly lower during seismic operations compared with non-seismic periods during seismic surveys in the northwest Atlantic (Moulton and Holst 2010). Baleen whales as a group showed localized avoidance of the operating array and were seen on average 200 m farther from the vessel during airgun activities vs. non-seismic periods (Moulton and Holst 2010). 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 with periods when airguns were not operating (Moulton and Holst 2010). In contrast, 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 PSOs 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; Barkaszi and Kelly 2019). 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).

Similarly, for all delphinid species combined during surveys conducted in the Gulf of Mexico (GoM) from 2002 through 2015, the CPA was significantly farther during full-source seismic operations compared to silent periods (Barkaszi and Kelly 2019). 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; Barkaszi and Kelly 2019). 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. (2018), 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. (2013b) reported decreased densities and reduced acoustic detections of harbor porpoise in response to a seismic survey in Moray Firth, Scotland, at ranges of 5–10 km (SPLs of 165–172 dB re 1 µPa, SELs of 145–151 dB $\mu Pa^2 \cdot s$). For the same survey, Pirotta et al. (2014) reported that the probability of recording a porpoise buzz decreased by 15% in the ensonified area, and that the probability was positively related to the distance from the seismic ship; the decreased buzzing occurrence may indicate reduced foraging efficiency. Nonetheless, animals returned to the area within a few hours (Thompson et al. 2013b). In a captive facility, harbor porpoise showed avoidance of a pool with elevated sound levels, but search time for prey within that pool was no different than in a quieter pool (Kok et al. 2017).

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

Odontocete reactions to large arrays of airguns are variable and, at least for delphinids, seem to be confined to a smaller radius than has been observed for the more responsive of the mysticetes and some other odontocetes. A ≥170 dB disturbance criterion (rather than ≥160 dB) is considered appropriate for delphinids, which tend to be less responsive than the more responsive cetaceans. NMFS is currently developing new guidance for predicting behavioral effects (Scholik-Schlomer 2015). 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). For all sea turtle species combined during surveys conducted in the GoM from 2002 through 2015, the CPA was significantly farther during full-source seismic operations compared to silent periods (Barkaszi and Kelly 2019).

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 (Elliott et al. 2019). 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).

Sea Otters

Information on potential effects of noise on sea otters are sparse. The behavior of sea otters along the California coast was monitored while they were exposed to a single 100-in^3 airgun and a 4089-in^3 array (Riedman 1983, 1984). No disturbance reactions were evident when the airgun array was as close as 0.9 km and sea otters did not respond noticeably to the single airgun. These results suggest that sea otters may be less responsive to marine seismic survey pulses than other marine mammals, especially given their poor sensitivity for low frequencies (Ghoul and Reichmuth 2014). Also, sea otters spend a great deal of time at the surface feeding and grooming (Riedman 1983, 1984). While at the surface, the potential exposure of sea otters to underwater sound would be much reduced by the pressure-release effect at the surface (Greene and Richardson 1988; Richardson et al. 1995).

***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, 2019; Finneran 2015). However, there has been no specific documentation of TTS let alone permanent hearing damage, i.e., PTS, in free-ranging marine mammals exposed to sequences of airgun pulses during realistic field conditions.

Additional data are needed to determine the received sound levels at which small odontocetes would start to incur TTS upon exposure to repeated, low-frequency pulses of airgun sound with variable received levels. To determine how close an airgun array would need to approach in order to elicit TTS, one would (as a minimum) need to allow for the sequence of distances at which airgun pulses would occur, and for the dependence of received SEL on distance in the region of the seismic operation (e.g., Breitzke and Bohlen

2010; Laws 2012). At the present state of knowledge, it is also necessary to assume that the effect is directly related to total received energy (SEL); however, this assumption is likely an over-simplification (Finneran 2012). There is recent evidence that auditory effects in a given animal are not a simple function of received acoustic energy (Finneran 2015). Frequency, duration of the exposure, and occurrence of gaps within the exposure can also influence the auditory effect (Finneran and Schlundt 2010, 2011, 2013; Finneran et al. 2010a,b; Popov et al. 2011, 2013; Finneran 2012, 2015; Kastelein et al. 2012a,b; 2013b,c, 2014, 2015a, 2016a,b, 2017, 2018, 2019b,c; Supin et al. 2016).

Studies have shown that the SEL required for TTS onset to occur increases with intermittent exposures, with some auditory recovery during silent periods between signals (Finneran et al. 2010b; Finneran and Schlundt 2011). Studies on bottlenose dolphins by Finneran et al. (2015) indicate that the potential for seismic surveys using airguns to cause auditory effects on dolphins could be lower than previously thought. Based on behavioral tests, no measurable TTS was detected in three bottlenose dolphins after exposure to 10 impulses from a seismic airgun with a cumulative SEL of up to ~195 dB re 1 $\mu Pa^2 \cdot s$ (Finneran et al. 2015; Schlundt et al. 2016). However, auditory evoked potential (AEP) 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 or change orientation in order to mitigate the impacts of exposure to loud sounds (e.g., Nachtigall and Supin 2013, 2014, 2015, 2016; Nachtigall et al. 2018; Kastelein et al. 2020).

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) and Tougaard and Beedholm (2019) 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.

Sea otters appear to have poor hearing underwater, especially at lower frequencies (Ghoul and Reichmuth 2014) and spend the majority of time with their ears above the water surface, where they would not be exposed to airgun sounds. Thus, the potential for TTS and PTS is greatly reduced for sea otters.

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. SPLs for impulsive sounds are generally lower just below the water surface, and seals swimming near the surface are likely to be exposed to lower sound levels than when swimming at depth (Kastelein et al. 2018). However, the underwater sound hearing sensitivity for seals is the same near the surface and at depth (Kastelein et al. 2018). 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 marine mammals close to an airgun array might incur at least mild TTS, there has been further speculation about the possibility that some individuals occurring very close to airguns might incur PTS (e.g., Richardson et al. 1995, p. 372*ff*; Gedamke et al. 2011). In terrestrial animals, exposure to sounds sufficiently strong to elicit a large TTS induces physiological and structural changes in the inner ear, and at some high level of sound exposure, these phenomena become non-recoverable (Le Prell 2012). At this level of sound exposure, TTS grades into PTS. Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage, but repeated or (in some cases) single exposures to a level well above that causing TTS onset might elicit PTS (e.g., Kastak and Reichmuth 2007; Kastak et al. 2008; Reichmuth et al. 2019).

The noise exposure criteria for marine mammals that were released by NMFS (2016a, 2018) 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 ($\mathrm{SEL_{cum}}$ over 24 hours) and peak $\mathrm{SPL_{flat}}$. Onset of PTS is assumed to be 15 dB higher when considering $\mathrm{SEL_{cum}}$ and 6 dB higher when considering $\mathrm{SPL_{flat}}$. Different thresholds are provided for the various hearing groups, including LF cetaceans, MF cetaceans, HF cetaceans, phocids, and otariids/sea otters. It should be recognized that there are a number of limitations and uncertainties associated with injury criteria (Southall et al. 2007). Lucke et al. (2020) caution that some current thresholds may not be able to accurately predict hearing impairment and other injury to marine mammals due to noise.

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. Morell et al. (2020) describe new methodology that visualizes scars in the cochlea to detect hearing loss in stranded marine mammals.

Since 1991, there have been 70 marine mammal Unusual Mortality Events (UME) in the U.S., including a current one for Alaska ice seals (NOAA 2019d). 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 physical 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 animal, the deep water in the majority of the survey area, and the planned monitoring and mitigation measures would further reduce the probability of exposure of marine mammals to sounds strong enough to induce non-auditory physical effects.

Sea Turtles

There is substantial overlap in the frequencies that sea turtles detect and 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 survey would be much less than during the aforementioned studies. Also, some 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 (DoN 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 survey. Information about this equipment was provided in § 2.2.3.1 of the PEIS. A review of the expected potential effects (or lack thereof) of MBESs, SBPs, and pingers on marine mammals 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 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 to two beaked whales stranded in the Gulf of California in 2002 that were observed during a seismic survey in the region by 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 has only been on study that examined marine mammal behavioral response to MBES sounds (Varghese et al. 2020), but there is no information on sea turtle responses to MBES systems. During a recent study, group vocal periods (GVPs) were used as proxies to assess foraging behavior of Cuvier’s beaked whales during multibeam mapping in southern California (Varghese et al. 2020). The study found that there was no significant difference between clicks per GVP, click rate, and duration during multibeam mapping and non-exposure periods, but the number of GVPs was greater during and after MBES exposure than before MBES exposure. The animals did not leave the area nor did they stop foraging during the MBES surveys. During an analogous study assessing naval sonar (McCarthy et al. 2011), significantly fewer GVPs were recorded during sonar transmission (McCarthy et al. 2011).

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, MBES sounds are quite different from naval sonars. Ping duration of the MBES is very short relative to naval sonars. Also, at any given location, an individual marine mammal would be in the beam of the MBES for much less time given the generally downward orientation of the beam and its narrow fore-aft beamwidth; naval sonars often use near-horizontally-directed sound. In addition, naval sonars have higher duty cycles. These factors would all reduce the sound energy received from the MBES relative to that from naval sonars.

In the fall of 2006, an Ocean Acoustic Waveguide Remote Sensing (OAWRS) experiment was carried out in the Gulf of Maine (Gong et al. 2014); the OAWRS emitted three frequency-modulated 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 Final EA is 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. (2018) 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; Kyhn et al. 2019); 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; Cholewiak et al. 2018; Putland 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; O'Brien et al. 2016; Tenessen and Parks 2016; Martins et al. 2018). Similarly, harbor seals increased the minimum frequency and amplitude of their calls in response to vessel noise (Matthews 2017); however, harp seals did not increase their call frequencies in environments with increased low-frequency sounds (Terhune and Bosker 2016).

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

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

Many odontocetes show considerable tolerance of vessel traffic, although they sometimes react at long distances if confined by ice or shallow water, if previously harassed by vessels, or if they 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 kts. However, McKenna et al. (2015) noted the potential absence of lateral avoidance demonstrated by blue whales and perhaps other large whale species to vessels. The PEIS concluded that the risk of collision of seismic vessels or towed/deployed equipment with marine mammals 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 survey is not expected to significantly interfere with sea turtle movements, including migration.

4.1.1.4 Mitigation Measures

Several mitigation measures would be an integral part of the planned activity. Proposed measures include the following: ramp up of the airgun array; 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); shut downs when marine mammals are detected in or about to enter designated EZ; and power downs (or if necessary shut downs) when sea turtles are detected in or about to enter the 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.

As a result of the very small population size of North Pacific right whales, a shutdown of all operating airguns would be implemented upon sighting of this species at any distance from the vessel. Additionally, concentrations of feeding whales would be avoided, to the extent possible, and the array would be shut down if necessary. For this survey, shutdowns would be implemented at the Level B zone for sea otters.

Previous and subsequent analysis of the potential impacts take 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. Although these measures have been proposed by the action proponents, ultimately, survey operations would be conducted in accordance with all applicable U.S. federal and state regulations, including IHA and ITS requirements.

4.1.1.5 Potential Numbers of Marine Mammals 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. Consistent with past similar proposed actions, NSF has followed the NOAA *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* for estimating and requesting Level A takes. However, given the small EZ and the proposed mitigation measures to be applied, injurious takes would not be expected. (However, as noted earlier and in the PEIS, there is no specific information demonstrating that injurious Level A "takes" would occur even in the absence of the planned mitigation measures.) In the sections below, we describe the methods used to estimate the number of potential exposures to Level A and Level B thresholds and present estimates of the numbers of marine mammals that could be affected during the proposed seismic survey. The estimates are based on consideration of the number of marine mammals that could be disturbed appreciably (to Level B levels) by the seismic survey of the Aleutian Arc. The main sources of distributional and numerical data used in deriving the estimates are described in the next subsection. The takes have been revised from the Draft EA to reflect changes in the ensonified areas due to adjustment of proposed transect lines to (1) avoid sea otter takes, (2) avoid Steller sea lion major rookeries, and (3) avoid Coral Habitat Protection Areas. In addition, the ensonified areas have changed slightly as part of the survey (10%) would be conducted with a smaller array.

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

For the proposed survey, we used habitat-based stratified marine mammal densities developed by the U.S. Navy for assessing potential impacts of training activities in the GOA (DoN 2014; Rone et al. 2014). Alternative density estimates available for species in this region are not stratified by water depth and therefore do not reflect the known variability in species distribution relative to habitat features. Rone et al. (2014) defined four strata: Inshore: all waters <1000 m deep; Slope: from 1000 m water depth to the Aleutian trench/subduction zone; Offshore: waters offshore of the Aleutian trench/subduction zone; Seamount: waters within defined seamount areas. Densities corresponding to these strata were based on data from several different sources, including Navy funded line-transect surveys in the GOA as described in Appendix B. Compared to the GOA study area (Rone et al. 2014), the proposed survey area does not have a consistent gradual decrease in water depth ("slope" habitat) from the 1000 m isobath to the Aleutian Trench, south of the Aleutian Islands. Instead, water depths initially decrease rapidly beyond the 1000-m isobath to ~4000 m, then rise again on Hawley Ridge before dropping in the Aleutian Trench. Additionally, waters north of the Aleutian Islands and beyond 1000 m drop rapidly to ~3000 m and remain at those depths to the northern extent of the survey lines. For those reasons, and because the Rone et al. (2014) inshore densities were for all waters <1000 m, the marine mammal densities for the Inshore region were used for both shallow (<100 m) and intermediate (100–1000 m) water depths, while offshore densities were used for all deep water >1000 m.

The estimated numbers of individuals potentially exposed are based on the 160-dB re 1 µPa$_{rms}$ criterion for all marine mammals. It is assumed that marine mammals exposed to airgun sounds that strong could change their behavior sufficiently to be considered "taken by harassment". Using the density estimates shown in Table 7, estimates of the number of marine mammals that potentially could be exposed to ≥160 dB re 1 µPa$_{rms}$ during the proposed seismic survey of the Aleutian Arc if no animals moved away from the survey vessel are shown in Table 8. The *Requested Take Authorization* is given in the right-most column of Table 8. For the North Pacific right whale, Risso's dolphin, and northern right whale dolphin we increased the *Requested Take Authorization* to mean group size based on Shelden et al. (2005), Waite et al. (2003), and Wade et al. (2011a) for North Pacific right whale and Barlow (2016) for Risso's and northern right whale dolphins, and Sato's beaked whale. In the absence of density information, for ribbon and spotted seals, we estimated the *Requested Take Authorization* as five animals. The calculations are shown in Appendix C.

It should be noted that the exposure estimates assume that the proposed survey would be fully completed; in fact, the calculated takes ***have been increased by 25%*** by assuming additional survey operations would take place (see below). In addition, the exposure estimates use the most conservative threshold distances for the survey, i.e., the 36-airgun array with a shot interval of 50 m. Thus, the following estimates of the numbers of marine mammals potentially exposed to sounds ≥160 dB re 1 µPa$_{rms}$ are precautionary and probably overestimate the actual numbers of marine mammals that could be involved. Consideration should be given to the hypothesis that delphinids are less responsive to airgun sounds than are mysticetes, as referenced in the NSF and 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) on one or more occasions were estimated by calculating the marine area that would be within the Level B threshold around the operating seismic source, along with the expected density of animals in the area. The area expected to be ensonified on that day was determined by entering the planned survey lines into a MapInfo GIS, using GIS to identify the relevant areas by "drawing" the applicable 160-dB (Table 1) and PTS threshold buffers (Table 2) around each line. The ensonified areas, increased by 25%, were then multiplied by the number of survey days (16.3 days). This is equivalent to adding an additional 25% to the proposed line km (Appendix D). The approach assumes that no marine mammals would move away or toward the trackline in response to increasing sound levels before the levels reach the specific thresholds as R/V *Langseth* approaches.

Consistent with past similar proposed actions, NSF has followed the *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* for estimating Level A takes for various hearing groups (see Table 2), if there were no mitigation measures (shut downs when PSOs observed animals approaching or inside the EZ) (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

TABLE 7. Densities of marine mammals (individuals/km^2) that could be exposed to Level B and Level A thresholds for NMFS defined hearing groups during the proposed survey of the Aleutian Arc (see Appendix B for more details).

	Shallow Water <100 m	**Intermediate Water 100-1000 m**	**Deep Water >1000 m**
LF Cetaceans			
North Pacific right whale	0.00001	0.00001	0.00001
Humpback whale	0.12900	0.12900	0.00100
Blue whale	0.00050	0.00050	0.00050
Fin whale	0.07100	0.07100	0.02100
Sei whale	0.00010	0.00010	0.00010
Minke whale	0.00060	0.00060	0.00060
Gray whale	0.04857	0	0
MF Cetaceans			
Sperm whale	0	0	0.00130
Killer whale	0.00500	0.00500	0.00200
Pacific white-sided dolphin	0.02080	0.02080	0.02080
Cuvier's beaked whale	0.00220	0.00220	0.00220
Baird's beaked whale	0.00050	0.00050	0.00050
Sato's beaked whale	N.A.	N.A.	N.A.
Stejneger's beaked whale	0.00001	0.00001	0.00142
Northern right whale dolphin	N.A.	N.A.	N.A.
Risso's dolphin	0.00001	0.00001	0.00001
HF Cetaceans			
Harbor Porpoise	0.04730	0.04730	0.00000
Dall's porpoise	0.21800	0.21800	0.03700
Otariid Seals			
Steller sea lion*	0.03920	0.03920	0.00980
Northern fur seal	0.01500	0.01500	0.01700
Phocid Seals			
Northern elephant seal	0.00220	0.00220	0.00220
Harbor seal	0.01000	0.01000	0.00001
Spotted seal	N.A.	N.A.	N.A.
Ribbon seal	N.A.	N.A.	N.A.

N.A. means not available.

* Adjusted from Navy densities (see Appendix B).

TABLE 8. Estimates of the possible numbers of marine mammals that could be exposed to Level B and Level A thresholds for various hearing groups during the proposed survey of the Aleutian Arc.

	Calculated Take				
Species	**Level B[1]**	**Level A[2]**	**Regional Population Size**	**% of Pop. (Level B Takes)[3]**	**Requested Take Authorization[4]**
LF Cetaceans					
North Pacific right whale[5]	0	0	400	0.0	**2**
Humpback whale[6]	1,842	106	21,063	9.2	1,948
Blue whale	23	2	1,647	1.5	25
Fin whale	1,650	104	13,620	12.9	1,754
Sei whale	5	0	27,197	0.02	5
Minke whale	27	2	20,000	0.1	29
Gray whale[7]	62	1	26,960	0.2	63
MF Cetaceans					
Sperm whale	43	0	26,300	0.2	43
Killer whale	141	0	5,000	2.8	141
Pacific white-sided dolphin	1,000	2	988,333	0.1	1,002
Cuvier's beaked whale	106	0	3,274	3.2	106
Baird's beaked whale	24	0	2,697	0.9	24
Sato's beaked whale[8]	N.A.	N.A.	N.A.	N.A.	**9**
Stejneger's beaked whale	47	0	3,044	1.6	47
Northern right whale dolphin[8]	N.A.	N.A.	26,556	N.A.	**58**
Risso's dolphin[8]	1	0	838,000	<0.01	**22**
HF Cetaceans					
Harbor Porpoise	679	23	79,261	0.9	702
Dall's porpoise	4,312	157	1,186,000	0.4	4,469
Otariid Seals					
Steller sea lion	907	2	53,303	1.7	909
Northern fur seal	788	1	1,100,000	0.1	789
Phocid Seal					
Northern elephant seal	105	1	210,000	0.1	106
Harbor seal	148	1	205,090	0.1	149
Spotted seal[9]	N.A.	N.A.	461,625	N.A.	**5**
Ribbon seal[9]	N.A.	N.A.	184,697	N.A.	**5**

N.A. means not available.

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

[2] Level A takes if there were no mitigation measures.

[3] Requested Level A and B takes expressed as % of population in the North Pacific; except for harbor porpoise and Steller sea lion for which % population is based on Alaska population size (see Table 4).

[4] Requested take authorization is Level A plus Level B calculated takes, except for those in bold. Columns do not necessarily sum due to rounding.

[5] Requested take authorization is mean group size based on Shelden et al. (2005), Waite et al. (2003), Wade et al. (2011).

[6] Requested take includes ~41 individuals from the Western North Pacific DPS, and ~214 whales from the Mexico DPS; the remainder are from the Hawaii DPS (see text).

[7] Requested take includes 1 individual from the Western North Pacific DPS (see text).

[8] Requested take authorization is mean group size based on Barlow (2016); for Sato's beaked whale, mean group size is based on Baird's beaked whale.

[9] In the absence of density information, requested take authorization was estimated.

mammals, as this species is known to approach vessels to bowride. However, Level A takes are considered highly unlikely for most marine mammal species that could be encountered in the proposed survey area, in particular sea otters, which spend a substantial amount of time each day on the surface of the water.

The estimate of the number of marine mammals that could be exposed to seismic sounds with received levels ≥160 dB re 1 µPa$_{rms}$ during the Aleutian Arc survey is 10,358 cetaceans and 1953 pinnipeds (Table 8). That total includes 2082 cetaceans listed as ***threatened*** or ***endangered*** under the ESA: 43 sperm whales, 5 sei whales, 1754 fin whales, 24 blue whales, representing 0.2%, 0.02%, 12.9%, 1.5% of their regional populations, respectively, as well as 1 Western North Pacific gray whale, 41 Western North Pacific humpback whales, and 214 humpbacks from the Mexico DPS. It was assumed that 1.1% of gray whales that occur in the Bering Sea are from the Western North Pacific DPS (NMFS pers. comm., based on Carretta et al. 2019), and that 2.1%, 86.8%, and 11% of humpbacks in the Aleutian Islands are from the Western Pacific DPS, Hawaii DPS, and Mexico DPS, respectively (Wade 2017). The total also includes 908 ***endangered*** Steller sea lions from the Western DPS which represents 1.7% of the population. In addition, 178 beaked whales could be exposed. Nearly half of all cetaceans potentially exposed would be porpoise. Dall's porpoise is expected to be the most common marine mammal species in the area, with up to 4469 exposures to ≥160 dB re 1 µPa$_{rms}$ (0.4% of their regional population). Based on discussions with USFWS, we believe there is less than a 50% probability of Level B harassment of a single sea otter based on the proposed transect lines and array volumes.

4.1.1.6 Conclusions for Marine Mammals and Sea Turtles

The proposed seismic survey would involve towing an array with up to 36 airguns and a discharge volume of up to 6600 in^3, 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, the PEIS concluded that airgun operations with implementation of the proposed monitoring and mitigation measures could result in a small number of Level B behavioral effects in some mysticete, odontocete, pinniped, and fissiped species, and that Level A effects were highly unlikely for most species, except Dall's porpoise in shallow water. Consistent with past similar proposed actions, NSF has followed the *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* for estimating Level A takes for the Proposed Action, however, following a different methodology than used in the PEIS and most previous analyses for NSF-funded seismic surveys. For recent NSF-funded seismic surveys, NMFS issued small numbers of Level A take for some marine mammal species (and recently not for MF species) for the remote possibility of low-level physiological effects; however, NMFS expected neither mortality nor serious injury of marine mammals to result from the surveys (NMFS 2019a,b).

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, for the species that would be affected, 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. Also, the actual numbers of animals potentially exposed to sound levels sufficient to cause disturbance (i.e., what would be considered takes) have almost always been much lower than the predicted and authorized takes.

TABLE 9. ESA determination for marine mammals for the proposed survey of the Aleutian Arc during 2020.

	ESA Determination		
Species	**No Effect**	**May Affect – Not Likely to Adversely Affect**	**May Affect – Likely to Adversely Affect**
North Pacific Right Whale			√
Humpback Whale (Western North Pacific DPS)			√
Humpback Whale (Mexico DPS)			√
Gray Whale (Western North Pacific DPS)			√
Sei Whale			√
Fin Whale			√
Blue Whale			√
Sperm Whale			√
Killer Whale (Southern Resident DPS)	√		
Steller Sea Lion (Western DPS)			√
Northern Sea Otter (Southwest Alaska DPS)		√	

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 a 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). During an NSF-funded ~3455 km, 2-D seismic survey conducted by R/V *Langseth* off the coast of Hawaii in 2018, no marine mammals were observed within the predicted 160-dB zone and potentially taken, representing 0% of the 11,068 takes authorized by NMFS (RPS 2019b). 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, and the low potential for sea turtles to occur in the proposed survey area, impacts would not be anticipated to be significant or likely to adversely affect sea turtles (Table 10).

4.1.2 Direct Effects on Marine Invertebrates, Fish, and Fisheries, EFH, 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; Elliott et al. 2019; Popper and Hawkins 2019; Hawkins et al. 2020), including how particle motion, rather than sound pressure level, affects invertebrates and fishes that are exposed to sound (Hawkins and Popper 2017; Popper and Hawkins 2018, 2019). 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 10. ESA determination for sea turtle species for the proposed survey of the Aleutian Arc during 2020.

Species	ESA Determination		
	No Effect	May Affect – Not Likely to Adversely Affect	May Affect – Likely to Adversely Affect
Leatherback Turtle		√	
Green Turtle	√		
Olive Ridley Turtle	√		
Loggerhead Turtle	√		

Substrate vibrations caused by sounds may also affect the epibenthos, but sensitivities are largely unknown (Roberts and Elliott 2017). Nonetheless, several studies have found that substrate-borne vibration and sound elicit behavioral responses in crabs (e.g., Roberts et al. 2016; Roberts and Laidre 2019) and mussels (Roberts et al. 2015). Solan et al. (2016) also reported behavioral effects on sediment-dwelling invertebrates during sound exposure. 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; Carroll et al. 2017; Edmonds et al. 2016; Weilgart 2018). The available information suggests that invertebrates, particularly crustaceans, may be relatively resilient to airgun sounds (Day et al. 2016a,b). 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 $\mu Pa^2 \cdot s$ 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 dB re 1 μPa^2. The study animals still incurred acoustic trauma and injury to statocysts, despite not being held in confined tanks with walls. A later study from this research group showed that statocyst damage was more severe in cephalopod hatchlings than in adults, suggesting a developmental period of greater sensitivity (Solé et al. 2018).

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 (Harrington et al. 2010; Parry et al. 2002; 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 μPa$^2 \cdot$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 μPa$^2 \cdot$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 with 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 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 2004; 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 airgun 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 hepatopancreas. 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.

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.

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 a 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 3D seismic survey; the maximum SEL and SPL $_{0\text{-pk}}$ were 204 dB re 1 µPa^2·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 (2018), Hawkins and Popper (2017), Popper et al. (2019b), Popper and Hawkins (2019), and Slabbekoorn et al. (2019); they include pathological, physiological, and behavioral effects. Radford et al. (2014) and Putland et al. (2018) 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, TTS, 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 µPa^2 · 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 µPa^2 · 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 µPa^2 · s SEL. Increases in alarm responses were seen in the fish at SELs >147–151 dB re 1 µPa^2 · 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 AEPs were examined for fish that had been in cages as close as 45 m from the pass of the seismic vessel and at a 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 $\mu Pa^2/Hz$ 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 with 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 airgun arrays used in the geophysical survey had sound pressure levels of 237 dB re 1µPa$_{0\text{-}p}$, 243 dB re 1µPa$_{p\text{-}p}$, 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 airgun 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.

Przeslawski et al. (2016) 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 3 years before the seismic survey to six months after completion of the survey in an area 13,000 km^2 which encompassed survey area. Overall, no significant adverse impacts of the seismic survey on catch rates were noted; six of the 15 species were actually 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, and EFH

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 commercial and recreation fisheries would not be significant. Interactions between the proposed survey and fishing operations in the survey area are expected to be limited. There could be a possible conflict with R/V *Langseth*'s towed equipment entangling with fishing gear. Fishing activities could occur within the proposed survey area; however, vessels actively fishing would need to maintain a safe distance from R/V *Langseth* and the towed seismic equipment. Conflicts would be avoided through communication with the fishing community before and during the survey. PSOs would also watch for 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. In addition, no adverse effects on EFH or HAPC are expected given the short-term nature of the study (~43 days) and minimal bottom disturbance.

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 1–2 kHz, with a hearing threshold of 58–71 dB re 1 μPa_{rms} (Hansen et al. 2017; Larsen et al. 2020). Great cormorants and gentoo penguins were found to respond to underwater sounds and may have special adaptations for hearing underwater (Johansen et al. 2016; Hansen et al. 2017; Larsen et al. 2020; Sørensen et al. 2020). African penguins 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 were 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 11. ESA determination for fish for the proposed survey of the Aleutian Arc during 2020.

	ESA Determination		
Species	**No Effect**	**May Affect – Not Likely to Adversely Affect**	**May Affect – Likely to Adversely Affect**
Steelhead Trout (Various DPSs)		√	
Chinook Salmon (Various ESUs)		√	
Chum Salmon (Hood Canal summer-run ESU)		√	
Coho Salmon (Lower Columbia River ESU)		√	
Sockeye Salmon (Snake River ESU)		√	
Green Sturgeon (Southern DPS)		√	

TABLE 12. ESA determination for seabird species for the proposed survey of the Aleutian Arc during 2020.

	ESA Determination		
Species	**No Effect**	**May Affect – Not Likely to Adversely Affect**	**May Affect – Likely to Adversely Affect**
Short-tailed Albatross		√	
Steller's Eider		√	
Spectacled Eider		√	

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, including EFH, 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 survey, 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 survey 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 Possible Effects on Subsistence Hunting and Fishing

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

Marine mammals are hunted legally in Alaskan waters by coastal Alaska Natives. Hunting communities in the Aleutians include Adak and Atka located within the proposed survey area, as well as Akutan, Nikolski, and Unalaska (Wolfe et al. 2012). Steller sea lions, harbor seals, sea otters, and small numbers of spotted and ringed seals are hunted (ADFG 1997). In 2008, it was estimated that 1462 harbor seals were taken throughout Alaska with the majority of takes in southeast Alaska; 3.4% were taken in the Aleutian Islands, mostly in Akutan and Adak (Wolfe et al. 2009). The seasonal distribution of harbor seal takes by Alaska Natives typically shows two distinct hunting peaks ― one during spring and one during fall and early winter; however, seals are taken in all months (Wolfe et al. 2012). In general, the months of highest harvest are September through December, with a smaller peak in February–March (Wolfe et al. 2012). Harvests are traditionally low from May through August, when harbor seals are raising pups and molting.

The most recent 5-year period with data available (2004–2008) shows an annual average catch of 172 Steller sea lions from the Western stock for all areas in Alaska combined, except the Pribilof Islands in the Bering Sea where the annual catch was 32.2 (Muto et al. 2019b). In 2008, the majority of sea lions were taken in the Aleutian Islands (45.8, with 35 of those in Atka), followed by the Pribilof Islands (29.3) (Wolfe et al. 2009). Most sea lions are harvested in late summer/fall and spring (Wolfe et al. 2009). The harvest of spotted and ringed seals in Alaska was highest in 2011, with at least 518 spotted seals and 1286 ringed seals taken; however, Muto et al. (2019b) did not report any harvest for the Aleutian Islands. Ringed seals would not occur in the proposed study area during September/October, as they move north with the receding ice.

The proposed survey could potentially impact the availability of marine mammals for harvest in a small area immediately around R/V *Langseth*, and for a very short time period during seismic operations. Considering the limited time that the planned seismic survey would take place close to the hunting communities of Adak and Atka, the proposed survey is not expected to have any significant impacts to the availability of marine mammals for the subsistence harvest.

Subsistence fisheries are open to participation by all Alaskan residents (ADFG 2020h). In the Aleutian Islands, important subsistence fisheries occur for all five salmon species, halibut, and shellfish within five management districts – Akutan, Unalaska, Umnak, Atka-Amlia Islands, and Adak (ADFG 2020h). The proposed survey area includes the Adak District. Subsistence fisheries may occur within or near the proposed survey area during September/October, particularly nearshore.

The ADFG Division of Commercial Fisheries manages subsistence salmon fisheries in the Adak District, for which subsistence permits are required (ADFG 2020h). Salmon may be caught for subsistence purposes at any time of year in the Adak, Akutan, Atka-Amlia, and Umnak districts (ADFG 2019c). Salmon subsistence fisheries in the Aleutian Islands and Adak District mainly consist of sockeye and Coho salmon, mostly caught using non-commercial gillnets and rod and reel (ADFG 2019c, 2020h). Most subsistence salmon fisheries in the Adak District occurs at Hidden Bay on Adak Island and Quail Bay and Galas Point on Kagalaska Island, with some pink and Coho salmon also harvested off northern Adak Island (ADFG 2020h). For 2019–2020, the Alaska Board of Fisheries determined that “13,500–23,000 salmon are reasonably necessary for subsistence uses in the Aleutian Islands Area” (ADFG 2019c). In the Adak District, no subsistence salmon fisheries may occur in freshwater bodies or in saltwater “within 100 yards of a stream terminus” for Adak and Kagalaska Islands (ADFG 2019c).

Subsistence fisheries for halibut are open to rural Alaska residents or members of an Alaskan native tribe, managed by the NMFS, and require a Subsistence Halibut Registration Certificate (SHARC) (ARO 2019; ADFG 2020h). Eligible Alaska communities and Native Tribes may also obtain special permits for community harvest, ceremonial, or educational purposes (NPFMC 2020b). The State of Alaska monitors subsistence halibut harvests using a combination of a mail-based survey and communication with personal contacts (ADFG 2020d). Fishing gear for subsistence halibut harvests may only include a single handheld line with up to two hooks (ADFG 2019c). Other than halibut, there are no harvest programs for groundfish subsistence fisheries in the Aleutian Islands, which variably occur for Pacific cod, sablefish, Atka mackerel, and rockfishes, particularly nearshore subsistence fisheries for black and dusky rockfishes (ADFG 2020h).

The Alaska Board of Fisheries deemed that "200,000–330,000 usable pounds of finfish other than salmon are reasonably necessary for subsistence uses in the Aleutian Islands Area" during 2019–2020 (ADFG 2019c).

In the Alaska Peninsula/Aleutian Islands Area, subsistence fishery permits are required from the ADFG for king and tanner crab west of Scotch Cap Light and east of 168ºW (ADFG 2020h). During 1999–2015, an average 222 subsistence harvest permits were issued per year for red king crab, with an annual average harvest of 1080 crabs in the Bering Sea/Aleutian Islands (Leon et al. 2017). Subsistence harvest for king crab decreased by the end of this period, with only ~145 crabs caught during 2015 (Leon et al. 2017). Most king crab caught in subsistence fisheries in the Bering Sea/Aleutian Islands are taken using pots, although some of the harvest is acquired by SCUBA divers (Leon et al. 2017). A partially limited subsistence shrimp fishery occurs within the Alaska Peninsula/Aleutian Islands Area, which requires a subsistence fishing permit and limits fishers to no more than 0.23 t of shrimp on board registered shrimp fishing vessels during/within a closed commercial shrimp season/area (ADFG 2019c). There are otherwise no closed seasons or bag/possession limits for subsistence shrimp fishers in the Area (ADFG 2019c). The Alaska Board of Fisheries determined that for 2019–2020, 1200–7400 king crab, 4200–16,200 tanner crab, and 22,000–68,000 lbs of "usable weight of Dungeness crab and miscellaneous shellfish" are "reasonably necessary for subsistence purposes in the Alaska Peninsula-Aleutian Island Area" and/or Kodiak Area (ADFG 2019c).

Seismic surveys can, at times, cause changes in the catchability of fish (see subsection 4.1.5, above). L-DEO would minimize the potential to negatively impact the subsistence fish harvest by avoiding areas where subsistence fishers are actively fishing, if requested or viewed necessary. Additionally, the PIs would conduct outreach with communities near the planned survey area to identify and avoid areas of potential conflict, including for marine subsistence activities (mammals and fisheries).

4.1.6 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 harvest. Interactions between the proposed surveys and fishing operations in the survey area are expected to be of limited duration. 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 survey.

There are numerous shipwrecks within or near the proposed study area. However, the proposed activities are of relative short duration (~43 days), and most of the shipwrecks (and dive sites) are not expected to occur right along the proposed transect lines. Nonetheless, conflicts would be avoided through communication with dive operators during the survey. Furthermore, OBSs would be deployed to avoid shipwrecks and would only cause minimal seafloor disturbances. Therefore, no adverse impacts to cultural resources are anticipated.

4.1.7 Direct Effects on SCUBA Diving and Their Significance

Most of the proposed survey area occurs in water deeper than 100 m, where limited diving activities, if any, are expected to occur. Significant impacts on, or conflicts with, divers or diving activities in shallow waters would be avoided through communication with the diving community during the survey.

4.1.8 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 survey 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.

4.1.8.1 Past and Future Research Activities

During 1970, a single-channel 2-D seismic survey occurred from M/V *Bartlett* that included 128 tracklines within the Aleutian Islands, Aleutian Basin, and Bering Sea; ~20 of these tracklines were within or near the western and eastern portions of the proposed survey area (USGS 2020). Two multi-channel 2-D seismic surveys were conducted within the proposed survey area from M/V *Samuel Phillips Lee* during 1980 and 1981; most of the effort occurred in the southern and eastern portions of the proposed survey area (USGS 2020). Another multi-channel 2D seismic survey was conducted northeast of the proposed survey area during 1982 for oil and gas exploration (USGS 2020). During September 1986, M/V *Farnella* conducted a single-channel 2-D seismic survey off the northern portion of the Aleutian Islands from Unimak Island to Bowers Ridge; part of this survey overlapped the proposed survey area (USGS 2020). A single-channel 2-D seismic survey was conducted by M/V *Farnella* south of the central/western Aleutian Islands during August-September 1987, some of which occurred within or near the southern portion of the proposed survey area (USGS 2020). M/V *Farnella* was also used to complete a single-channel 2-D seismic survey off the southern Aleutian Islands during June–July 1988, including within the southern portion of the proposed survey area (USGS 2020). TGS (2020) collected well data during an unspecified date within the proposed survey area, in southeastern Kuluk Bay, Adak Island, at ~51.86ºN, 176.47ºW; the well site is adjacent to the western-most part of the proposed survey area.

During 1994, seismic data were acquired by two vessels, R/V *Maurice Ewing* and R/V *Alpha Helix*, to determine the velocity structure and crustal composition of the Aleutian island arc in Seguam Pass, within and/or east of the proposed survey area between Seguam and Amlia Islands (Holbrook et al. 1999). The Seguam Pass data were collected using a 20-element airgun array, multi-channel streamer, hydrophones and seismometers deployed on the seabed, and portable seismometers that were deployed on various Aleutian Islands (Holbrook et al. 1999). The most relevant data regarding the proposed study are from the NSF-funded 1997 Aleutian seismic experiment (Aleut); what was learned from that study motivated the current project. The most relevant Aleut lines are A1 and A2 – A1 was an across-arc transect that crossed the arc at Seguam Pass, just east of the proposed survey area. Seguam Pass exists at the intersection of two distinct arc segments, and so the structure at that intersection is not representative of typical arc-crust formation. A2 was an along-arc transect that was very sparsely instrumented, with an OBS spacing of ~100 km. During 2005, an NSF-funded L-DEO seismic survey took place in the Aleutian Arc spanning from Unalaska to Attu islands by the R/V *Thomas G. Thompson*. The study used a generator injector (GI) airgun as well as rock dredging to examine the apparent systematic westward decreases in the rate of subduction and sediment delivery to the Aleutian trench, and to locate sites of seafloor volcanism (Ireland et al. 2005). In addition, L-DEO conducted academic seismic surveys in the western GOA during 2001 (RPS 2011) and 2019 (RPS 2019a).

As part of an ecological recovery effort following the 2008 volcanic eruption of Kasatochi Island, located between Adak and Atka islands and within the central portion of the proposed survey area, a geological survey of the Kasatochi volcano was completed during mid-June to late-August 2009–2013 which included mapping, high-resolution photographs, and the collection of rock samples for elemental analyses (Nye et al. 2017). A team of 25 geoscientists from 11 different institutions studied volcanoes along the Aleutian Arc during summer 2015 as a component of the NFS' Geodynamic Processes at Rifting and Subducting Margins (GeoPRISMS) program (NSF 2015). Two research vessels, *Maritime Maid* and *Sikuliaq*, were used to collect offshore and onshore geochemical and seismic data, surface deformation information, and electrical conductivity data for volcanoes within the Aleutian Islands (NSF 2015).

An autonomous underwater vehicle (AUV) survey was conducted for SIO during 1989 by Project Recover and U.S. Navy members of submerged World War II battlefield sites in Kiska Harbor, west of the proposed survey area. The survey included the collection of side scan sonar, multibeam, and magnetometer data, camera footage, and benthic physical oceanographic data, and the discovery of a missing section of the sunken U.S. Navy destroyer, USS *Abner Read*, that was lost in 1943 (NOAA 2020g). An expedition led by the University of New Hampshire collected high-resolution mapping data of the seabed on Bowers Ridge and the Beringian Margin in the Bering Sea, northwest of the survey area. The survey was a component of the Extended Continental Shelf (ECS) Project and was conducted during 2003 using R/V *Davidson* (NOAA 2019e).

Scientific research surveys may occur in the future within or near the survey area to assess fish stocks for fisheries management purposes. The AFSC regularly conducts groundfish trawl surveys in the Aleutian Islands to aid in stock assessments and biomass modelling (AFSC 2019). The IPHC monitors halibut abundance, population structure, ecology, and movements via annual longline surveys which are used to inform stock assessments and management strategies (ADFG 2020b). The abundance and movement rates of Atka mackerel are similarly monitored via ongoing tagging studies by the NMFS (AFSC 2019).

4.1.8.3 Vessel Traffic

Vessel traffic near the proposed survey area would consist of fishing vessels, as well as other commercial (cargo) vessels; however, most vessels appear to transit outside of the survey area (e.g., MarineTraffic 2020). Sullender et al. (2017) show transit corridors for cargo vessels and tankers to the north and south of the proposed survey area, with fishing vessels concentrated along the northern coasts of Adak, Atka, and Amlia islands, and in southern Seguam Pass. The GOA is a busy shipping route, and there is also substantial traffic to the north and south of the Aleutian Islands. A total of 41.2 million tons of waterborne cargo were handled at Alaskan ports in 2017, including domestic and foreign exports and imports, and intrastate shipments (WCSC 2018). Six Alaskan ports were ranked among the busiest U.S. ports by cargo tonnage in 2018 (AAPA 2018): Valdez, Nikishka, Kivilina, Anchorage, Ketchikan, and Unalaska Island.

The Alaska Marine Highway System (AMHS) provides year-round service to over 30 communities in Alaska, as far west as Unalaska. The AMHS currently operates eleven vessels, and the busiest months in Southwest Alaska are June and July (AMHS 2015). In 2015, the AMHS carried a total of 288,133 passengers and 100,547 vehicles (AMHS 2015). The bulk of this is in Southeast Alaska, with 65,133 passengers and 26,148 vehicles carried in Southwest Alaska in 2015 (AMHS 2015). In 2015, AMHS vessels travelled >200,000 km in Southwest Alaska (AMHS 2015). The total distance of ~7600 km (including 3224 km of seismic survey effort plus transits) to be traveled by R/V *Langseth* would be small relative to total transit length for vessels operating in the general region around the proposed survey area. Thus, the addition of the seismic source vessel traffic to existing shipping and fishing operations (see below) is expected to result in a only a minor increase in overall ship traffic.

4.1.8.4 Fisheries Interactions

The commercial fisheries in the general area of the proposed survey are described in § III. The primary contributions of fishing to potential cumulative impacts on marine mammals and sea turtles involve noise, potential entanglement, and removal of prey items (e.g., Reeves et al. 2003). Entanglement in fishing gear can lead to serious injury or mortality of some marine mammals. Section 118 of the MMPA requires all commercial fisheries to be placed in one of three categories based on the level of incidental take of marine mammals relative to the Potential Biological Removal (PBR) for each marine mammal stock. Category I, II, and III fisheries are those for which the combined take is ≥50%, 1%–50%, and <1%, respectively, of PBR for a particular stock. In 2019, most fisheries in the Alaska Bering Sea/Aleutian Islands were listed as Category III; however, the Alaska Bering Sea/Aleutian Islands trawl fishery for flatfish, pollock, and rockfish were listed as Category II, as well as the Alaska Bering Sea/ Aleutian Islands Pacific cod longline fishery (NOAA 2019f). In addition, the Alaska Peninsula/Aleutian Islands salmon gillnet fisheries were listed as Category II because of bycatch of porpoise, pinnipeds, and otters (NOAA 2019f). Lewison et al. (2014) reported bycatch of marine mammals in the longline and trawl fisheries for the proposed survey area.

The highest annual mortality rate of any cetacean in Alaska attributable to commercial fisheries, as reported by Muto et al. (2019b) is the harbor porpoise. Harbor porpoises of the GOA stock had an annual mortality rate of 72 animals; incidental takes of Dall's porpoise was also high, with 37 animals taken annually (Muto et al. 2019b). The highest minimum mean annual mortality rate for baleen whales in Alaska fisheries was reported for the humpback whale (8 whales); sperm whales (4.4), killer whales (2), and fin whales (0.2) also succumbed to commercial fisheries annually (Muto et al. 2019b). For 2012–2016, Helker et al. (2019) reported that the Steller sea lion had the highest total human-caused serious injuries and mortalities (due to fisheries, hunting, entanglements, etc.) in Alaska, followed by humpback whales, northern fur seal, and the harbor seal. Of the pinniped species, the highest incidental mean annual mortality rates attributable to commercial fisheries have been reported for the Western Stock of Steller sea lions (35 animals) and PWS of harbor seals (24 animals); other harbor seal stocks (2.5), ribbon seal (1.1), spotted seals (0.9), and northern fur seals (0.2) also had mortalities (Muto et al. 2019b). Raum-Suryan et al. (2009) reported that Steller sea lions get entangled in and ingest fishing gear; packing and rubber bands were the most common neck entanglements, followed by rope, nets, and monofilament line. Ingested fishing gear consisted mainly of salmon fishery flashers, longline gear, hook and line, spinners/spoons, and bait hooks; the incidence of entanglement was determined to be 0.26% (Raum-Suryan et al. 2009).

Lewison et al. (2004) estimated that 20,000 to 40,000 leatherbacks were taken as bycatch in longlines in 2000 in the Pacific; however, none of these appear to have occurred in Alaska (Lewison et al. 2014). Entanglement of sea turtles in seismic gear is also a concern; there have been reports of turtles being trapped and killed between the gaps in tail-buoys offshore of West Africa (Weir 2007). The probability of entanglements would be a function of turtle density in the study area, which is expected to be low. Towing of hydrophone streamers or other equipment is not expected to significantly interfere with sea turtle movements, including migration, unless they were to become entrapped as indicated above.

Entanglement in fishing gear and hooking can also lead to mortality of seabirds. Thousands of seabirds are bycaught annually in Alaska fisheries. Krieger et al. (2018) reported that 31 short-tailed albatross were taken as bycatch in Alaskan fisheries from 2010 to 2014, but there were no takes from 2015 to 2018. In the Aleutian Islands, 291 seabird mortalities are reported annually, most of which were northern fulmars; no short-tailed albatross were reported (Krieger et al. 2018). The implementation of scaring lines has greatly reduced bycatch of albatross (Suryan and Kuletz 2018). Bycatch of marbled murrelet in Alaska gillnet fisheries may be substantial, on the order of hundreds of birds annually and was listed as the second most important human cause for this species' decline in its 2006 Alaska status review (Piatt et al. 2007). Although Lewison et al. (2014) did not report any bycatch of seabirds for the proposed survey area, bycatch in longline and gillnet fisheries were reported for the Alaskan Peninsula and the western Aleutian Islands. According to Krieger et al. (2018), 291 seabirds are taken as by-catch annually in fisheries in the Aleutian Islands; the majority are northern fulmars, followed by Laysan albatross, shearwaters, and gulls.

There might also be some localized avoidance by marine mammals of fishing vessels near the proposed seismic survey area. The proposed operations in the survey area would be limited (~43 days), and the addition of the proposed survey to existing commercial fishing operations is expected to result in only a negligible increase in overall disturbance effects on marine mammals and sea turtles. The addition of R/V *Langseth*'s operations to existing fishing operations would result in no increase in serious injuries or mortality to marine mammals or sea turtles.

4.1.8.5 Subsistence Hunting

Marine mammals are legally hunted in Alaskan waters by coastal Alaska Natives. In the Aleutian Islands, Steller sea lions, harbor seals, sea otters, and small numbers of spotted and ringed seals are hunted (ADFG 1997). The hunt is described in § 4.1.5, above. In addition to the species taken at the Aleutian Islands, bearded seals, ribbon seals, northern fur seals, walrus, bowhead whales, and beluga are also hunted in Alaska. The hunting communities in the Aleutian Islands include Adak, Akutan, Atka, Nikolski, and Unalaska Islands (Wolfe et al. 2009). The planned project (unlike subsistence hunting activities) would not result in directed or lethal takes of marine mammals. Thus, the combined effects of the project and of subsistence on marine mammal stocks will not differ from that of subsistence harvesting alone.

4.1.9 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 is a temporary phenomenon that does not involve injury, and if it were to occur, it would be limited to a few individuals 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. Effects on recruitment or survival would be expected to be (at most) negligible.

4.1.10 Coordination with Other Agencies and Processes

This Final EA has been prepared by LGL on behalf of L-DEO and NSF pursuant to NEPA. Potential impacts to marine mammals, endangered species, and critical habitat have also been assessed in the document. The Draft EA was used to support the ESA Section 7 consultation process with NMFS and USFWS and other regulatory processes, such as EFH consultation. The Draft EA was also used as supporting documentation for an IHA application submitted by L-DEO, on behalf of itself, NSF and the other Proposing Institutions, to NMFS, under the U.S. MMPA, for "taking by harassment" (disturbance) of small numbers of marine mammals, for the proposed seismic survey. NSF coordinated with NMFS to complete the Final EA prior to issuance of an IHA and Biological Opinion/ITS to accommodate NMFS' need to adopt NSF's Final EA as part of the NMFS NEPA process associated with issuing authorizations. NSF had enhanced coordination with NMFS throughout the IHA and ESA consultation processes to facilitate this streamlined approach. Although an IHA application was submitted to USFWS, after discussions with USFWS staff, the project was adjusted to avoid take of sea otters and the IHA application was withdrawn. In addition to federal environmental regulatory requirements, NSF and L-DEO coordinated with fishers to avoid space-use conflicts. For security matters related to equipment use, activities were coordinated with the Navy.

NSF posted the Draft EA on the NSF website for a 30-day public comment period from 29 June 2020 to 28 July 2020, and emailed project information and notice of availability to comment to interested parties in the survey area. Comments were received from three entities (i.e., Groundfish Forum, Aleutian King Crab Research Foundation, NMFS Alaska Region Habitat Conservation Division) and are addressed herein (see Appendix E). NSF anticipates limited space-use conflict with the fishing industry; nonetheless, the vessel would communicate with other ocean users via Notice to Mariners and radio communications during operations. NSF also contacted organizations regarding subsistence; no issues with the proposed seismic surveys with respect to subsistence were brought to NSF's attention. In particular, the Aleut Marine Mammal Commission noted they had no issues with the survey.

(a) Endangered Species Act (ESA)

The Draft EA was used during the ESA Section 7 consultation process with NMFS and USFWS. On 23 April 2020, NSF submitted a letter of concurrence request to USFWS that the proposed activity may affect but was not likely to adversely affect the ***endangered*** short-tailed albatross, the ***threatened*** Steller's, and spectacled eiders. On 11 June 2020, the concurrence letter was modified to include the Southwest DPS of northern sea otter and their critical habitat. On 26 June 2020, USFWS provided a letter of concurrence (Appendix F) that the proposed project activities were not likely to adversely affect any listed species or their designated critical habitat. Mitigation measures for these species would include shut downs for sea otters and power downs/shut downs for diving or foraging ESA-listed seabirds within the EZ. On 27 March 2020, NSF submitted a formal ESA Section 7 consultation request, including the Draft EA, to NMFS for the proposed activity. As previously noted, NSF had enhanced coordination with NMFS during the consultation process. Based on this enhanced coordination, NSF anticipates that a Biological Opinion and ITS will be issued for the proposed activity with a finding of "may affect but not likely to adversely affect" threatened and endangered species. As part of its decision-making process for the Proposed Action, NSF will take into consideration the Biological Opinion and ITS issued by NMFS and the results of the entire environmental review process.

(b) Marine Mammal Protection Act (MMPA)

The Draft EA was also used as supporting documentation for an IHA application submitted on 27 March 2020 by L-DEO on behalf of itself, NSF, and the researchers, to NMFS, under the U.S. MMPA, for "taking by harassment" (disturbance) of small numbers of marine mammals during the proposed seismic survey. On 28 July 2020, NMFS issued in the Federal Register a notice of intent to issue an IHA for the survey and a 30-day public comment period. NMFS will consider the comments received and will provide responses as required per the IHA process. As previously noted, NSF had enhanced coordination with NMFS during the IHA application process. Based on this enhanced coordination, NSF anticipates that an IHA will be issued for the proposed activity. As part of its decision-making process for the Proposed Action, NSF will take into consideration the IHA issued by NMFS and the results of the entire environmental review process.

(c) Essential Fish Habitat (EFH)

EFH was identified to occur within the proposed survey area, but HAPCs are >100 km away. Although NSF anticipated no significant impacts to EFH and HAPC, in accordance with the Magnuson-Stevens Fishery Conservation and Management Act, NSF requested consultation with NMFS on 5 June 2020. On 30 July 2020, NOAA noted in response that they had "no issues with the survey as documented". As such, NMFS did not provide additional conservation recommendations for Proposed Action, thus satisfying the requirements of both sections 305(b)(2)(A) and sections 305(b)(2)(B) of the Magnuson-Stevens Act.

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 and an opportunity for international scientific collaboration would be lost. Research that would contribute to our understanding of the architecture of oceanic-arc crust, to infer processes that control chemical fractionation and lead to the creation of continent-like compositions, and that would add to the comprehensive assessment of geohazards for the Alaska region, such as earthquake and tsunami hazards, would not be conducted. The No Action Alternative would not meet the purpose and need for the proposed activity.

V LIST OF PREPARERS

LGL Ltd., environmental research associates

Taylor Beyea, M.Sc., Bryan, TX
Susan Dufault, M.Sc., Bryan, TX
Darren Ireland, M.Sc., Bryan, TX*
Meike Holst, M.Sc., Sidney, BC*
Tony Lang, St. John’s, NL
Sarah Penney-Belbin, M.Sc., St. John’s, NL
W. John Richardson, Ph.D., King City, ON

Lamont-Doherty Earth Observatory

Anne Bécel, Ph.D., Palisades, NY
Sean Higgins, Ph.D., Palisades, NY

National Science Foundation

Holly E. Smith, M.A., Alexandria, VA

* Principal preparers of this specific document. Others listed above contributed to a lesser extent, or contributed substantially to previous related documents from which material has been excerpted.

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LIST OF APPENDICES

APPENDIX A: DETERMINATION OF MITIGATION ZONES

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APPENDIX A: DETERMINATION OF MITIGATION ZONES

During the planning phase, mitigation zones for the proposed marine seismic survey were calculated based on both modeling by L-DEO for the Level A and Level B (160 dB re 1µPa$_{\text{rms}}$) threshold and using empirical measurements from Crone et al. (2014) from the Cascadia Margin. 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 18- and 36-airgun array and for a single 1900LL 40-in^3 airgun, which would be used during power downs for sea turtles and ESA-listed diving seabirds; all models used a 9-m tow depth. This LDEO 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).

Typically, for deep and intermediate-water cases, the field measurements cannot be used readily to derive mitigation radii, as at those GoM 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 L-DEO modeling 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 have been used for previous EAs to derive mitigation radii.

However, L-DEO collected a multichannel seismic (MCS) data set from R/V *Langseth* on an 8 km streamer in 2012 on the shelf of the Cascadia Margin in water up to 200 m deep that allowed Crone et al. (2014) to analyze the hydrophone streamer (>1100 individual shots). These empirical data were then analyzed to determine in situ sound levels for shallow and upper intermediate water depths to provide mitigation radii.

This analysis is summarized in the Addendum at the end of this Appendix. Similarly, data collected by Crone et al. (2017) during a survey off New Jersey in 2014 and 2015 confirmed that *in situ* measurements and estimates of the 160- and 180-dB distances collected by R/V *Langseth* hydrophone streamer were 2–3 times smaller than the predicted operational mitigation radii. In fact, five separate comparisons conducted of the L-DEO model with *in situ* received levels[3] have confirmed that the L-DEO model generated conservative threshold distances, resulting in significantly larger mitigation zones than required by National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS).

For the proposed survey in deep water (>1000 m), we use the deep-water radii obtained from L-DEO model results down to a maximum water depth of 2000 m for the 36-airgun (Fig. A-1) and 18-airgun (Fig. A-2) arrays (Table A-1). For the 36-airgun array, the radius (8233 m) for intermediate-water depths (100–1000 m) is taken from Crone et al. (2014). The intermediate radius from the L-DEO model derived from the deep-water ones by applying a correction factor (multiplication) of 1.5 is quite consistent (estimated at 8444 m), 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 radius at 160 dB for the 36-airgun array is obtained directly from the empirical data from Crone et al. (2014) at 11 km (Table A-1; see Addendum). Likewise, the 175-dB radii for intermediate and shallow water have been calculated from the empirical data from Crone et al. (2014) for the 36-airgun array and are provided in Table A-1.

For the 18-airgun array, the radii for shallow and intermediate-water depths are taken from Crone et al. (2014) and scaled to account for the difference in airgun volume. The proposed survey would acquire data with an 18-airgun array at a tow depth of 9 m while the data collected in 2012 were acquired with a 36-airgun array at a tow depth of 9 m. To account for the differences in array volume, we calculated a scaling factor using the deep-water modeling. The 150 dB SEL corresponds to deep-water maximum radii of 9149 m for the 36-airgun array and 4391 m for the 18-airgun array, yielding a scaling factor of 2.09. When this is applied to the 160-dB radius in shallow water (11 km) from Crone et al. (2014), it results in a shallow-water radius of 5263 m for the 18-airgun array; when applied to the intermediate-water radius (8233 m) from Crone et al. (2014), it results in a radius of 3939 m for the 18-airgun array. Similarly, the 175-dB radii for intermediate and shallow water have been calculated from the empirical data from Crone et al. (2014), using the scaling factor (Table A-1).

Measurements have not been reported for the single 40-in^3 airgun. L-DEO model results are used to determine the 160-dB radius for the 40-in^3 airgun at a 9-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 GoM field measurements (Fig. A-4) obtained for the 36-airgun array was used.

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

TABLE A-1. Level B. Predicted distances to which sound levels ≥160-dB and ≥175-dB re 1 μPa_{rms} could be received during the proposed survey of the Aleutian Arc. 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	9	>1000 m	388[1]	66[1,4]
		100–1000 m	582[2]	99[2,4]
		<100 m	938[3]	145[3]
2 strings, 18 airguns, 3300 in^3	9	>1000 m	3,562[1]	775[1]
		100–1000 m	3,939[5]	1,057[5]
		<100 m	5,263[5]	1,633[5]
4 strings, 36 airguns, 6600 in^3	9	>1000 m	5,629[1]	1,618[1]
		100–1000 m	8,233[6]	2,210[6]
		<100 m	11,000[6]	3,412[6]

[1] Distance based on L-DEO model results. [2] Distance based on L-DEO model results with a 1.5 × correction factor between deep and intermediate water. [3] Distance based on empirically derived measurements in the GOM with scaling applied to account for differences in tow depth. [4] An EZ of 100 m would be used as the shut-down distance for sea turtles in all water depths. [5] Based on empirical data from Crone et al. (2014) with scaling factor based on deep-water modeling applied to account for differences in array size; see Appendix A for details. [6] Based on empirical data from Crone et al. (2014); see Appendix A for details.

In July 2016, NMFS released technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (NMFS 2016, 2018). The 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-5) 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/sea otters underwater (OW). 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 (DoN 2017) were also used here. The NMFS guidance did not alter the current threshold, 160 dB re 1μPa_{rms}, for Level B harassment (behavior). Southall et al. (2019) provided updated scientific recommendations regarding noise exposure criteria which are similar to those presented by NMFS (2016, 2018), but include all marine mammals (including sirenians), and a re-classification of hearing groups.

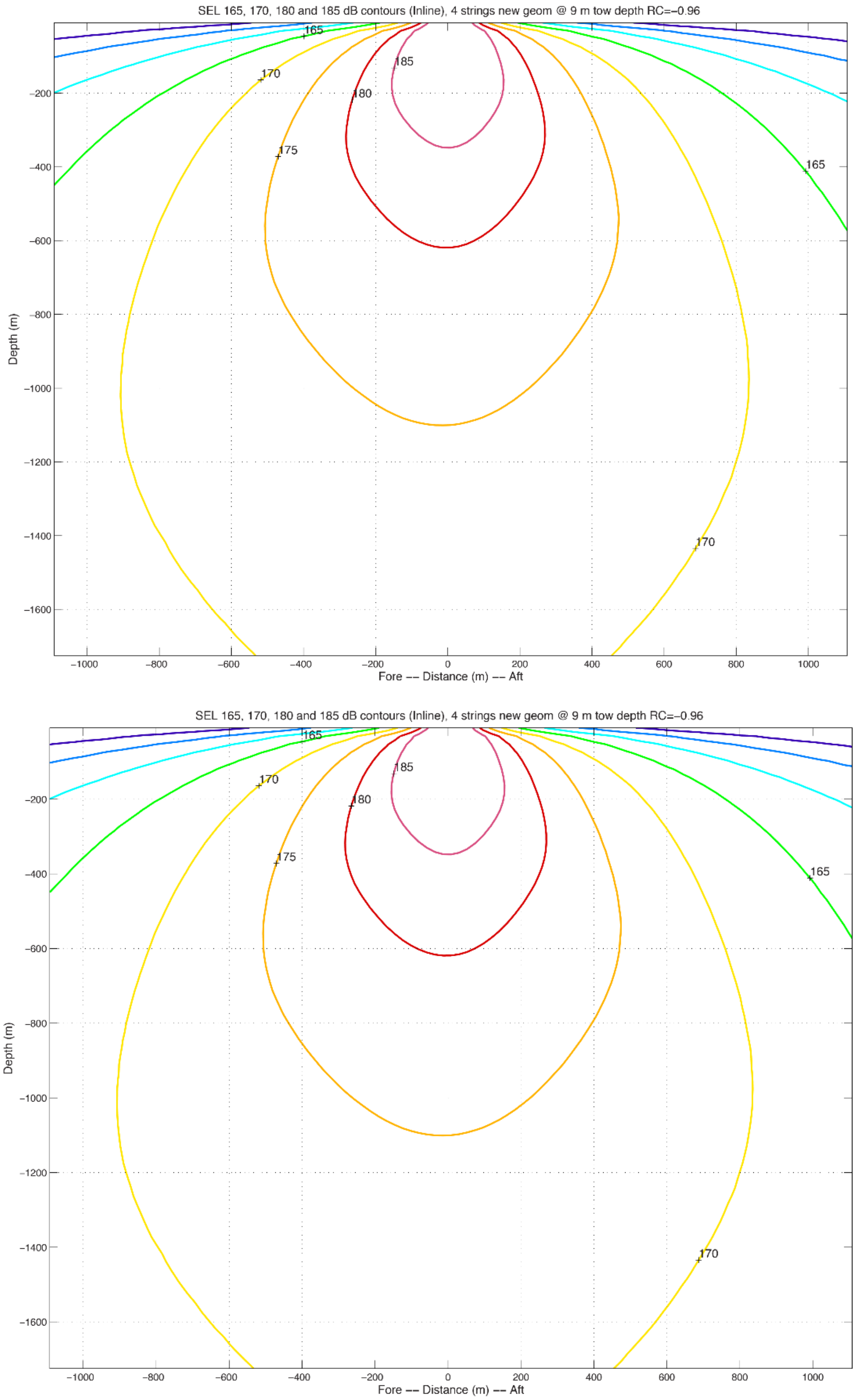


FIGURE A-1. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array at a 9-m tow depth planned for use during the proposed survey of the Aleutian Arc. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.

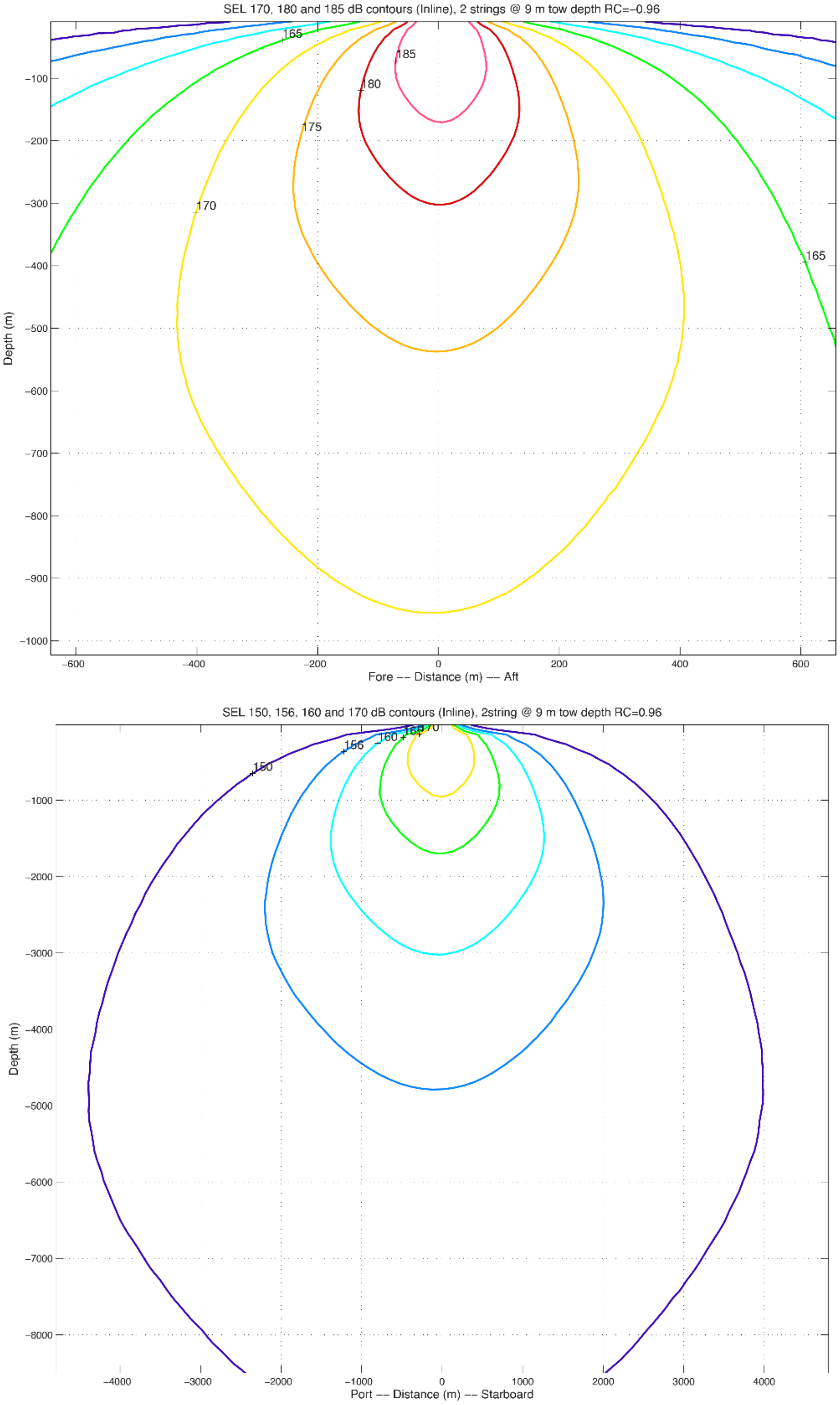


FIGURE A-2. Modeled deep-water received sound exposure levels (SELs) from the 18-airgun array at a 9-m tow depth planned for use during the proposed survey of the Aleutian Arc. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.

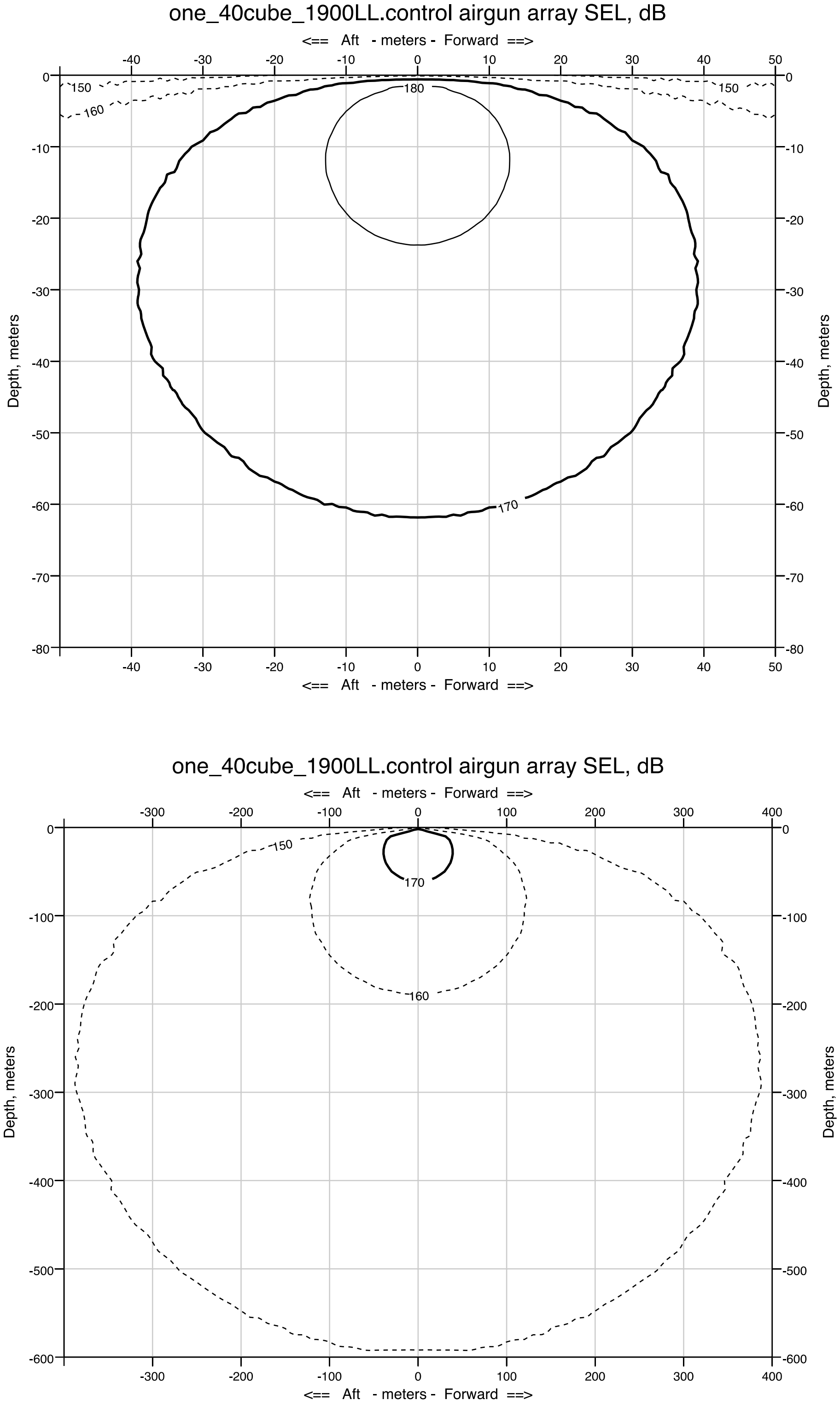


FIGURE A-3. Modeled deep-water received SELs from a single 40-in^3 airgun towed at a 9-m depth, which is planned for use as a mitigation airgun for sea turtles and ESA-listed diving seabirds during the proposed survey of the Aleutian Arc. Received rms levels (SPLs) are expected to be ~10 dB higher. For 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.

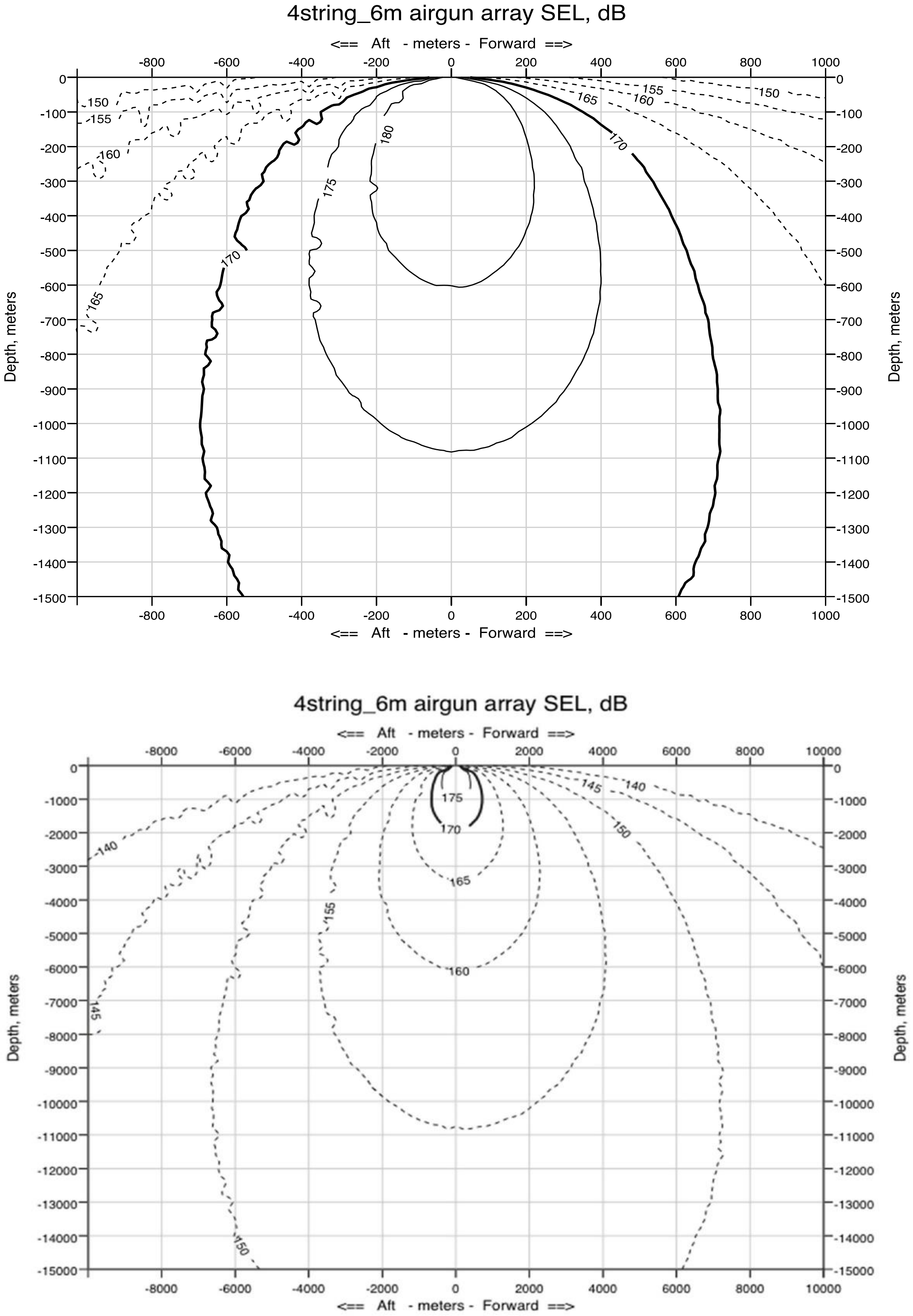


FIGURE A-4. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array at a 6-m tow depth used during the GoM calibration survey. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150 dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.

The SEL_{cum} for R/V *Langseth* array is derived from calculating the modified farfield signature. The farfield signature is often used as a theoretical representation of the source level. To compute the farfield signature, the source level is estimated at a large distance directly below the array (e.g., 9 km), and this level is back projected mathematically to a notional distance of 1 m from the array's geometrical center. However, it has been recognized that the source level from the theoretical farfield signature is never physically achieved at the source when the source is an array of multiple airguns separated in space (Tolstoy et al. 2009). Near the source (at short ranges, distances <1 km), the pulses of sound pressure from each individual airgun in the source array do not stack constructively as they do for the theoretical farfield signature. The pulses from the different airguns spread out in time such that the source levels observed or modeled are the result of the summation of pulses from a few airguns, not the full array (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 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 2.315 m/s and repetition rate of 21.598 s were used as inputs to the NMFS User Spreadsheet for calculating the distances to the SEL_{cum} PTS thresholds (Level A) for the 18- and 36-airgun arrays and the single 40-in^3 mitigation airgun.

For the LF cetaceans during operations with the 36-airgun array, we estimated an adjustment value by computing the distance from the geometrical center of the source to where the 183 dB SEL_{cum} isopleth is the largest. We first ran the modeling for a single shot without applying any weighting function; we then ran the modeling for a single shot with the LF cetacean weighting function applied to the full spectrum. The difference between these values provides an adjustment factor of -11.98 dB assuming a propagation of $20\log_{10}$(Radial distance) (Table A-2).

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

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

SEL_{cum} Threshold	**LF** **183**	**MF** **185**	**HF** **155**	**PW** **185**	**OW/Otters** **203**	**Turtles** **204**
Radial Distance (m) (no weighting function)	307.1047	241.9511	7789	241.9511	25.3278	22.5598
Modified Farfield SEL*	232.7457	232.6746	232.8296	232.6746	231.0719	231.0667
Radial Distance (m) (with weighting function)	77.331	N.A.	N.A.	N.A.	N.A.	N.A.
Adjustment (dB)	-11.98	N.A.	N.A.	N.A.	N.A.	N.A.

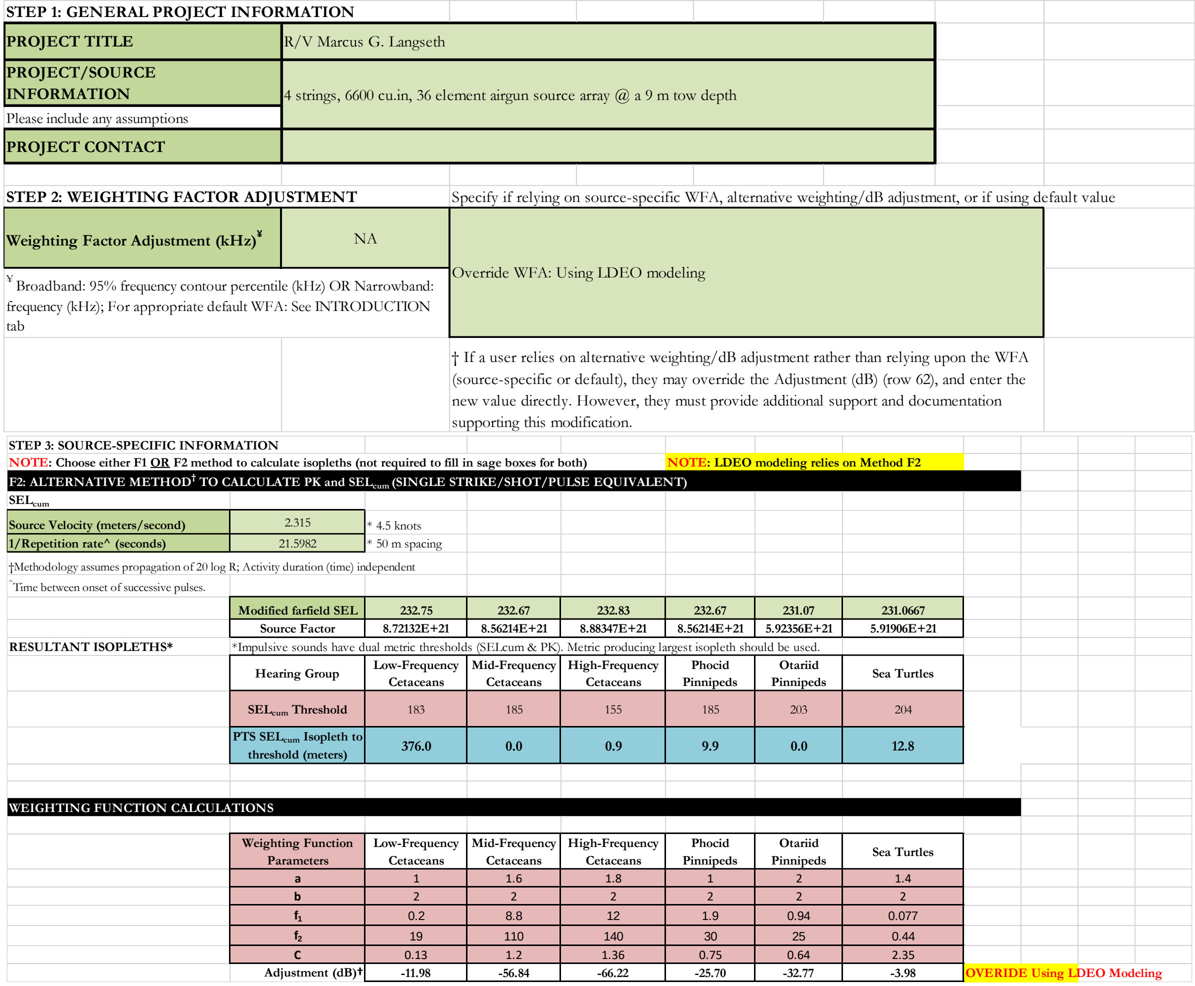
* A propagation of 20 $\log_{10}$ (Radial distance) is used to estimate the modified farfield SEL. N.A. means not applicable.

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. Figure A-6 shows the modeled amplitude spectral density of the 36-airgun array farfield signature. Figures A-7–A-9 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure A-10 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans. The thresholds for Peak SPL_{flat} for the 36-airgun array, as well as the distances to the PTS thresholds, are shown in Table A-4. Figures A-11–A-13 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 18-airgun array, 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 18-airgun array are shown in Table A-7. Figure A-14 shows the modeled amplitude spectral density of the 36-airgun array farfield signature. Figures A-15–A-17 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure A-18 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans. The thresholds for Peak SPL_{flat} for the 18-airgun array, as well as the distances to the PTS thresholds, are shown in Table A-8. Figures A-19–A-21 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-9.

For the single 40 in^3 mitigation airgun, the results for single shot SEL source level modeling are shown in Table A-10. 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-11. Figure A-22 shows the impact of weighting functions by hearing group for the single mitigation airgun. Figures A-23–A-24 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure A-25 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-12. Figures A-26–A-27 show the modeled received sound levels to the Peak SPL_{flat} thresholds, for a single shot.

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



STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	R/V Marcus G. Langseth
PROJECT/SOURCE INFORMATION	4 strings, 6600 cu.in, 36 element airgun source array @ a 9 m tow depth
Please include any assumptions	
PROJECT CONTACT	

STEP 2: WEIGHTING FACTOR ADJUSTMENT

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

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

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

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

STEP 3: SOURCE-SPECIFIC INFORMATION

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

NOTE: LDEO modeling relies on Method F2

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

SEL_{cum}

Source Velocity (meters/second)	2.315	* 4.5 knots
1/Repetition rate^ (seconds)	21.5982	* 50 m spacing

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

^Time between onset of successive pulses.

Modified farfield SEL	**232.75**	**232.67**	**232.83**	**232.67**	**231.07**	**231.0667**
Source Factor	**8.72132E+21**	**8.56214E+21**	**8.88347E+21**	**8.56214E+21**	**5.92356E+21**	**5.91906E+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)	**376.0**	**0.0**	**0.9**	**9.9**	**0.0**	**12.8**

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)†	**-11.98**	**-56.84**	**-66.22**	**-25.70**	**-32.77**	**-3.98**	**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 Fig. A-6).

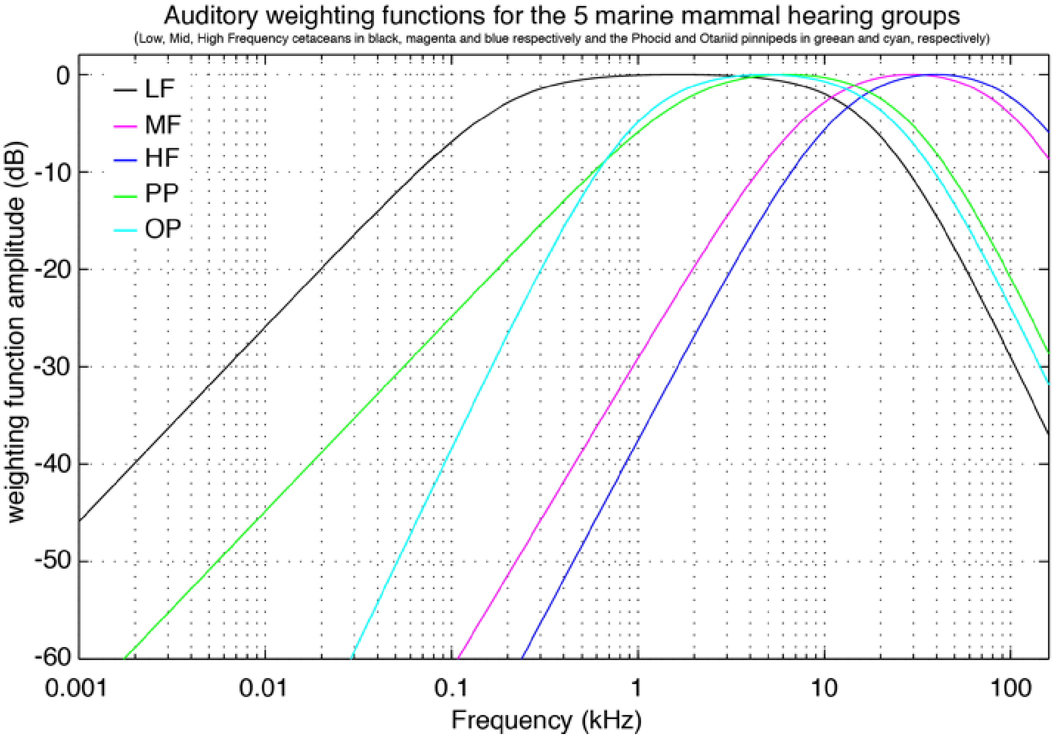


FIGURE A-5. Auditory weighting functions for five marine mammal hearing groups from the NMFS Technical Guidance.

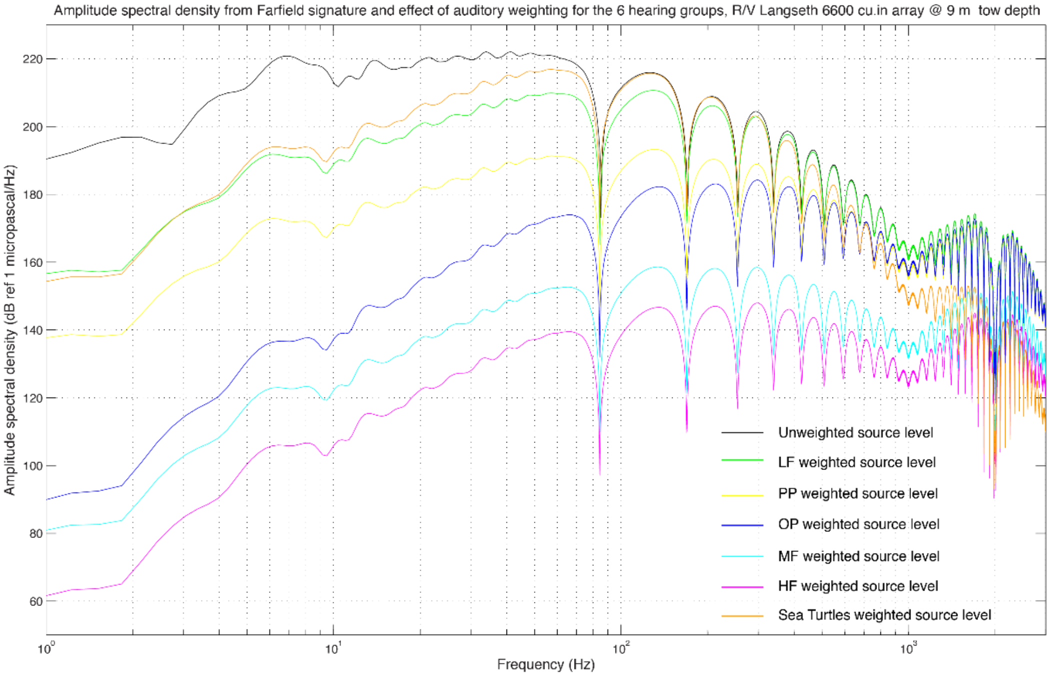


FIGURE A-6. Modeled amplitude spectral density of the 36-airgun array farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral levels are used to calculate the difference between the unweighted and weighted source level at each frequency and to derive the adjustment factors for the hearing groups as inputs into the NMFS User Spreadsheet.

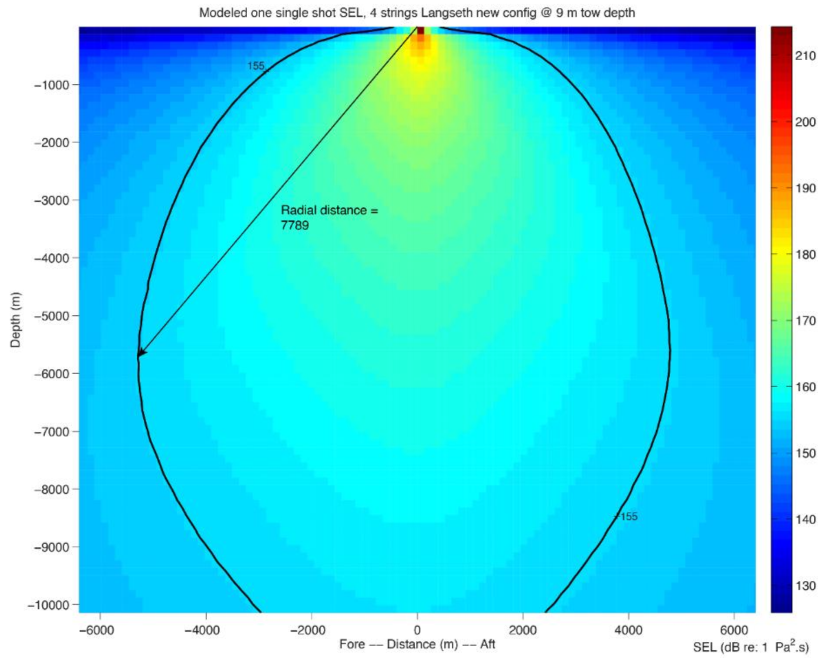


FIGURE A-7. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 155-dB SEL isopleth (7789 m). Radial distance allows us to determine the modified farfield SEL using a propagation of $20\log_{10}$(radial distance).

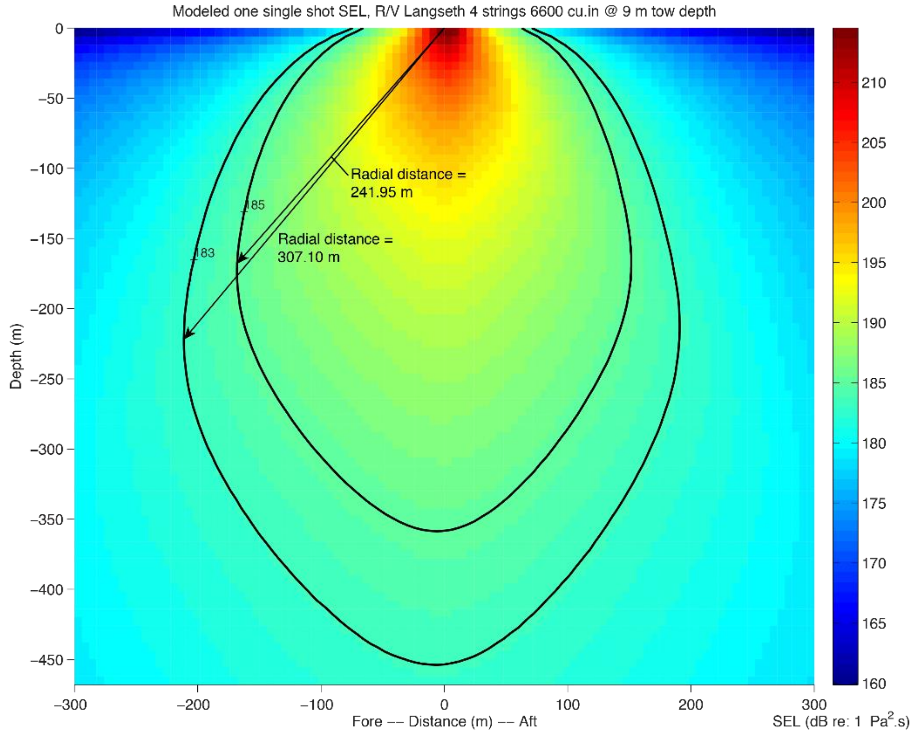


FIGURE A-8. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 183–185-dB SEL isopleths (307.1 and 242.0 m, respectively).

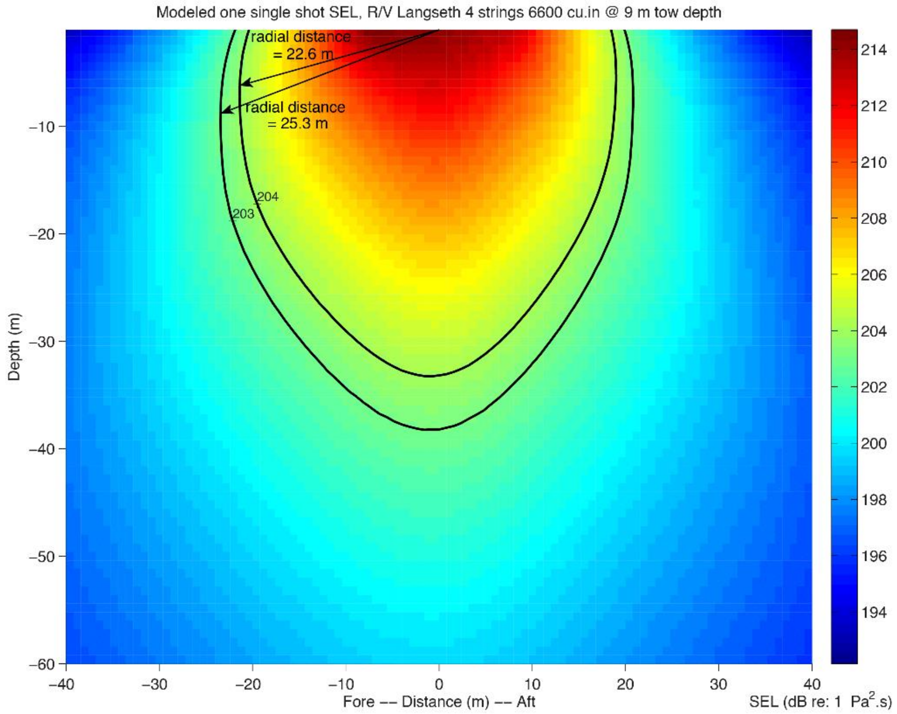


FIGURE A-9. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 203-dB SEL isopleth (25.3 m) and 204-dB SEL isopleth (22.6 m).

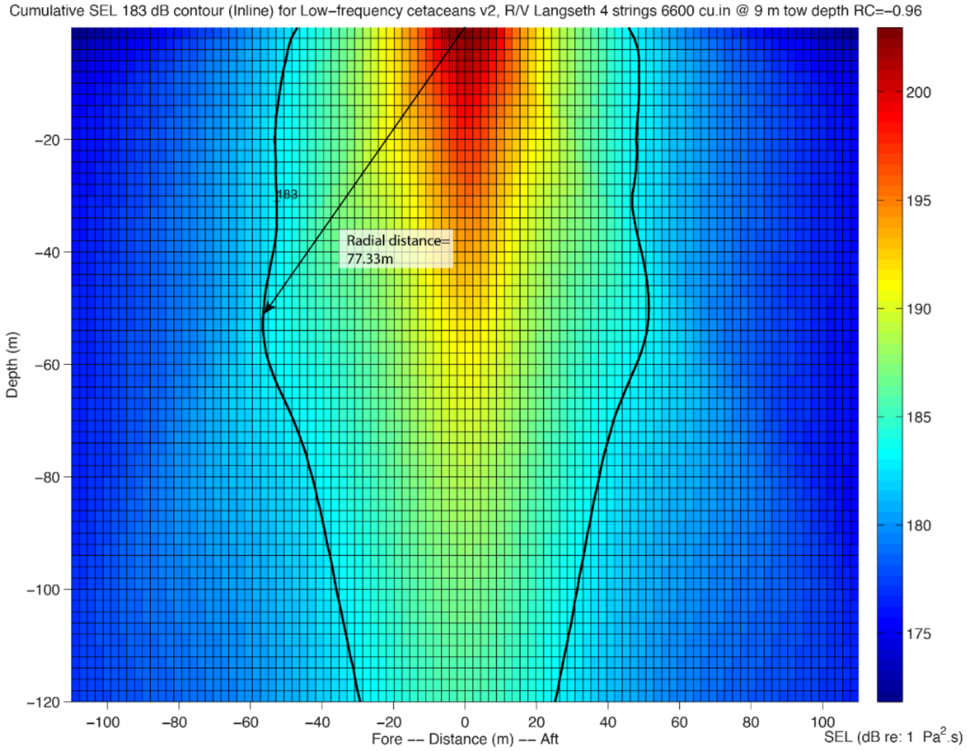


FIGURE A-10. Modeled received sound exposure levels (SELs) from the 36-airgun array at a 9-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one shot. The difference in radial distances between Fig. A-7 and this figure allows us to estimate the adjustment in dB.

TABLE A-4. NMFS Level A acoustic thresholds (Peak SPL$_{flat}$) for impulsive sources for marine mammals and predicted distances to Level A thresholds for various marine mammal hearing groups and sea turtles that could be received from the 36-airgun array during the proposed survey of the Aleutian Arc.

Hearing Group	**Low-Frequency Cetaceans**	**Mid-Frequency Cetaceans**	**High-Frequency Cetaceans**	**Phocid Pinnipeds**	**Otariid Pinnipeds/Sea Otters/Sea Turtles**
Peak Threshold	**219**	**230**	**202**	**218**	**232**
Radial Distance to Threshold (m)	38.78	13.75	235.43	42.17	10.87
PTS Peak Isopleth (Radius) to Threshold (m)	38.78	13.75	229.15	42.12	10.87

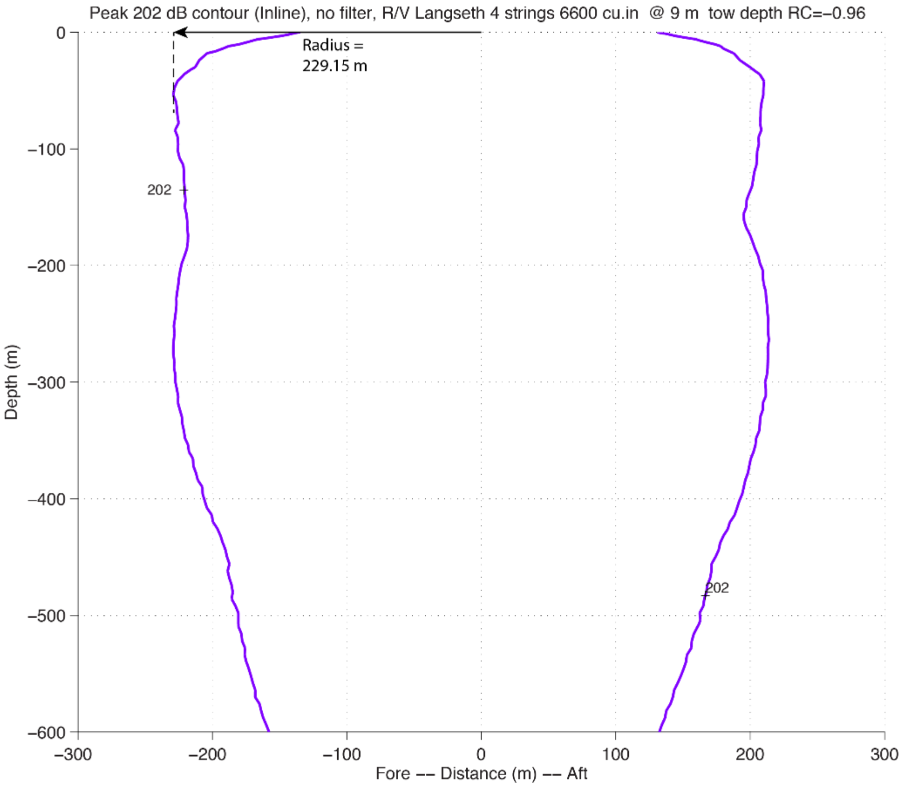


FIGURE A-11. Modeled deep-water received Peak SPL from the 36-airgun array at a 9-m tow depth. The plot provides the distance to the 202-dB Peak isopleth (229.15).

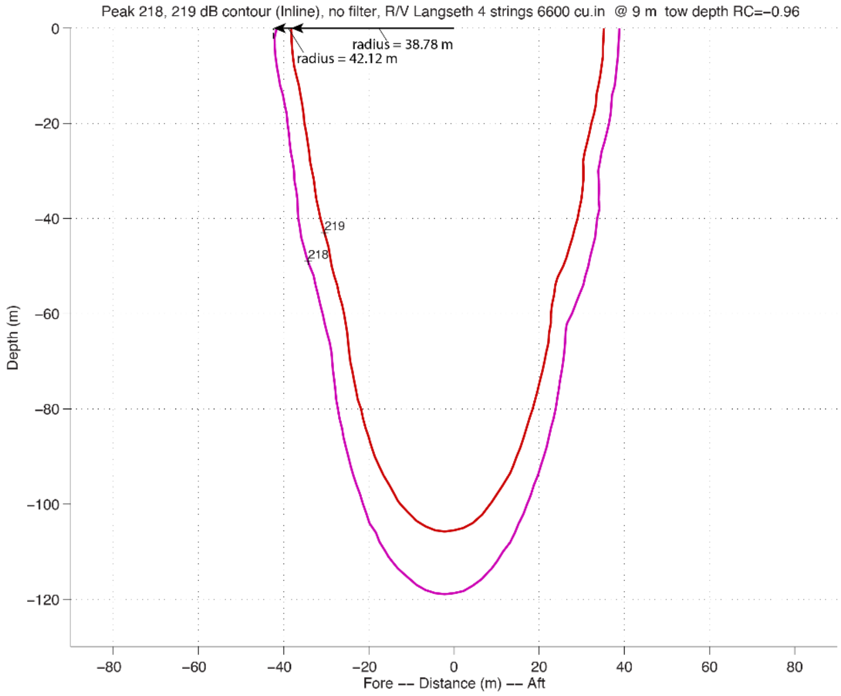


FIGURE A-12. Modeled deep-water received Peak SPL from the 36-airgun array at a 9-m tow depth. The plot provides the distances to the 218- and 219-dB Peak isopleths (42.2 m and 38.9 m, respectively).

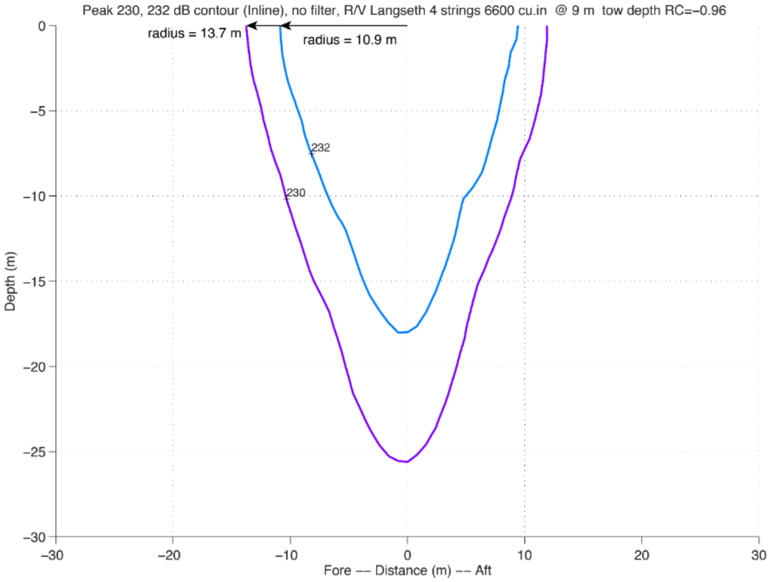


FIGURE A-13. Modeled deep-water received Peak SPL from the 36-airgun array at a 9-m tow depth. The plot provides the distances to the 230- and 232-dB Peak isopleths.

TABLE A-5. Level A threshold distances for different hearing groups for the 36-airgun array and a shot interval of 50 m[1]. As required by NMFS (2016a, 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					
	LF Cetaceans	MF Cetaceans	HF Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds/Otters	Sea Turtles
PTS SEL_{cum}	**376.0**	0	0.9	9.9	0	**12.8**
PTS Peak	38.8	**13.8**	**229.2**	**42.1**	**10.9**	10.9

TABLE A-6. Results for single shot SEL source level modeling for the 18-airgun array with and without applying weighting function to the five marine mammal hearing groups and sea turtles. The modified farfield signature is estimated using the distance from the source array geometrical center to where the SEL_{cum} threshold is the largest.

SEL_{cum} Threshold	**LF 183**	**MF 185**	**HF 155**	**PW 185**	**OW/Otters 203**	**Turtles 204**
Radial Distance (m) (no weighting function)	144.8528	113.9293	3869.7	113.9293	15.6619	14.6698
Modified Farfield SEL*	226.2185	226.1327	226.7535	226.1327	226.8969	227.3238
Radial Distance (m) (with weighting function)	29.536	N.A.	N.A.	N.A.	N.A.	N.A.
Adjustment (dB)	-13.81	N.A.	N.A.	N.A.	N.A.	N.A.

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

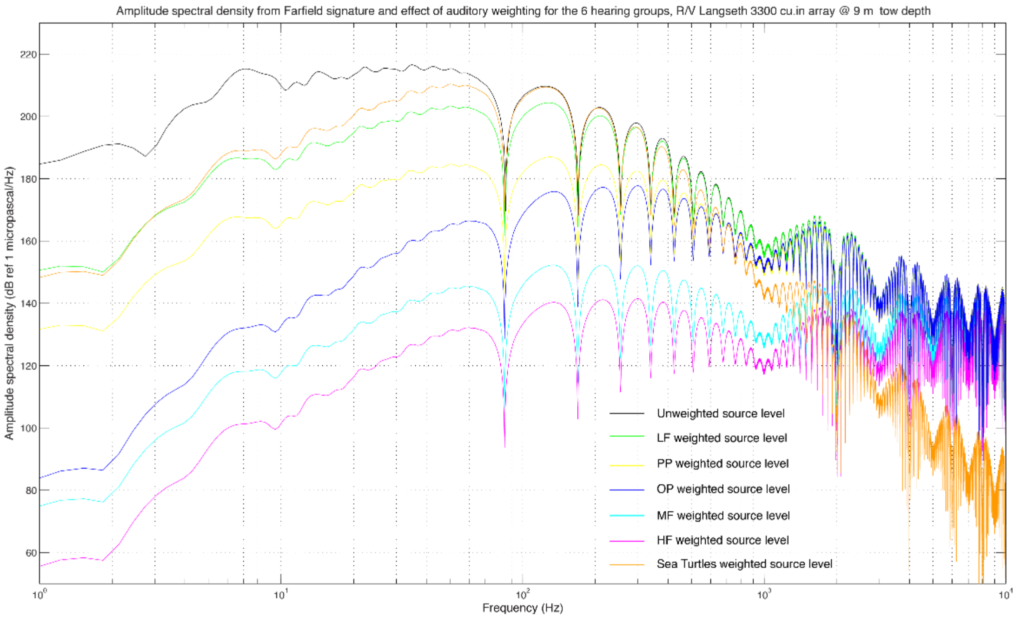
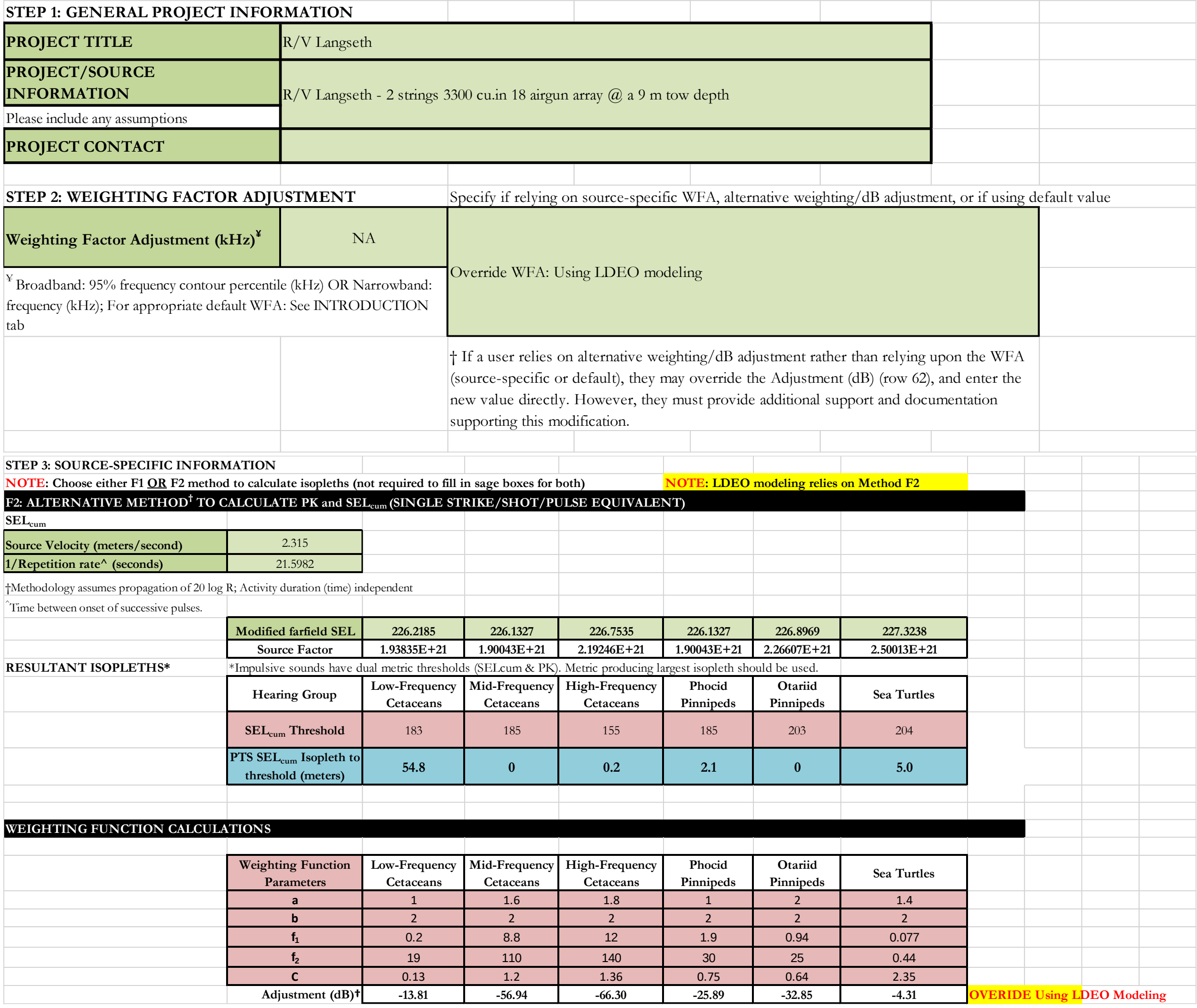


FIGURE A-14. Modeled amplitude spectral density of the 18-airgun array farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), Otariid Pinnipeds (OP), and sea turtles.

TABLE A-7. Results for modified farfield SEL source level modeling for the 18-airgun array with weighting function calculations for the SEL_{cum} criteria, as well as resulting isopleths to thresholds for various hearing groups.



STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	R/V Langseth
PROJECT/SOURCE INFORMATION Please include any assumptions	R/V Langseth - 2 strings 3300 cu.in 18 airgun array @ a 9 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)	2.315
1/Repetition rate^ (seconds)	21.5982

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

^Time between onset of successive pulses.

Modified farfield SEL	226.2185	226.1327	226.7535	226.1327	226.8969	227.3238
Source Factor	1.93835E+21	1.90043E+21	2.19246E+21	1.90043E+21	2.26607E+21	2.50013E+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)	**54.8**	**0**	**0.2**	**2.1**	**0**	**5.0**

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)†	-13.81	-56.94	-66.30	-25.89	-32.85	-4.31	**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-14).

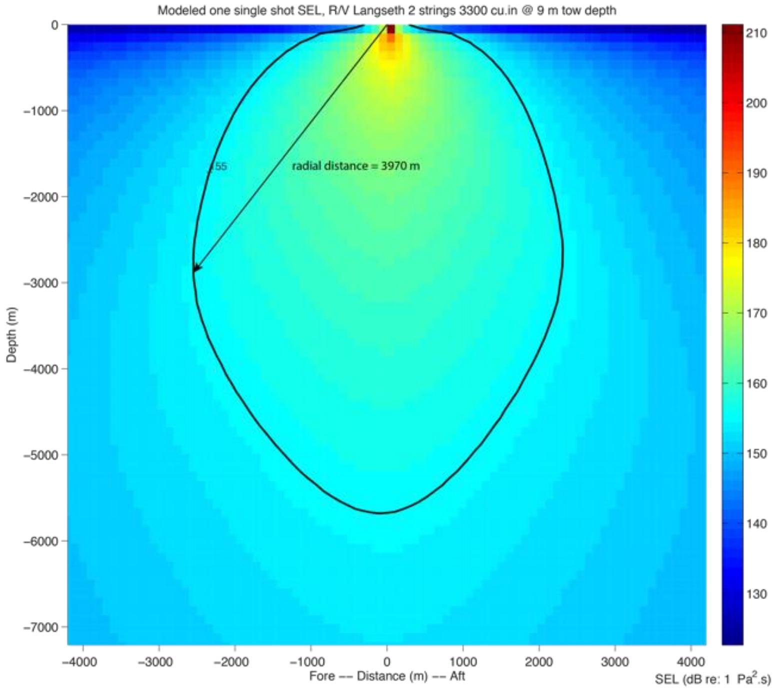


FIGURE A-15. Modeled received sound levels (SELs) in deep water from the 18-airgun array. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (3970 m).

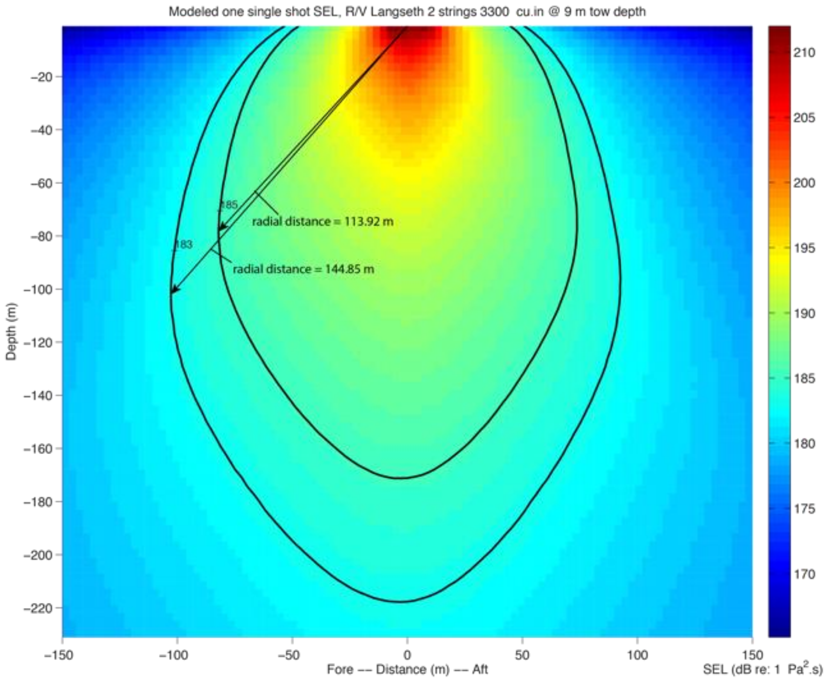


FIGURE A-16. Modeled received sound levels (SELs) in deep water from the 18-airgun array. The plot provides the distance from the geometrical center of the source array to the 183–185-dB SEL isopleths

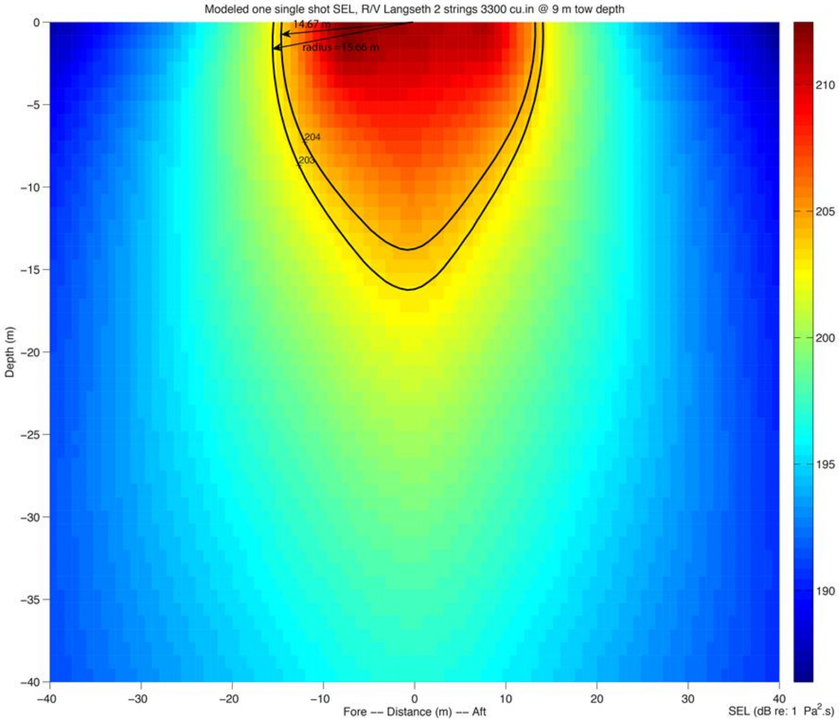


FIGURE A-17. Modeled received sound levels (SELs) in deep water from the 18-airgun array. The plot provides the distance from the geometrical center of the source array to the 203-dB SEL isopleth.

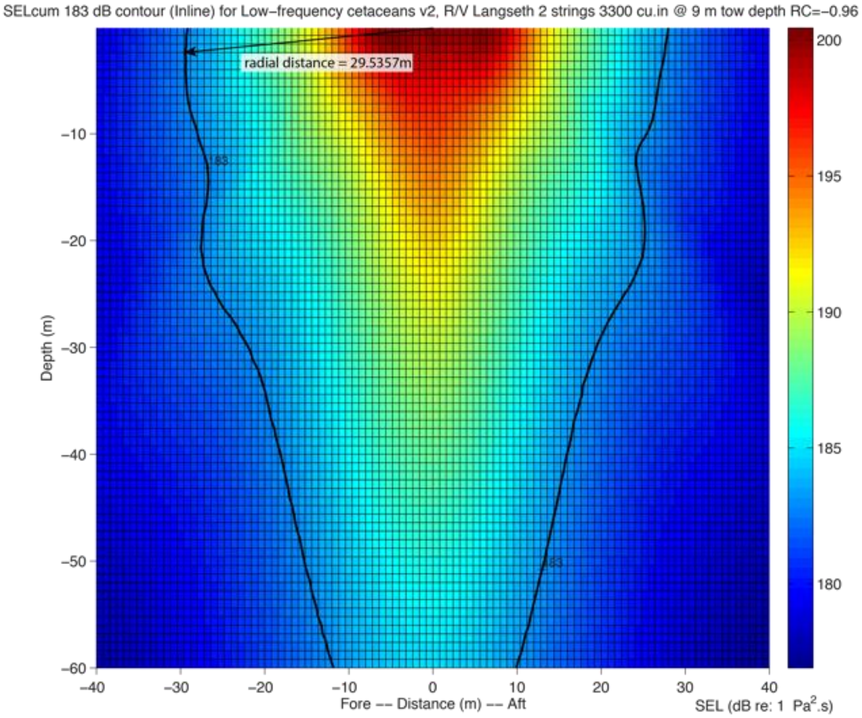


FIGURE A-18. Modeled received sound exposure levels (SELs) from the 18-airgun array at a 9-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following to the NMFS Technical Guidance. The plot provides the radius to the 183-dB SEL_{cum} isopleth for one shot.

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 and sea turtles that could be received from the 18-airgun array during the proposed survey of the Aleutian Arc.

Hearing Group	**Low-Frequency Cetaceans**	**Mid-Frequency Cetaceans**	**High-Frequency Cetaceans**	**Phocid Pinnipeds**	**Otariid Pinnipeds/ Sea Otters/ Sea Turtles**
Peak Threshold	**219**	**230**	**202**	**218**	**232**
PTS Peak Isopleth (radius) to threshold (m)	23.268	11.198	118.955	25.217	9.919
Modified Farfield Peak	246.335	250.983	243.641	246.034	251.929

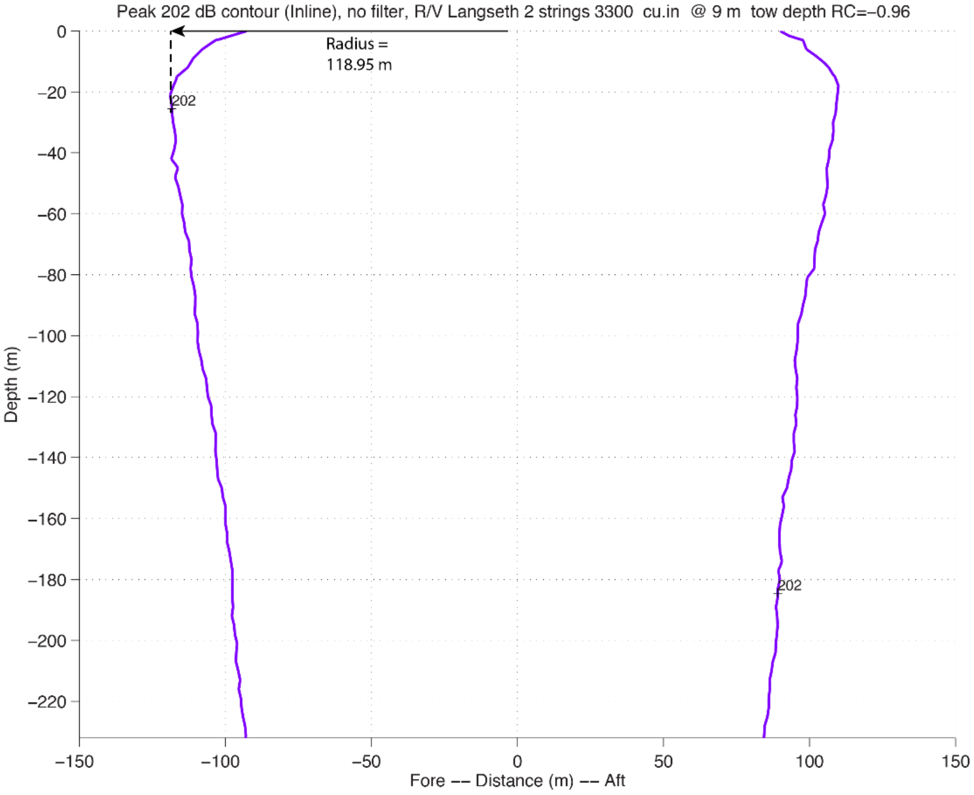


FIGURE A-19. Modeled deep-water received Peak SPL from the 18-airgun array at a 9-m tow depth. The plot provides the distance to the 202-dB Peak isopleth.

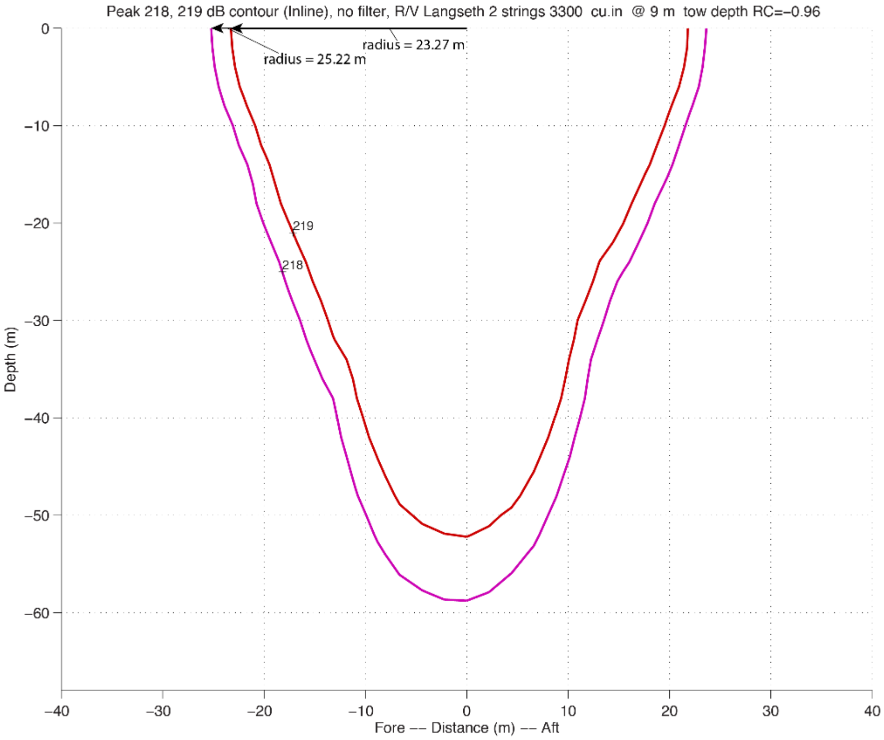


FIGURE A-20. Modeled deep-water received Peak SPL from the 18-airgun array at a 9-m tow depth. The plot provides the distances to the 218- and 219-dB Peak isopleths.

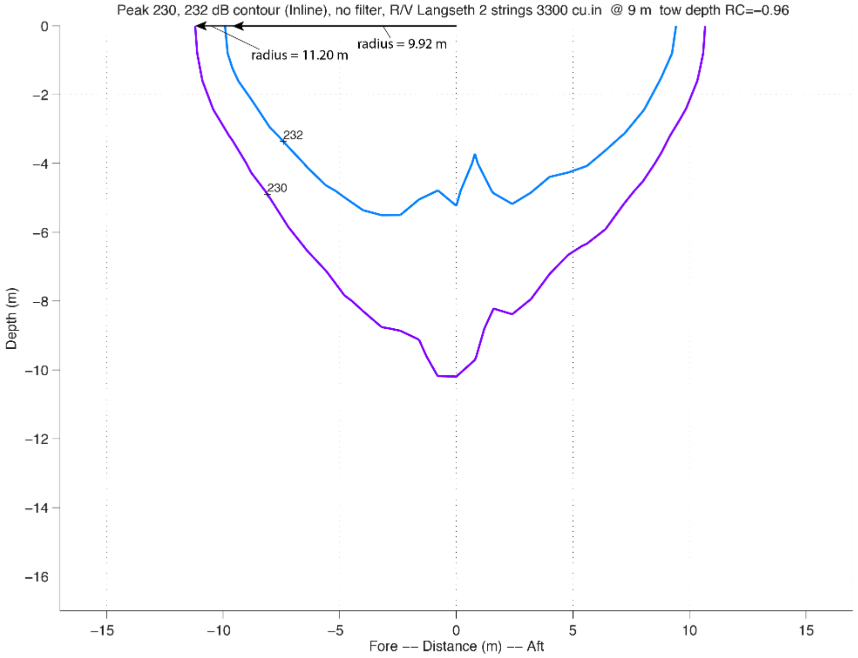


FIGURE A-21. Modeled deep-water received Peak SPL from the 18-airgun array at a 9-m tow depth. The plot provides the distances to the 230- and 232-dB Peak isopleths.

TABLE A-9. Level A threshold distances for different hearing groups for the 18-airgun array and a shot interval of 50 m[1]. As required by NMFS (2016a, 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.

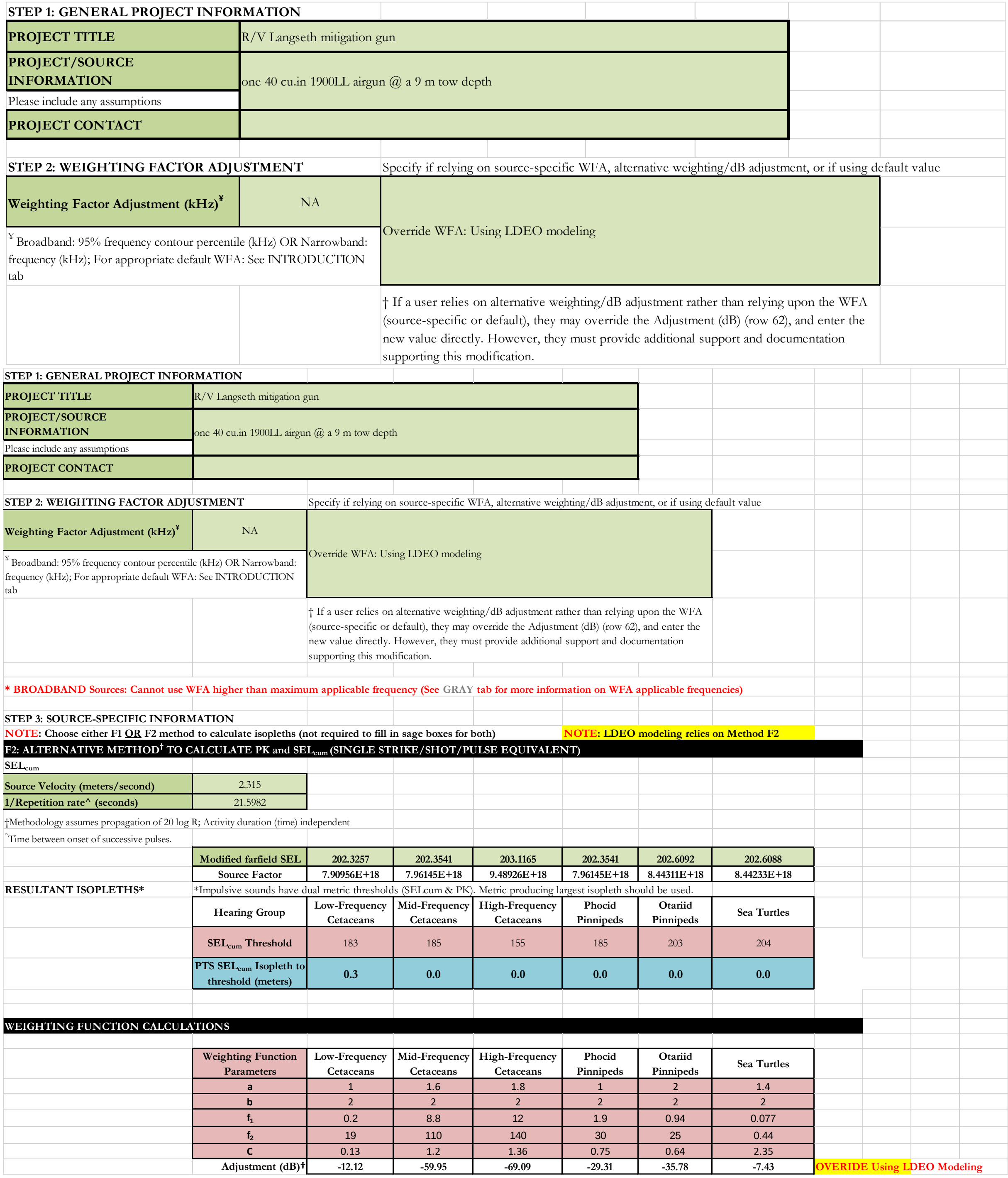
	Level A Threshold Distances (m) for Various Hearing Groups					
	LF Cetaceans	MF Cetaceans	HF Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds/Otters	Sea Turtles
PTS SEL_{cum}	**54.8**	0	0.2	2.1	0	5.0
PTS Peak	23.3	**11.2**	**119.0**	**25.2**	**9.9**	**9.9**

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

SEL_{cum} Threshold	**LF 183**	**MF 185**	**HF 155**	**PW 185**	**OW/Otters 203**	**Turtles 204**
Radial Distance (m) (no weighting function)	9.253	7.374	254.579	7.374	0.956	0.852
Modified Farfield SEL*	202.9907	202.8948	204.3680	202.8948	202.3491	202.3491
Radial Distance (m) (with weighting function)	2.292	N.A.	N.A.	N.A.	N.A.	N.A.
Adjustment (dB)	-12.12	N.A.	N.A.	N.A.	N.A.	N.A.

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

TABLE A-11. Results for modified farfield SEL source level modeling for the single 40-in^3 mitigation airgun with weighting function calculations for the SEL$_{cum}$ criteria, as well as resulting isopleths to thresholds for various hearing groups.



STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	R/V Langseth mitigation gun
PROJECT/SOURCE INFORMATION	one 40 cu.in 1900LL airgun @ a 9 m tow depth
Please include any assumptions	
PROJECT CONTACT	

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

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

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

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

STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	R/V Langseth mitigation gun
PROJECT/SOURCE INFORMATION	one 40 cu.in 1900LL airgun @ a 9 m tow depth
Please include any assumptions	
PROJECT CONTACT	

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

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

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

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

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

STEP 3: SOURCE-SPECIFIC INFORMATION

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

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

SEL$_{cum}$

Source Velocity (meters/second)	2.315
1/Repetition rate^ (seconds)	21.5982

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

^Time between onset of successive pulses.

Modified farfield SEL	**202.3257**	**202.3541**	**203.1165**	**202.3541**	**202.6092**	**202.6088**
Source Factor	**7.90956E+18**	**7.96145E+18**	**9.48926E+18**	**7.96145E+18**	**8.44311E+18**	**8.44233E+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**	**Sea Turtles**
SEL$_{cum}$ Threshold	183	185	155	185	203	204
PTS SEL$_{cum}$ Isopleth to threshold (meters)	**0.3**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

WEIGHTING FUNCTION CALCULATIONS

Weighting Function Parameters	**Low-Frequency Cetaceans**	**Mid-Frequency Cetaceans**	**High-Frequency Cetaceans**	**Phocid Pinnipeds**	**Otariid Pinnipeds**	**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)†	**-12.12**	**-59.95**	**-69.09**	**-29.31**	**-35.78**	**-7.43**	**OVERIDE Using LDEO Modeling**

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†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 Fig. A-22).

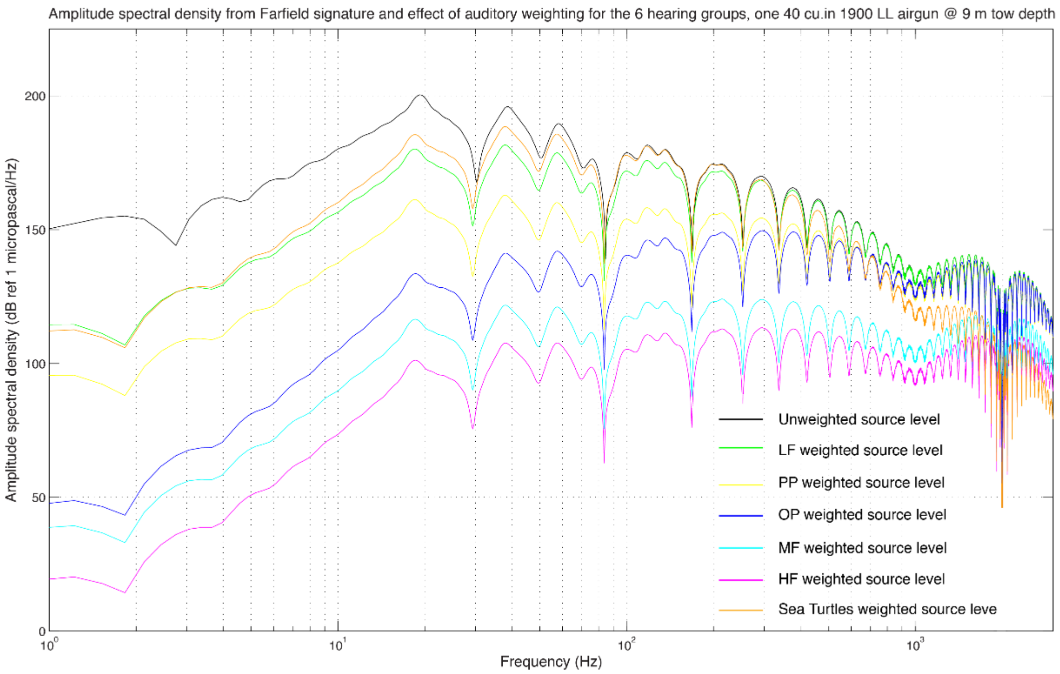

FIGURE A-22. Modeled amplitude spectral density of the 40-in³ airgun farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral levels are 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.

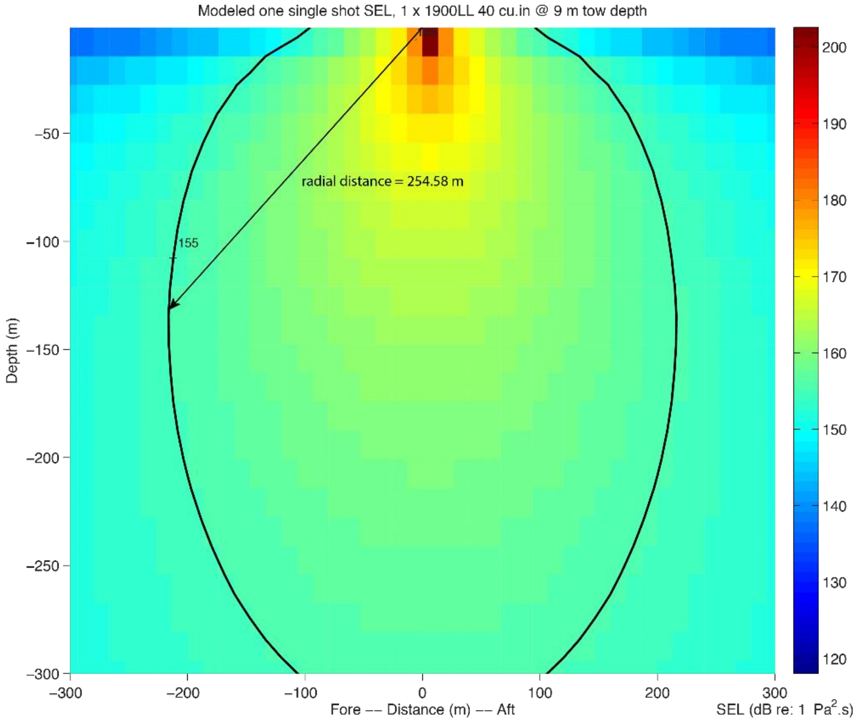

FIGURE A-23. Modeled received sound levels (SELs) in deep water from one 40-in³ airgun at a 9-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (254.6 m).

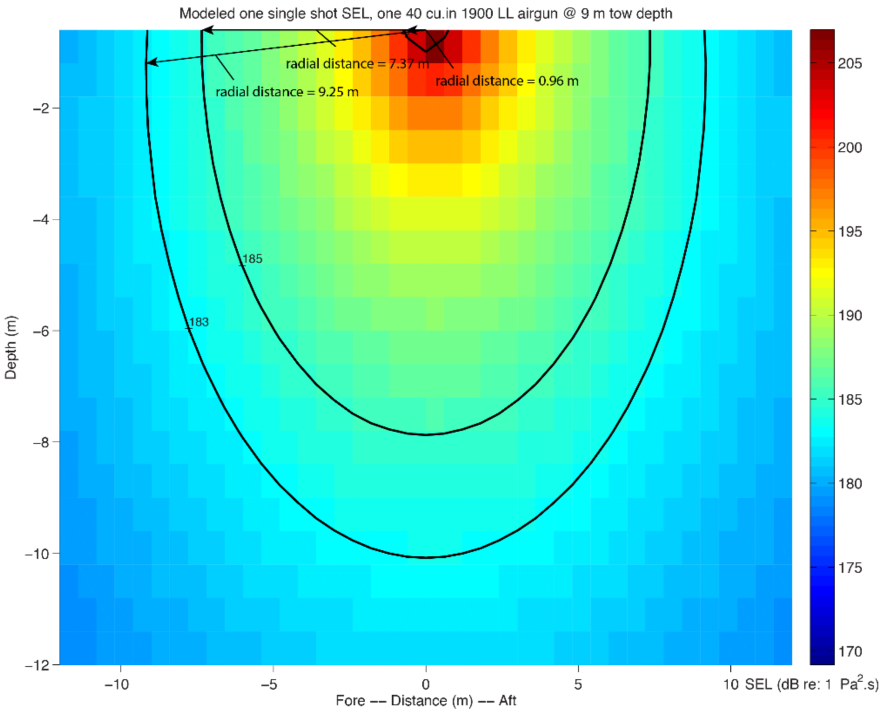

FIGURE A-24. Modeled received sound levels (SELs) in deep water from one 40-in^3 airgun at a 9-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183–185 dB and 203 dB SEL isopleths.

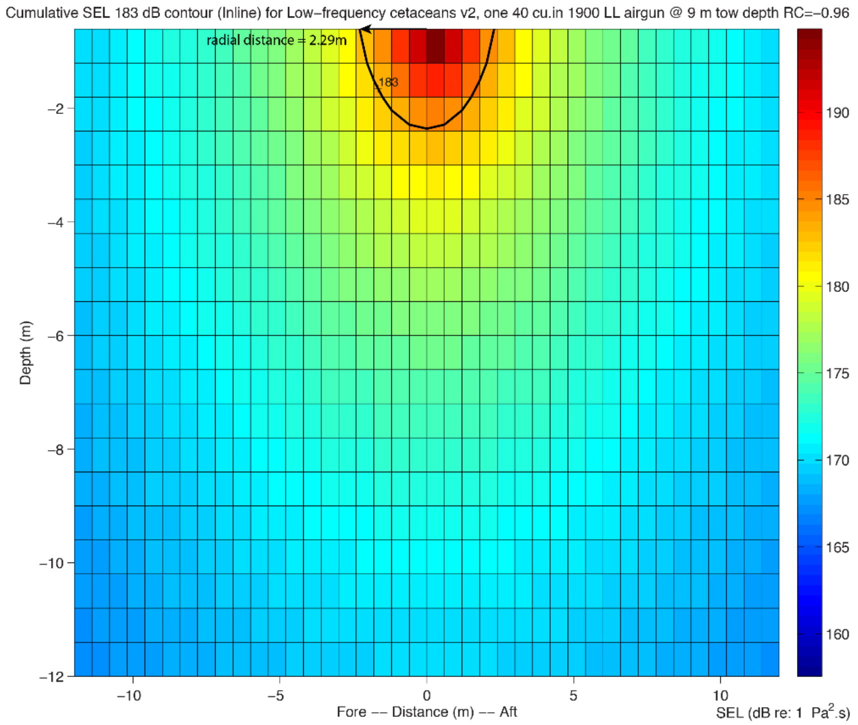

FIGURE A-25. Modeled received sound exposure levels (SELs) from one 40-in^3 mitigation at a 9-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one shot. The difference in radial distances between Fig. A-15 and this figure allows us to estimate the adjustment in dB.

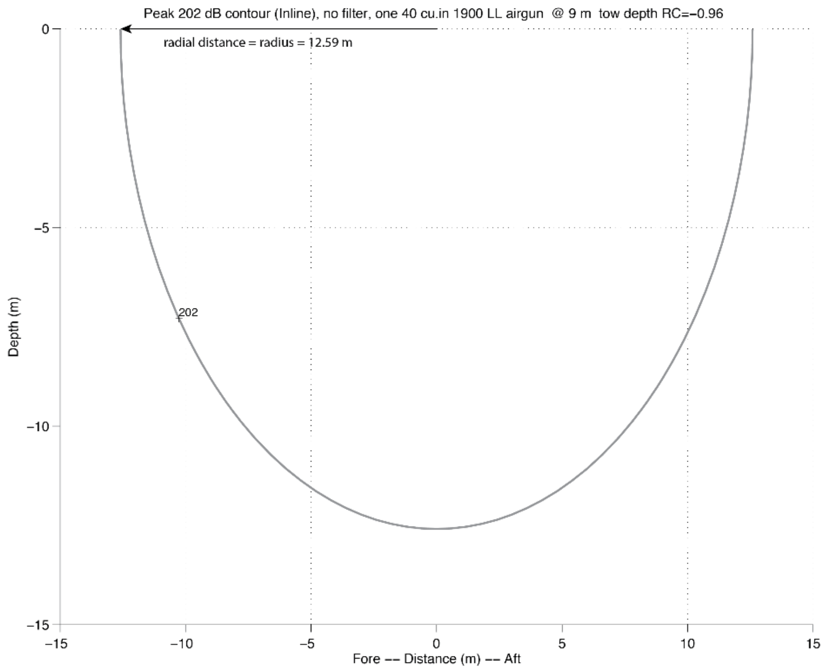

FIGURE A-26. Modeled deep-water received Peak SPL from one 40 in^3 airgun at a 9-m tow depth. The plot provides the radial distance from the source geometrical center to the 202-dB Peak isopleth (12.59).

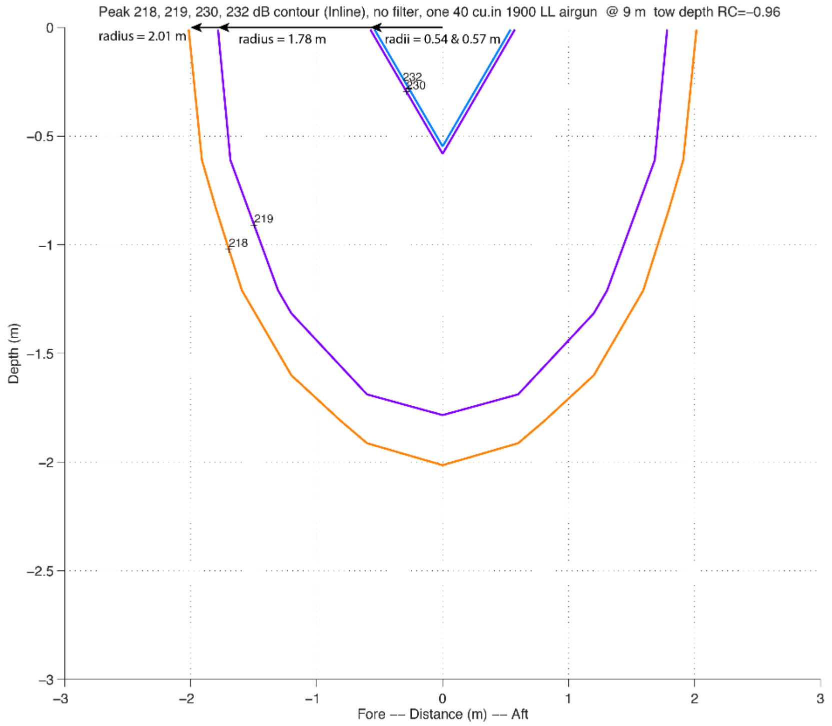

FIGURE A-27. Modeled deep-water received Peak SPL from one 40 in^3 airgun at a 9-m tow depth. The plot provides the radial distances from the source geometrical center to the 218-232-dB Peak isopleths.

TABLE A-12. NMFS Level A acoustic thresholds (Peak SPL_{flat}) for impulsive sources for marine mammals and predicted distances to Level A thresholds for various marine mammal hearing groups that could be received from the 40-in^3 airgun during the proposed seismic survey of the Aleutian Arc.

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds/ Sea Otters/ Sea Turtle
Peak Threshold	**219**	**230**	**202**	**218**	**232**
Radial Distance to Threshold (m)	1.78	0.57	12.59	2.01	0.54
PTS Peak Isopleth (Radius) to Threshold (m)	1.78	0.57	12.59	2.01	0.54

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ADDENDUM

Using Empirical Data for Estimation of Level B Radii

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

To estimate Level B (behavioral disturbance or harassment) radii in shallow and intermediate water depths, we used the received levels from MCS data collected by R/V *Langseth* during the COAST survey (Crone et al. 2014). Streamer data in shallow water collected in 2012 have the advantage of including the effects of local and complex subsurface geology, seafloor topography, and water column properties and thus allow us to establish mitigation radii more confidently than by using the data from calibration experiments in the Gulf of Mexico (Tolstoy et al. 2004, 2009; Diebold et al. 2010).

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

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

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

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Extracted from Crone et al. 2014 – Section 4.1

4. Discussion

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

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

****

The entire 16 0dB$_{SEL}$ level data are within the length of the streamer and are well behaved throughout this depth profile. The measured sound level data in this area suggest that the 160d B$_{SEL}$ mitigation radius distance would be well defined at a maximum of 8192 m, but that the 160 dB$_{RMS}$ would be close to ~11 km (Fig. 1). For a few shots along this profile, the 160 dB$_{RMS}$ is just beyond the end of the streamer (8 km). For these shots, extrapolation was necessary. Crone et al. (2014) could only extrapolate the 160 dB$_{RMS}$ levels up to a distance of ~11 km (~133% of the length of the streamer). However, the stable 160 dB$_{SEL}$ levels across this interval would support an extrapolated value of not much more than 11 km for the 160 dB$_{RMS}$ level given that the 160 dB$_{RMS}$ and 160 dB$_{SEL}$ levels track consistently along the profile (Fig. 1).

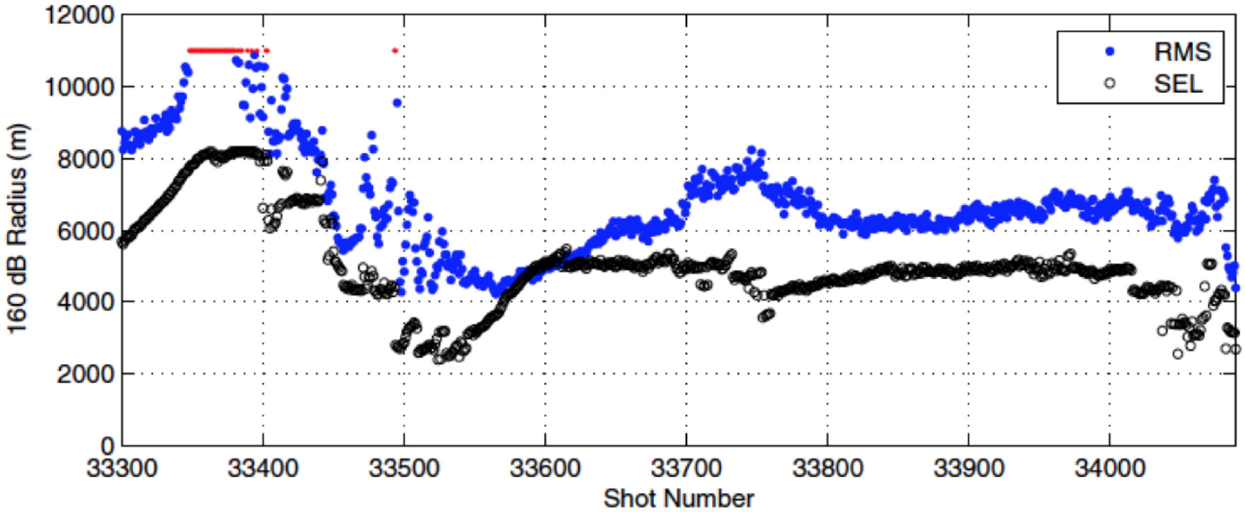

FIGURE 1. Measured radius distances to the 160 dB radii for both SEL and RMS along line A/T collected in 2012 at Cascadia with R/V *Langseth* 6600 in^3 airgun array towed at a depth of 9 m (Fig. 12 from Crone et al. 2014). This line extends across the shelf from ~50m water depth (Shot 33,300), 100m water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

As noted in Table 2 of Crone et al. (2014). the full range of 160 dB$_{RMS}$ measured radii for intermediate waters is 4291m to 8233 m. The maximum 160 dB$_{RMS}$ measured radii, 8233 m (represented by a single shot at ~33750 from Figure 1), was selected for the 160 dB$_{RMS}$ measured radii in Table 1. Only 2 shots in water depths >100 have radii that exceed 8000 m, and there were over 1100 individual shots analyzed in the data; thus, the use of 8233 m is conservative.

Summary

The empirical data collected during the COAST Survey on Cascadia Margin and measured 160 dB$_{RMS}$ and 160 dB$_{SEL}$ values demonstrate that the modeled predictions are quite conservative by a factor of up to ~2 to 2.5 times less than modeled predictions for the 2020 Cascadia project. While we have sought to err on the conservative side for our activities, being overly conservative can dramatically overestimate potential and perceived impacts of a given activity. We understand that the 160 dB$_{RMS}$ is the current threshold, and have highlighted that here as the standard metric to be used. However, evidence from multiple publications including Crone et al. (2014) have argued that SEL is a more appropriate metric for mitigation radii calculations. However, it is important to note that use of either measured SEL or RMS metrics yields significantly smaller radii in shallow water than model predictions.

TABLE 1. Comparison of modeled mitigation radii with empirically-derived radii from the Cascadia Margin during the 2012 COAST survey for the 36 airgun array.

Array	Water Depth (m)	Radii using L-DEO Modeling	Radii using Empirical Data (Crone et al. 2014)	
		Distance (m) to 160-dB$_{rms}$ at 9 m tow depth	**Distance (m) to 160-dB$_{SEL}$ at 9 m tow depth**	**Distance (m) to 160-dB$_{rms}$ at 9 m tow depth**
4 strings 36 airguns 6600 in^3	<100	22,102	8,192	11,000*
	100-1000	8,444	5,487	8,233

*This value is extrapolated from end of 8-km streamer. Based on stable SEL values at same shot values. RMS extrapolated value is reasonable approximation.

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

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

For these reasons, we believe the more scientifically appropriate approach for the proposed survey is to use Level B threshold distances based on the empirical data for shallow and intermediate water depths.

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APPENDIX B: MARINE MAMMAL DENSITIES

For the proposed survey, we used habitat-based stratified marine mammal densities developed by the U.S. Navy for assessing potential impacts of training activities in the GOA (DoN 2014; Rone et al. 2014). Alternative density estimates available for species in this region are not stratified by water depth and therefore do not reflect the known variability in species distribution relative to habitat features. Rone et al. (2014) defined four strata: Inshore: all waters <1000 m deep; Slope: from 1000 m water depth to the Aleutian trench/subduction zone; Offshore: waters offshore of the Aleutian trench/subduction zone; Seamount: waters within defined seamount areas. Densities corresponding to these strata were based on data from several different sources, including Navy funded line-transect surveys in the GOA as described below. Compared to the GOA study area (Rone et al. 2014), the proposed survey area does not have a consistent gradual decrease in water depth ("slope" habitat) from the 1000 m isobath to the Aleutian Trench, south of the Aleutian Islands. Instead, water depths initially decrease rapidly beyond the 1000-m isobath to ~4000 m, then rise again on Hawley Ridge before dropping in the Aleutian Trench. Additionally, waters north of the Aleutian Islands and beyond 1000 m drop rapidly to ~3000 m and remain at those depths to the northern extent of the survey lines. For those reasons, and because the Rone et al. (2014) inshore densities were for all waters <1000 m, the marine mammal densities for the Inshore region were used for both shallow (<100 m) and intermediate (100–1000 m) water depths, while offshore densities were used for all deep water areas >1000 m.

To develop densities specific to the GOA, the Navy conducted two comprehensive marine mammal surveys in the Temporary Marine Activities Area (TMAA) in the GOA prior to 2014. The first survey was conducted from 10 to 20 April 2009 and the second was from 23 June to 18 July 2013. Both surveys used systematic line-transect survey protocols including visual and acoustic detection methods (Rone et al. 2010, 2014). The data were collected in four strata that were designed to encompass the four distinct habitats within the TMAA and greater GOA. Rone et al. (2014) provided stratified line-transect density estimates used in this analysis for fin, humpback, blue, sperm, and killer whales, as well as northern fur seals (Table B-1). Data from a subsequent survey in 2015 were used to calculate alternative density estimates for several species (Rone et al. 2017); however, the reported densities for blue, fin and humpback whales were not prorated for unidentified large whale sightings so the densities from Rone et al. (2014) were maintained. The density estimates for Dall's porpoise in Rone et al. (2017) were somewhat larger than those in Rone et al. (2014), so the larger densities were used as a cautionary approach.

There were insufficient sightings data from the 2009, 2013 and 2015 line-transect surveys to calculate reliable density estimates for other marine mammal species in the GOA. DoN (2014) derived gray whale densities in two zones, nearshore (0–2.25 n.mi from shore) and offshore (from 2.25–20 n.mi. from shore). In our calculations, the nearshore density was used to represent shallow water (<100 m deep), and the offshore density was used for intermediate and deep water. Harbor porpoise densities in DoN (2014) were derived from Hobbs and Waite (2010) which included additional shallow water depth strata. The density estimate from the 100–200 m depth strata was used for both shallow and intermediate-depth water in this analysis. Similarly, harbor seals typically remain close to shore so minimal estimates for deep water and a one thousand fold increase of the minimal density was used for shallow and intermediate waters (DoN (2014).

Densities for minke whale, Pacific white-sided dolphin, and Cuvier's and Baird's beaked whales were based on Waite (2003 *in* DoN 2009). Although sei whale sightings and Stejneger's beaked whale acoustic detections were recorded during the Navy funded GOA surveys, data were insufficient to calculate densities for these species, so predictions from a global model of marine mammal densities were used (Kaschner et al. 2012 *in* DoN 2014). Steller sea lion and northern elephant seal densities were calculated using shore-based population estimates divided by the area of the GOA Large Marine Ecosystem (DoN 2014). Here we have adjusted the Steller sea lion densities in water <1000 m to more accurately reflect the densities expected to occur in the nearshore waters of the proposed survey area (see NMFS 2019); thus, the correction factor applied by DoN (2014) was removed. The North Pacific right whale and Risso's dolphin are only rarely observed in or near the survey area, so minimal densities were used to represent their potential presence (DoN 2014).

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

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TABLE B-1. Densities of marine mammals in the GOA that were used for the proposed survey of the Aleutian Arc.

	Estimated Density (#/1000 km^2)				
Species	**Inshore** <1000 m	**Slope** (1000 m to Aleutian Trench)	**Offshore** (Offshore of Aleutian Trench)	**Seamount** (In Defined Seamount Areas)	**Source**
LF Cetaceans					
North Pacific right whale	0.01	0.01	0.01	0.01	DoN (2014)
Humpback whale	129.00	0.20	1.00	1.00	Rone et al. (2014)
Blue whale	0.50	0.50	0.50	2.00	Rone et al. (2014)
Fin whale	71.00	14.00	21.00	5.00	Rone et al. (2014)
Sei whale	0.10	0.10	0.10	0.10	DoN (2014)
Minke whale	0.60	0.60	0.60	0.60	Waite (2003) in DoN (2009)
Gray whale	48.57	2.43	0.00	0.00	DoN (2014)
MF Cetaceans					
Sperm whale	0.00	3.30	1.30	0.36	DoN (2014)
Killer whale	5.00	20.00	2.00	2.00	Rone et al. (2014)
Pacific white-sided dolphin	20.80	20.80	20.80	20.80	Waite (2003) in DoN (2009)
Cuvier's beaked whale	2.20	2.20	2.20	2.20	Waite (2003) in DoN (2009)
Baird's beaked whale	0.50	0.50	0.50	0.50	Waite (2003) in DoN (2009)
Stejneger's beaked whale	0.01	1.42	1.42	1.42	DoN (2014)
Risso's dolphin	0.01	0.01	0.01	0.01	DoN (2014)
HF Cetaceans					
Harbor Porpoise	47.30	0.00	0.00	0.00	Hobbs and Waite (2010) in DoN (2014)
Dall's porpoise	218.00	196.00	37.00	24.00	Rone et al. (2017)
Otariid Seals					
Steller sea lion*	39.20	9.80	9.80	9.80	DoN (2014)
California sea lion	0.01	0.01	0.01	0.01	DoN (2014)
Northern fur seal	15.00	4.00	17.00	6.00	Rone et al. (2014)
Phocid Seal					
Northern elephant seal	2.20	2.20	2.20	2.20	DoN (2014)
Harbor seal	10.00	0.01	0.01	0.01	DoN (2014)

* Correction factor used by DoN (2014) removed for water <1000 m deep.

APPENDIX C: MARINE MAMMAL TAKE CALCULATIONS

TABLE C-1. Densities of marine mammals and areas ensonified above threshold levels used to calculate potential takes for the proposed survey of the Aleutian Arc.

	Estimated Density (#/km^2)				Level B (160 dB) Daily Ensonified Area (km^2)			Level A Daily Ensonified Area (km^2)							
Species	Shallow <100 m	Intermediate 100-1000 m	Deep >1000 m	Regional Population Size	Shallow <100 m	Intermediate 100-1000 m	Deep >1000 m	Shallow <100 m	Intermediate 100-1000 m	Deep >1000 m	Survey Days	Level A Takes	Level B Takes	% of Pop. (Level B + Level A Takes)	Requested Take Authorization[1]
LF Cetaceans															
North Pacific right whale	0.0000100	0.0000100	0.0000100	400	79.6	831.5	2,046.5	1.5	47.9	136.9	16.3	0	0	0	**2**
Humpback whale	0.1290000	0.1290000	0.0010000	21,063	79.6	831.5	2,046.5	1.5	47.9	136.9	16.3	106	1,842	9.2	1,948
Blue whale	0.0005000	0.0005000	0.0005000	1,647	79.6	831.5	2,046.5	1.5	47.9	136.9	16.3	2	23	1.5	25
Fin whale	0.0710000	0.0710000	0.0210000	13,620	79.6	831.5	2,046.5	1.5	47.9	136.9	16.3	104	1,650	12.9	1,754
Sei whale	0.0001000	0.0001000	0.0001000	27,197	79.6	831.5	2,046.5	1.5	47.9	136.9	16.3	0	5	0.0	5
Minke whale	0.0006000	0.0006000	0.0006000	20,000	79.6	831.5	2,046.5	1.5	47.9	136.9	16.3	2	27	0.1	29
Gray whale	0.0485700	0	0	26,960	79.6	831.5	2,046.5	1.5	47.9	136.9	16.3	1	62	0.2	63
MF Cetaceans															
Sperm whale	0	0	0.0013000	26,300	79.6	831.5	2,046.5	0.1	1.8	5.0	16.3	0	43	0.2	43
Killer whale	0.0050000	0.0050000	0.0020000	5,000	79.6	831.5	2,046.5	0.1	1.8	5.0	16.3	0	141	2.8	141
Pacific white-sided dolphin	0.0208000	0.0208000	0.0208000	988,333	79.6	831.5	2,046.5	0.1	1.8	5.0	16.3	2	1,000	0.1	1,002
Cuvier's beaked whale	0.0022000	0.0022000	0.0022000	3,274	79.6	831.5	2,046.5	0.1	1.8	5.0	16.3	0	106	3.2	106
Baird's beaked whale	0.0005000	0.0005000	0.0005000	2,697	79.6	831.5	2,046.5	0.1	1.8	5.0	16.3	0	24	0.9	24
Sato's bekaed whale	N.A.	N.A.	N.A.	N.A.	79.6	831.5	2,046.5	0.1	1.8	5.0	16.3	N.A.	N.A.	N.A.	**9**
Stejneger's beaked whale	0.0000100	0.0000100	0.0014200	3,044	79.6	831.5	2,046.5	0.1	1.8	5.0	16.3	0	47	1.6	47
Northern right whale dolphin	N.A.	N.A.	N.A.	26,556	79.6	831.5	2,046.5	0.1	1.8	5.0	16.3	N.A.	N.A.	N.A.	**58**
Risso's dolphin	0.0000100	0.0000100	0.0000100	838,000	79.6	831.5	2,046.5	0.1	1.8	5.0	16.3	0	0	0.0001	**22**
HF Cetaceans															
Harbor Porpoise	0.0473000	0.0473000	0.0000000	79,261	79.6	831.5	2,046.5	0.9	29.2	83.5	16.3	23	679	0.9	702
Dall's porpoise	0.2180000	0.2180000	0.0370000	1,186,000	79.6	831.5	2,046.5	0.9	29.2	83.5	16.3	157	4,312	0.4	4,469
Otariid Seals															
Steller sea lion	0.0392000	0.0392000	0.0098000	53,303	79.6	831.5	2,046.5	0.04	1.4	4.0	16.3	2	907	1.7	909
Northern fur seal	0.0150000	0.0150000	0.0170000	1,100,000	79.6	831.5	2,046.5	0.04	1.4	4.0	16.3	1	788	0.1	789
Phocid Seal															
Northern elephant seal	0.0022000	0.0022000	0.0022000	210,000	79.6	831.5	2,046.5	0.2	5.4	15.3	16.3	1	105	0.1	106
Harbor seal	0.0100000	0.0100000	0.0000100	205,090	79.6	831.5	2,046.5	0.2	5.4	15.3	16.3	1	148	0.1	149
Spotted seal	N.A.	N.A.	N.A.	461,625	79.6	831.5	2,046.5	0.2	5.4	15.3	16.3	N.A.	N.A.	N.A.	5
Ribbon seal	N.A.	N.A.	N.A.	184,697	79.6	831.5	2,046.5	0.2	5.4	15.3	16.3	N.A.	N.A.	N.A.	5

[1] Takes in bold adjusted to mean group size.

APPENDIX D: ENSONIFIED AREAS FOR MARINE MAMMAL TAKE CALCULATIONS

TABLE D-1. Areas ensonified above threshold levels used to calculate potential takes for the proposed survey of the Aleutian Arc.

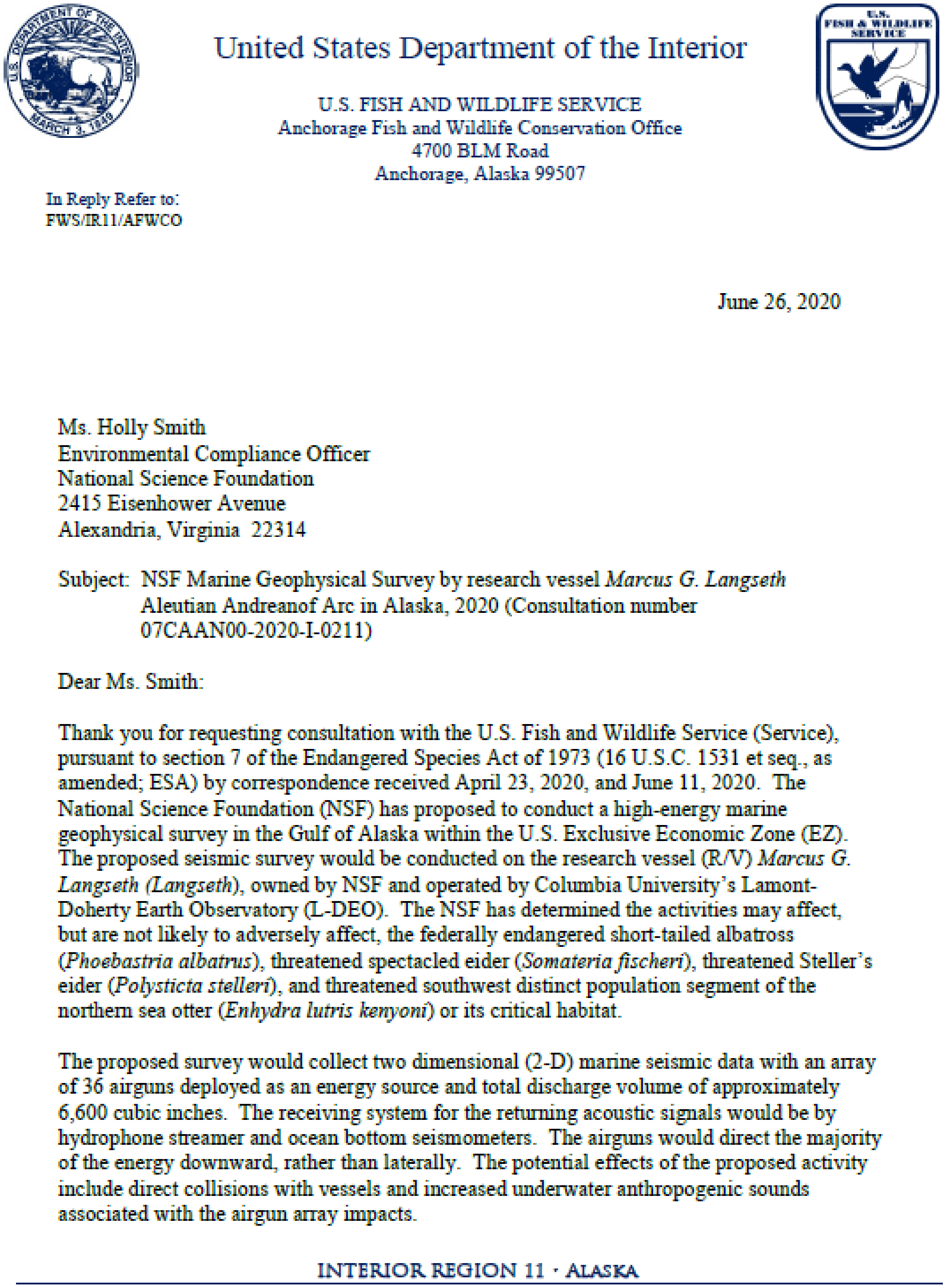
		All Lines - 1 Pass		**2nd Pass for Dip/Strike Lines**				
Survey Zone	**Criteria**	**Daily Ensonified Area (km^2)**	**Total Survey Days**	**Daily Ensonified Area (km^2)**	**Total Survey Days**	**25% Increase**	**Total Ensonified Area (km^2)**	**Relevant Isopleth (m)**
Shallow (<100 m)	160 dB	53.8	10.1	79.5	6.2	1.25	1,296.0	11,000
Intermediate (100-1000 m)	160 dB	596.8	10.1	775.4	6.2	1.25	13,544.6	8,233
Deep (>1000 m)	160 dB	1,695.6	10.1	1,543.1	6.2	1.25	33,337.9	5,629
Overall	**160 dB**	**2,346.2**	**10.1**	**2,398.0**	**6.2**	**1.25**	**48,178.6**	
All zones	LF Cetacean	149.4	10.1	148.5	6.2	1.25	3,035.1	376.0
All zones	MF Cetacean	5.5	10.1	5.5	6.2	1.25	111.4	13.8
All zones	HF Cetacean	91.1	10.1	90.5	6.2	1.25	1,850.1	229.2
All zones	Otariid	4.3	10.1	4.3	6.2	1.25	88.0	10.9
All zones	Phocid	16.7	10.1	16.6	6.2	1.25	339.8	42.1
All zones	Sea Turtle	5.1	10.1	5.1	6.2	1.25	103.3	12.8

APPENDIX E: NEPA COMMENTS

TABLE E-1. Comments received during the NEPA public comment period.

Commenter	Comment Summary	NSF Response
Ground Fish Forum	Ground Fish Forum noted concern that the proposed survey timing overlaps with the typical timing of significant fishing efforts. They expressed concern about potential impacts of seismic air guns on schooling target species, reduced populations, and negative impacts on fishing activities. They offered to provide additional information on regulatory constraints for fishing with a goal of coordination, and to avoid conflicts and inconveniencing the proposed survey and fishing activities. They requested NSF coordinate with their association and member companies before and during research activities to avoid conflicts with fisheries, and, with NMFS, North Pacific Fishery Management Council, and the State of Alaska.	We appreciate the comments received from Ground Fish Forum. NSF consulted with NMFS for the project pursuant to the MMPA, ESA, and EFH. Due to COVID-19, there would be limited opportunity for advance coordination, but to avoid potential conflict, LDEO would coordinate with fishers in the survey area via ship radio and Notice to Mariners. As part of NEPA and other regulatory processes, NSF did reach out to various organizations including NMFS, North Pacific Fishery Management Council, and the State of Alaska. NSF acknowledges the significant regulatory constraints for fishing in the survey area. Based on the illustrative charts provided highlighting some of these constraints, a significant portion of the proposed survey would occur outside of viable fishing areas, reducing chance for time/space overlap. Given the seismic survey portion of the Proposed Action would only take approximately 16 days the chance for interaction with fishing vessels would be limited further. The R/V Langseth, would move continuously during the survey, making two passes along the proposed survey tracks, spending approximately 2 hours in any particular area at a time, and 4 hours in total. For those areas where there could be overlap with fishing vessels, we would work to avoid time/space overlap through communication with fishers in the area. Any impacts on fish species in specific areas would be anticipated to be limited, very brief and temporary in nature.
NMFS Alaska Region Habitat Conservation Division (AKR HCD)	The NMFS Alaska Region Habitat Conservation Division (AKR HCD) requested an Essential Fish Habitat (EFH) Assessment for the Proposed Action. In particular, they noted the Proposed Action: would occur within areas of EFH; overlaps with Aleutian Islands Coral Habitat Protection Areas (AICHPA); may overlap and have impacts with Atka Mackerel.	NSF included information relevant to an EFH consultation in its Draft EA. NSF submitted an EFH consultation request to the NOAA EFH Alaska Regional Office. NOAA concurred with our assessment. Survey tracklines and OBSs were adjusted slighlty to entirely avoid overlap AICHPA; AICHPA was included in Figure 1 of the Final EA.
Aleutian King Crab Research Foundation (AKCRF)	The Aleutian King Crab Research Foundation (AKCRF) noted concern about potential time/space overlap with the Proposed Action and the golden king crab resource and fishery which begins August 1, noting their membership would have all gear and vessels fully deployed through the SEP-OCT period. In addition, they expressed concerns about negative impacts there could be to golden king crab at different life stages (adults, juveniles, and larvae) from exposure to seismic research as proposed. AKCRF will closely monitor catches before, during, and after the seismic research, noting the proximity to actively fishing AIGKC pot gear and requested that NSF researchers work with them and their collaborating partners to help with accurate record keeping and reporting. While the AKCRF would not anticipate difficulties that may arise from a direct gear interaction or conflict (entanglement with lines) they would be willing to share information to avoid any problems. AKCRF requested the action proponents coordinate directly with the AIGKC stakeholders and resource managers.	We appreciate the concerns expressed by AKCRF. Any impacts on fish species in specific areas would be anticipated to be limited. The seismic survey portion of the Proposed Action would only take approximately 16 days. The survey vessel, R/V Langseth, would move continuously during the survey, making two passes along the proposed survey tracks, spending approximately 2 hours in any particular area at time, and 4 hours in total. For these reasons, any impacts, especially catch rates, would be anticipated to be very brief and temporary in nature. The NSF researchers would be willing to work with AKCRF and their collaborating partners to help with accurate record keeping and reporting. The action proponents are willing to coordinate directly with the AIGKC stakeholders and resource managers to avoid direct gear interaction and entanglement.

APPENDIX F: USFWS LETTER OF CONCURRENCE



United States Department of the Interior

U.S. FISH AND WILDLIFE SERVICE
Anchorage Fish and Wildlife Conservation Office
4700 BLM Road
Anchorage, Alaska 99507

In Reply Refer to:
FWS/IR11/AFWCO

June 26, 2020

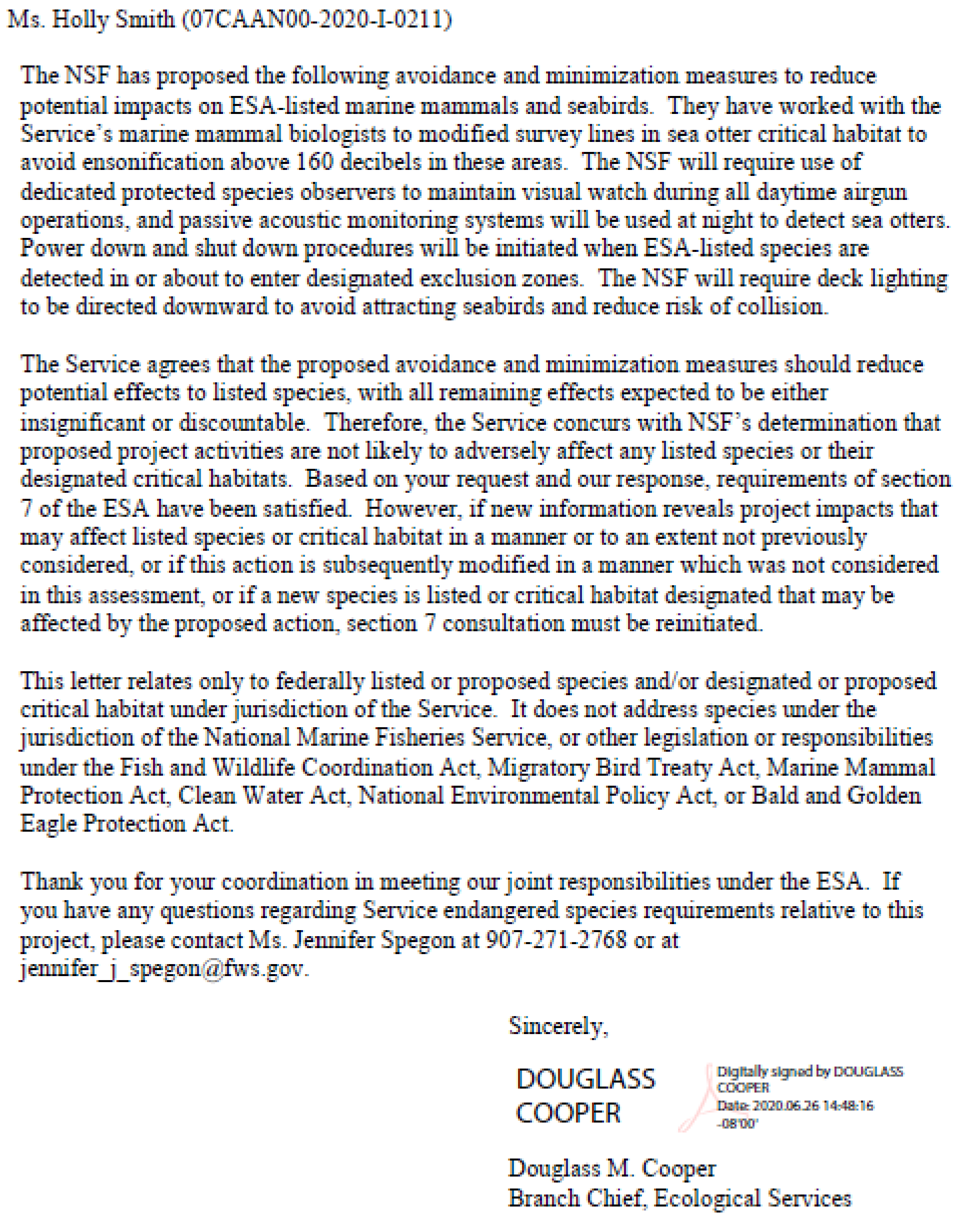
Ms. Holly Smith
Environmental Compliance Officer
National Science Foundation
2415 Eisenhower Avenue
Alexandria, Virginia 22314

Subject: NSF Marine Geophysical Survey by research vessel *Marcus G. Langseth* Aleutian Andreanof Arc in Alaska, 2020 (Consultation number 07CAAN00-2020-I-0211)

Dear Ms. Smith:

Thank you for requesting consultation with the U.S. Fish and Wildlife Service (Service), pursuant to section 7 of the Endangered Species Act of 1973 (16 U.S.C. 1531 et seq., as amended; ESA) by correspondence received April 23, 2020, and June 11, 2020. The National Science Foundation (NSF) has proposed to conduct a high-energy marine geophysical survey in the Gulf of Alaska within the U.S. Exclusive Economic Zone (EZ). The proposed seismic survey would be conducted on the research vessel (R/V) *Marcus G. Langseth (Langseth*), owned by NSF and operated by Columbia University's Lamont-Doherty Earth Observatory (L-DEO). The NSF has determined the activities may affect, but are not likely to adversely affect, the federally endangered short-tailed albatross (*Phoebastria albatrus*), threatened spectacled eider (*Somateria fischeri*), threatened Steller's eider (*Polysticta stelleri*), and threatened southwest distinct population segment of the northern sea otter (*Enhydra lutris kenyoni*) or its critical habitat.

The proposed survey would collect two dimensional (2-D) marine seismic data with an array of 36 airguns deployed as an energy source and total discharge volume of approximately 6,600 cubic inches. The receiving system for the returning acoustic signals would be by hydrophone streamer and ocean bottom seismometers. The airguns would direct the majority of the energy downward, rather than laterally. The potential effects of the proposed activity include direct collisions with vessels and increased underwater anthropogenic sounds associated with the airgun array impacts.



The NSF has proposed the following avoidance and minimization measures to reduce potential impacts on ESA-listed marine mammals and seabirds. They have worked with the Service's marine mammal biologists to modified survey lines in sea otter critical habitat to avoid ensonification above 160 decibels in these areas. The NSF will require use of dedicated protected species observers to maintain visual watch during all daytime airgun operations, and passive acoustic monitoring systems will be used at night to detect sea otters. Power down and shut down procedures will be initiated when ESA-listed species are detected in or about to enter designated exclusion zones. The NSF will require deck lighting to be directed downward to avoid attracting seabirds and reduce risk of collision.

The Service agrees that the proposed avoidance and minimization measures should reduce potential effects to listed species, with all remaining effects expected to be either insignificant or discountable. Therefore, the Service concurs with NSF's determination that proposed project activities are not likely to adversely affect any listed species or their designated critical habitats. Based on your request and our response, requirements of section 7 of the ESA have been satisfied. However, if new information reveals project impacts that may affect listed species or critical habitat in a manner or to an extent not previously considered, or if this action is subsequently modified in a manner which was not considered in this assessment, or if a new species is listed or critical habitat designated that may be affected by the proposed action, section 7 consultation must be reinitiated.

This letter relates only to federally listed or proposed species and/or designated or proposed critical habitat under jurisdiction of the Service. It does not address species under the jurisdiction of the National Marine Fisheries Service, or other legislation or responsibilities under the Fish and Wildlife Coordination Act, Migratory Bird Treaty Act, Marine Mammal Protection Act, Clean Water Act, National Environmental Policy Act, or Bald and Golden Eagle Protection Act.

Thank you for your coordination in meeting our joint responsibilities under the ESA. If you have any questions regarding Service endangered species requirements relative to this project, please contact Ms. Jennifer Spegon at 907-271-2768 or at jennifer_j_spegon@fws.gov.

Sincerely,

DOUGLASS
COOPER

Digitally signed by DOUGLASS COOPER
Date: 2020.06.26 14:48:16 -08'00'

Douglass M. Cooper
Branch Chief, Ecological Services