Request by Lamont-Doherty Earth Observatory for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during a Marine Geophysical Survey by R/V Marcus G. Langseth of the Aleutian Arc, September–October 2020

submitted by

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to

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Request by Lamont-Doherty Earth Observatory
for an Incidental Harassment Authorization to Allow the
Incidental Take of Marine Mammals during a Marine
Geophysical Survey by R/V Marcus G. Langseth of the Aleutian
Arc, September–October 2020

SUMMARY

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 L-DEO under an existing Cooperative Agreement. The proposed two-dimensional (2-D)
seismic survey would occur within Exclusive Economic Zones (EEZ) of the U.S., in water ~35 to 7100 m
deep. This request is submitted pursuant to Section 101 (a)(5)(D) of the Marine Mammal Protection Act
(MMPA), 16 U.S.C. § 1371(a)(5).

Numerous species of marine mammals inhabit the Aleutian Islands survey 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 U.S. Fish and
Wildlife Service (USFWS); all others are managed by NMFS. After discussions with USFWS, the original
survey design was adjusted to avoid take of sea otters and, accordingly, an IHA will not be sought.

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

I. OPERATIONS TO BE CONDUCTED

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

Overview of the Activity

The proposed study would use 2-D seismic surveying 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 survey would occur within the area of ~49–53.5°N, ~172.5–179°W;
representative survey tracklines are shown in Figure 1. As described further in this document, however,
some deviation in actual tracklines, 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. However, deviations in tracklines are expected to be limited and would have minimal effect on the ensuing analysis. The survey is proposed to occur within the EEZ of the U.S., in water ranging from ~35 to 7100 m deep. The proposed survey would be expected to last for ~48 days during September–October 2020, including ~16 days of seismic operations, 19 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.).

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.

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. 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, which would tow an airgun array consisting of up to 36 airguns with a discharge volume of up to ~6600 in³ at a depth of 9 m. 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 study consists of one east-west strike-line transect (~540 km), two north-south dip-line transects (~420 km and ~285 km), connecting MCS transects (~480 km), and an MCS survey of the Amlia Fracture Zone (~285 km). The representative tracklines shown in Figure 1 have a total length of 2010 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 be surveyed, and the OBSs would then be recovered, before moving onto the next line. After all refraction data is acquired, the strike and dip lines would 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 line km to be acquired during the entire survey is expected to be ~3255 km.

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 studies. The vessel would be self-contained, and the crew would live aboard the vessel.
I. Operations to be Conducted

Source Vessel Specifications

R/V Marcus G. Langseth is described in § 2.2.2.1 of the Final Programmatic Environmental Impact Statement (PEIS)/Overseas Environmental Impact Statement (OEIS) for Marine Seismic Research funded by the National Science Foundation or Conducted by the U.S. Geological Survey (NSF and USGS 2011) and Record of Decision (NSF 2012), referred to herein as the PEIS\(^1\). The vessel speed during seismic operations would be ~4.5 kts (~8.3 km/h) during the survey.

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 discharge 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 array is described in § 2.2.3.1 of the PEIS, and the airgun configuration is illustrated in Figure 2-11 of the PEIS. The array would be towed at a depth of 9 m. 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.

Predicted Sound Levels

Mitigation zones for the proposed marine seismic survey were not derived from the farfield signature but 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. 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; this level is used by NMFS, as well as the DoN (2017), to determine behavioral disturbance for sea turtles, which is included in the table for consistency with the Draft EA.

The thresholds for permanent threshold shift (PTS) onset or Level A Harassment (injury) for marine mammals for impulsive sounds use dual metrics of cumulative sound exposure level (SEL_{cum} over 24 hours) and peak sound pressure levels (SPL_{flat}). Different thresholds are provided for the various hearing groups, including low-frequency (LF) cetaceans (e.g., baleen whales), mid-frequency (MF) cetaceans (e.g., most delphinids), high-frequency (HF) cetaceans (e.g., harbor porpoise and Kogia spp.), phocids underwater (PW), and otariids/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 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-in³ airgun; a 100-m EZ was established and monitored for shutdowns of the single airgun. Although the associated Draft EA proposed use of power downs for marine mammals, based on subsequent direction from NMFS, power downs would not be allowable under the IHA and therefore are not proposed in this revised IHA application. Enforcement of mitigation zones via shutdowns would be implemented as described in § XI.

OBS Description and Deployment

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; a response
I. Operations to be Conducted

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, which is included for consistency with the Draft EA.

<table>
<thead>
<tr>
<th>Source and Volume</th>
<th>Tow Depth (m)</th>
<th>Water Depth (m)</th>
<th>Predicted distances (in m) to the 160-dB Received Sound Level</th>
<th>Predicted distances (in m) to the 175-dB Received Sound Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 strings, 18 airguns, 3300 in³</td>
<td>&gt;1000 m</td>
<td></td>
<td>3,562¹</td>
<td>775¹</td>
</tr>
<tr>
<td></td>
<td>100–1000 m</td>
<td>3,939²</td>
<td>1,057²</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt;100 m</td>
<td>5,263²</td>
<td>1,633²</td>
<td></td>
</tr>
<tr>
<td>4 strings, 36 airguns, 6600 in³</td>
<td>&gt;1000 m</td>
<td></td>
<td>5,629¹</td>
<td>1,618¹</td>
</tr>
<tr>
<td></td>
<td>100–1000 m</td>
<td>8,233³</td>
<td>2,210³</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt;100 m</td>
<td>11,000³</td>
<td>3,412³</td>
<td></td>
</tr>
</tbody>
</table>

¹ Distance based on L-DEO model results. ² 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. ³ 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 (SELcum or Peak SPLflat) was used to calculate Level A takes and threshold distances.

<table>
<thead>
<tr>
<th>Level A Threshold Distances (m) for Various Hearing Groups</th>
</tr>
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<tbody>
<tr>
<td>LF Cetaceans</td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td>18 airguns</td>
</tr>
<tr>
<td>PTS SELcum</td>
</tr>
<tr>
<td>PTS Peak</td>
</tr>
<tr>
<td>36 airguns</td>
</tr>
<tr>
<td>PTS SELcum</td>
</tr>
<tr>
<td>PTS Peak</td>
</tr>
</tbody>
</table>

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.

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.

Description of Operations

The procedures to be used for the proposed survey would be similar to those used during previous seismic surveys by L-DEO and would use conventional seismic methodology. The survey would involve one source vessel, R/V Langseth, which is owned by NSF and operated on its behalf by L-DEO. R/V Langseth would deploy an array of up to 36 airguns as an energy source with a total volume of up to ~6600 in³. The receiving system would consist of an 8-km long hydrophone streamer and 50 OBSs.
As the airgun arrays are 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. Approximately ~3224 km of transect lines would be surveyed. 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, and 25% has been added to the survey to account for those addition operations in the take calculations. 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, the ocean floor would be mapped with the Kongsberg EM 122 MBES and a Knudsen Chirp 3260 SBP. A Teledyne RDI 75 kHz Ocean Surveyor ADCP would be used to measure water current velocities. These sources are described in § 2.2.3.1 of the PEIS. 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).

II. DATES, DURATION, AND REGION OF ACTIVITY

The proposed survey would occur within the area of ~49–53.5°N, ~172.5–179°W; representative survey tracklines are shown in Figure 1. As described further in this document, however, some deviation in actual track lines, including the order of survey operations, could be necessary for reasons such as science drivers, poor data quality, inclement weather, 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. The survey is proposed to occur within the EEZ of the U.S., in water depths ranging from 35 to 7100 m.

The proposed survey would be expected to last for 48 days, including ~16 days of seismic operations, 19 days of 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 during September–October 2020. The exact cruise dates have not been confirmed at the time of writing. Seasonality of the proposed survey operations does not affect the ensuing analysis (including take estimates), because the best available species densities for any time of the year have been used.

III. SPECIES AND NUMBERS OF MARINE MAMMALS IN AREA

The 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). Seventeen cetacean species, six pinniped species, and the northern sea otter are known to or could occur in the proposed Aleutian Arc survey area (Table 3). 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
### TABLE 3. The habitat, abundance, and conservation status of marine mammals that could occur in or near the proposed seismic survey area of the Aleutian Arc.

<table>
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<tr>
<th>Species</th>
<th>Habitat</th>
<th>Occurrence in Study Area*</th>
<th>Abundance (Alaska)</th>
<th>Regional Abundance (North Pacific)</th>
<th>ESA¹</th>
<th>IUCN²</th>
<th>CITES³</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mysticetes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Pacific right whale</td>
<td>Coastal, shelf</td>
<td>Rare</td>
<td>28-31⁴</td>
<td>400-500⁵</td>
<td>EN</td>
<td>CR⁵⁹</td>
<td>I</td>
</tr>
<tr>
<td>Gray whale</td>
<td>Mainly coastal</td>
<td>Rare</td>
<td>N.A.</td>
<td>26,960⁶ 290⁷</td>
<td>EN/DL⁸</td>
<td>EN⁵⁰</td>
<td>I</td>
</tr>
<tr>
<td>Humpback whale</td>
<td>Coastal, banks</td>
<td>Uncommon</td>
<td>1107⁹ 10,103¹⁰⁴</td>
<td>21,063¹¹</td>
<td>EN/T/DL¹²</td>
<td>LC</td>
<td>I</td>
</tr>
<tr>
<td>Common minke whale</td>
<td>Coastal, shelf</td>
<td>Common</td>
<td>1233¹³</td>
<td>20,000¹⁴</td>
<td>NL</td>
<td>LC</td>
<td>I</td>
</tr>
<tr>
<td>Sei whale</td>
<td>Pelagic</td>
<td>Uncommon</td>
<td>N.A.</td>
<td>27,197¹⁵</td>
<td>EN</td>
<td>EN</td>
<td>I</td>
</tr>
<tr>
<td>Fin whale</td>
<td>Pelagic</td>
<td>Uncommon</td>
<td>1652¹³</td>
<td>13,620-18,680¹⁶²</td>
<td>EN</td>
<td>VU</td>
<td>I</td>
</tr>
<tr>
<td>Blue whale</td>
<td>Pelagic, shelf, coastal</td>
<td>Uncommon</td>
<td>N.A.</td>
<td>1647¹⁷</td>
<td>EN</td>
<td>EN</td>
<td>I</td>
</tr>
<tr>
<td><strong>Odontocetes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sperm whale</td>
<td>Pelagic</td>
<td>Common</td>
<td>159¹⁸</td>
<td>26,300¹⁹</td>
<td>EN</td>
<td>VU</td>
<td>I</td>
</tr>
<tr>
<td>Cuvier’s beaked whale</td>
<td>Pelagic</td>
<td>Uncommon</td>
<td>N.A.</td>
<td>3274²⁰</td>
<td>NL</td>
<td>LC</td>
<td>II</td>
</tr>
<tr>
<td>Baird’s beaked whale</td>
<td>Pelagic</td>
<td>Uncommon</td>
<td>N.A.</td>
<td>2697²⁰ 5029²¹</td>
<td>NL</td>
<td>DD</td>
<td>I</td>
</tr>
<tr>
<td>Stejneger’s beaked whale</td>
<td>Likely pelagic</td>
<td>Uncommon</td>
<td>N.A.</td>
<td>3044²⁰ 23²³</td>
<td>NL</td>
<td>DD</td>
<td>II</td>
</tr>
<tr>
<td>Pacific white-sided dolphin</td>
<td>Pelagic, shelf, coastal</td>
<td>Uncommon</td>
<td>26,880²⁴</td>
<td>988,333²⁵</td>
<td>NL</td>
<td>LC</td>
<td>II</td>
</tr>
<tr>
<td>Northern right whale dolphin</td>
<td>Slope, pelagic</td>
<td>Rare</td>
<td>N.A.</td>
<td>26,556²⁰</td>
<td>NL</td>
<td>LC</td>
<td>II</td>
</tr>
<tr>
<td>Risso’s dolphin</td>
<td>Pelagic, shelf, coastal</td>
<td>Rare</td>
<td>N.A.</td>
<td>838,000²⁶</td>
<td>NL</td>
<td>LC</td>
<td>II</td>
</tr>
<tr>
<td>Killer whale</td>
<td>Pelagic, shelf, coastal</td>
<td>Common</td>
<td>2347²⁷ 587²⁸ 300²⁹</td>
<td>5000³⁰</td>
<td>NL</td>
<td>DD</td>
<td>II</td>
</tr>
<tr>
<td>Harbor porpoise</td>
<td>Coastal</td>
<td>Common</td>
<td>48,215²⁴ 31,046²³</td>
<td>N.A.</td>
<td>NL</td>
<td>LC</td>
<td>II</td>
</tr>
<tr>
<td>Dall’s porpoise</td>
<td>Pelagic</td>
<td>Common</td>
<td>83,400²⁴</td>
<td>1,186,000³⁵</td>
<td>NL</td>
<td>LC</td>
<td>II</td>
</tr>
<tr>
<td><strong>Pinnipeds</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northern fur seal</td>
<td>Pelagic, breeds coastally</td>
<td>Common</td>
<td>620,660²⁶</td>
<td>1.1 million³⁷</td>
<td>NL</td>
<td>VU</td>
<td>NL</td>
</tr>
<tr>
<td>Steller sea lion</td>
<td>Coastal, offshore</td>
<td>Common</td>
<td>43,201³⁸ 53,624³⁹</td>
<td>N.A.</td>
<td>EN/DL⁴⁰</td>
<td>EN⁴¹</td>
<td>NL</td>
</tr>
<tr>
<td>Harbor seal</td>
<td>Coastal</td>
<td>Common</td>
<td>5588⁴¹</td>
<td>205,090⁴²</td>
<td>NL</td>
<td>LC</td>
<td>NL</td>
</tr>
<tr>
<td>Northern elephant seal</td>
<td>Coastal, offshore</td>
<td>Uncommon</td>
<td>N.A.</td>
<td>210,000-239,000⁴³</td>
<td>NL</td>
<td>LC</td>
<td>NL</td>
</tr>
<tr>
<td>Ribbon seal</td>
<td>Mostly pelagic, ice-associated</td>
<td>Uncommon</td>
<td>184,697⁴⁴</td>
<td>N.A.</td>
<td>NL</td>
<td>LC</td>
<td>NL</td>
</tr>
<tr>
<td>Spotted seal</td>
<td>Pelagic, coastal, ice-associated</td>
<td>Rare</td>
<td>461,625⁴⁴</td>
<td>N.A.</td>
<td>NL</td>
<td>LC</td>
<td>NL</td>
</tr>
<tr>
<td><strong>Fissipeds</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northern Sea Otter</td>
<td>Coastal</td>
<td>Common</td>
<td>54,771⁴⁵ 25,712⁴⁶</td>
<td>18,297⁴⁷</td>
<td>N.A.</td>
<td>T⁴⁸</td>
<td>EN</td>
</tr>
</tbody>
</table>

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).
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 Northeast 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).
25 North Pacific Ocean (Miyashita 1993b).
26 Western North Pacific Ocean (Miyashita 1993a).
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 Northeast 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).
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.
III and IV. Marine Mammals Potentially Affected

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 when the proposed survey is scheduled to occur, 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 their critical habitat. To avoid redundancy, we have included the required information about the species and (insofar as it is known) numbers of these species in § IV, below.

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

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

Sections III and IV are integrated here to minimize repetition. General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of marine mammals are given in § 3.6.1, § 3.7.1, and § 3.8.1 of the 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 3.

Mysticetes

North Pacific Right Whale (Eubalaena japonica)

North Pacific right whales summer in the northern North Pacific, primarily in the Okhotsk Sea (Brownell et al. 2001) and 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 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.

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. It is possible although unlikely that a right whale could be seen during the proposed survey.

**Gray Whale (Eschrichtius robustus)**

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

**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/km² (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/km² (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.

**Common Minke Whale** (*Balaenoptera acutorostrata scammoni*)

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, Waita (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.

**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.

**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 Witteveen 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/km² (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/km² (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.

**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 2004; 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 2004; 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.

**Odontocetes**

**Sperm Whale** (*Physeter macrocephalus*)

The sperm whale is widely distributed, occurring from the edge of the polar pack ice to the Equator in both hemispheres, with the sexes occupying different distributions (Whitehead 2018). In general, it is distributed over large temperate and tropical areas that have high secondary productivity and steep underwater topography, such as volcanic islands (Jaquet and Whitehead 1996). Its distribution and relative abundance can vary in response to prey availability, most notably squid (Jaquet and Gendron 2002). Females generally inhabit waters $>$1000 m deep at latitudes $<$40º where sea surface temperatures are $<$15ºC; adult males move to higher latitudes as they grow older and larger in size, returning to warm-water breeding grounds according to an unknown schedule (Whitehead 2018). 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 (~51.7ºN, 179.3ºW), northeast of Seguam Island (~52.6ºN, 172.1ºW), and within (52.6ºN, 172.6ºW) 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.

**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.

**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 Stejnegger’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.

**Baird’s Beaked Whale (Berardius bairdii)**

Baird’s beaked whale has a fairly extensive range across the North Pacific north of 30°N, and strandings have occurred as far north as the Pribilof Islands (Rice 1986). Two forms of Baird’s beaked whales have been recognized – the common slate-gray form and a smaller, rare black form (Morin et al. 2017). The gray form is seen off Japan, the Aleutians, and on the west coast of North America, whereas the black form has been reported for northern Japan and the Aleutians (Morin et al. 2017). Recent genetic studies suggest that the black form could be a separate species (Morin et al. 2017). Baird’s beaked whale is currently divided into three distinct stocks: Sea of Japan, Okhotsk Sea, and Bering Sea/eastern North Pacific (Balcomb 1989; Reyes 1991). Baird’s beaked whales sometimes are seen close to shore, but their primary habitat is over or near the continental slope and oceanic seamounts in waters 1000–3000 m deep (Jefferson et al. 1993; Kasuya and Ohsumi 1984; 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.

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.

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.

**Risso’s Dolphin (*Grampus griseus*)**

Risso’s dolphin is distributed worldwide in mid-tropical and tropical oceans (Kruse et al. 1999). Although it shows a preference for mid-tropical 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 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.

**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 Unmak 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.

**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 ~30–62°N (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/km² (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 (~51.6°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.

**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/km² (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.

**Pinnipeds**

**Northern Fur Seal (Callorhinus ursinus)**

The northern fur seal is endemic to the North Pacific Ocean and occurs from southern California to the Bering Sea, Okhotsk Sea, and Honshu Island, Japan (Muto et al. 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 Unmak 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.

**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). The survey area lies within the range of the endangered Western DPS and includes critical habitat (Fig. 1). 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). 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.

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 counts of Steller sea lions, numbers have continued to decline west of Samalga Pass (Sweeney et al. 2017; Rand et al. 2019). During surveys of the central Aleutian Islands in June–July 2017, the highest number of sea lions for the islands surveyed occurred on Gramp Rock, near Tanaga Island, and at Ulak/Hasgox Point, Ulak Island (Sweeney et al. 2017). However, 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 (Rand et al. 2019; Fritz 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.
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 45°N (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 Boeuf 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.

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 Anyanof 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.

**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.

**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: the Bering Sea DPS, the Okhotsk DPS, and the 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).

**Marine Fissipeds**

**Northern Sea Otter** (*Enhydra lutris kenyoni*)

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). Sea otters occupied coastal areas from Hokkaido, Japan, around the North Pacific Rim to central Baja California (Rotterman and Simon-Jackson 1988). Commercial exploitation reduced the total sea otter population to as low as 2000 in 13 locations (Kenyon 1969). In 1911, sea otters received protection under the North Pacific Fur Seal Convention, and populations recovered quickly (Kenyon 1969).

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. 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 to USFWS 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.

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 et al. (2014) reported sea otter hotspots in the Aleutian Islands. Sea otters are likely to be common in the nearshore waters of the Aleutian Islands.

V. TYPE OF INCIDENTAL TAKE AUTHORIZATION REQUESTED

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

L-DEO requests an IHA pursuant to Section 101 (a)(5)(D) of the MMPA for incidental take by harassment during its planned seismic survey of the Aleutian Arc during September–October 2020. The operations outlined in § 1 have the potential to take marine mammals by harassment. Sounds would be generated by the airguns used during the survey, by echosounders, and by general vessel operations. “Takes” by harassment would potentially result when marine mammals near the activity are exposed to the pulsed sounds, such as those generated by the airguns. The effects would depend on the species of marine mammal, the behavior of the animal at the time of reception of the stimulus, as well as the distance and
received level of the sound (see § VII). Disturbance reactions are likely amongst some of the marine mammals near the tracklines of the source vessel.

At most, effects on marine mammals would be anticipated as falling within the MMPA definition of “Level B Harassment” for those species managed by NMFS. No take by serious injury is expected, given the nature of the planned operations and the mitigation measures that are planned (see § XI, MITIGATION MEASURES), and no lethal takes are expected. 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. However, Dall’s porpoise could be more susceptible to exposure to sound levels that exceed the PTS threshold than other marine mammals, as it is known to approach vessels to bowride.

VI. NUMBERS OF MARINE MAMMALS THAT COULD BE TAKEN

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

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

VII. ANTICIPATED IMPACT ON SPECIES OR STOCKS

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

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

- First we summarize the potential impacts on marine mammals of airgun operations, as called for in § VII. A more comprehensive review of the relevant background information appears in § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS.
- Then we summarize the potential impacts of operations by the echosounders. A more comprehensive review of the relevant background information appears in § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS.
- Finally, we estimate the numbers of marine mammals that could be affected by the proposed survey of the Aleutian Arc. As called for in § VI, this section includes a description of the rationale for the estimates of the potential numbers of harassment “takes” during the planned survey, as well Level A “takes”.

Summary of Potential Effects of Airgun Sounds

As noted in the PEIS (§ 3.6.4.3, § 3.7.4.3, § 3.8.4.3), the effects of sounds from airguns could include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and at least in theory, temporary or permanent hearing impairment, or non-auditory physical or physiological effects (Richardson et al. 1995; Gordon et al. 2004; Nowacek et al. 2007; Southall et al. 2007; Erbe 2012; Peng et al. 2015; Erbe et al. 2016, 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 (PTS), in the unlikely event that it occurred, would constitute injury, but TTS is not considered an injury (Southall et al. 2007; Le Prell 2012). Physical damage to a mammal’s hearing apparatus can occur if it is exposed to sound impulses that have very high peak pressures, especially if the impulses have very short rise times (e.g., Morell et al. 2017). However, the impulsive nature of sound is range-dependent, becoming less harmful over distance from the source (Hastie et al. 2019). TTS is not considered an injury (Southall et al. 2007; Le Prell 2012). Rather, the onset of TTS has been considered an indicator that, if the animal is exposed to higher levels of that sound, physical damage is ultimately a possibility. Nonetheless, research has shown that sound exposure can cause cochlear neural degeneration, even when threshold shifts and hair cell damage are reversible (Kujawa and Liberman 2009; Liberman et al. 2016). These findings have raised some doubts as to whether TTS should continue to be considered a non-injurious effect (Weilgart 2014; Tougaard et al. 2015, 2016). Although the possibility cannot be entirely excluded, it is unlikely that the proposed 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. Kyhn et al. (2019) reported that baleen whales and seals were likely masked over an extended period of time during four concurrent seismic surveys in Baffin Bay, Greenland. Nieukirk et al. (2012),
Blackwell et al. (2013), and Dunlop (2018) also noted the potential for masking effects from seismic surveys on large whales.

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

Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors (Richardson et al. 1995; Wartzok et al. 2004; Southall et al. 2007; Weilgart 2007; Ellison et al. 2012, 2018; 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., New et al. 2013b; King et al. 2015; Costa et al. 2016a,b; Ellison et al. 2016; Harwood et al. 2016; Nowacek et al. 2016; Farmer et al. 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.
cases, this approach likely overestimates the numbers of marine mammals that would be affected in some biologically important manner.

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

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

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

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

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

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

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

Bowhead whale calls detected in the presence and absence of airgun sounds have been studied extensively in the Beaufort Sea. Bowheads continue to produce calls of the usual types when exposed to airgun sounds on their summering grounds, although numbers of calls detected are significantly lower in the presence than in the absence of airgun pulses (Blackwell et al. 2013, 2015). Blackwell et al. (2013) reported that calling rates in 2007 declined significantly where received SPLs from airgun sounds were 116–129 dB re 1 µPa; at SPLs <108 dB re 1 µPa, calling rates were not affected. When data for 2007–2010 were analyzed, Blackwell et al. (2015) reported an initial increase in calling rates when airgun pulses became detectable; however, calling rates leveled off at a received CSEL_{10-min} (cumulative SEL over a 10-min period) of ~94 dB re 1 µPa²·s, decreased at CSEL_{10-min} >127 dB re 1 µPa²·s, and whales were nearly silent at CSEL_{10-min} >160 dB re 1 µPa²·s. Thus, bowhead whales in the Beaufort Sea apparently decreased their calling rates in response to seismic operations, although movement out of the area could also have contributed to the lower call detection rate (Blackwell et al. 2013, 2015).

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

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

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

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

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 did not seem affected by a seismic survey in its feeding ground during a previous year. In addition, bowhead whales have continued to travel to the eastern Beaufort Sea each summer, and their numbers have increased notably, despite seismic exploration in their summer and autumn range for many years. Pirotta et al. (2018) used a dynamic state model of behavior and physiology to assess the consequences of disturbance (e.g., seismic surveys) on whales (in this case, blue whales). They found that the impact of localized, acute disturbance (e.g., seismic surveys) depended on the whale’s behavioral response, with whales that remained in the affected area having a greater risk of reduced reproductive success than whales that avoided the disturbance. Chronic, but weaker disturbance (e.g., vessel traffic) appeared to have less effect on reproductive success.

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

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

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

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

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

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

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

The limited available data suggest that *harbor porpoises* show stronger avoidance of seismic operations than do Dall’s porpoises. The apparent tendency for greater responsiveness in the harbor porpoise is consistent with its relative responsiveness to boat traffic and some other acoustic sources (Richardson et al. 1995; Southall et al. 2007). Based on data collected by observers on seismic vessels off the U.K. from 1994 to 2010, detection rates of harbor porpoises were significantly higher when airguns were silent vs. when large or small arrays were operating (Stone 2015). In addition, harbor porpoises were seen farther away from the array when it was operating vs. silent, and were most often seen traveling away from the airgun array when it was in operation (Stone 2015). Thompson et al. (2013b) reported decreased densities and reduced acoustic detections of harbor porpoise in response to a seismic survey in Moray Firth, Scotland, at ranges of 5–10 km (SPLs of 165–172 dB re 1 µPa, SELs of 145–151 dB µPa$^2$·s). For the same survey, Pirotta et al. (2014) reported that the probability of recording a porpoise buzz decreased by 15% in the ensonified area, and that the probability was positively related to the distance from the seismic ship; the decreased buzzing occurrence may indicate reduced foraging efficiency. Nonetheless, animals returned to the area within a few hours (Thompson et al. 2013). In a captive facility, harbor porpoise showed avoidance of a pool with elevated sound levels, but search time for prey within that pool was no different than in a quieter pool (Kok et al. 2017).
Kastelein et al. (2013a) reported that a harbor porpoise showed no response to an impulse sound with an SEL below 65 dB, but a 50% brief response rate was noted at an SEL of 92 dB and an SPL of 122 dB re 1 μPa0-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 in³ airgun for 1 min at 2–3 s intervals at ranges of 420–690 m and levels of 135–147 dB μPa²·s. One porpoise moved away from the sound source but returned to natural movement patterns within 8 h, and two porpoises had shorter and shallower dives but returned to natural behaviors within 24 h.

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

**Pinnipeds.**—Pinnipeds are not likely to show a strong avoidance reaction to an airgun array. Visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds and only slight (if any) changes in behavior. However, telemetry work has suggested that avoidance and other behavioral reactions may be stronger than evident to date from visual studies (Thompson et al. 1998). Observations from seismic vessels operating large arrays off the U.K. from 1994 to 2010 showed that the detection rate for grey seals was significantly higher when airguns were not operating; for surveys using small arrays, the detection rates were similar during seismic vs. non-seismic operations (Stone 2015). No significant differences in detection rates were apparent for harbor seals during seismic and non-seismic periods (Stone 2015). There were no significant differences in CPA distances of grey or harbor seals during seismic vs. non-seismic periods (Stone 2015). Lallas and McConnell (2015) made observations of New Zealand fur seals from a seismic vessel operating a 3090 in³ 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 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-in³ airgun and a 4089-in³ 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; Finneran 2015). However, there has been no
specific documentation of TTS let alone permanent hearing damage, i.e., PTS, in free-ranging marine mammals exposed to sequences of airgun pulses during realistic field conditions.

Additional data are needed to determine the received sound levels at which small odontocetes would start to incur TTS upon exposure to repeated, low-frequency pulses of airgun sound with variable received levels. To determine how close an airgun array would need to approach in order to elicit TTS, one would (as a minimum) need to allow for the sequence of distances at which airgun pulses would occur, and for the dependence of received SEL on distance in the region of the seismic operation (e.g., Breitzke and Bohlen 2010; Laws 2012). At the present state of knowledge, it is also necessary to assume that the effect is directly related to total received energy (SEL); however, this assumption is likely an over-simplification (Finneran 2012). There is recent evidence that auditory effects in a given animal are not a simple function of received acoustic energy (Finneran 2015). Frequency, duration of the exposure, and occurrence of gaps within the exposure can also influence the auditory effect (Finneran and Schlundt 2010, 2011, 2013; Finneran et al. 2010a,b; Popov et al. 2011, 2013; Ketten 2012; Finneran 2012, 2015; Kastelein et al. 2012a,b; 2013b,c, 2014, 2015a, 2016a,b, 2017, 2018, 2019a,b; Supin et al. 2016).

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

Studies have also shown that the SEL necessary to elicit TTS can depend substantially on frequency, with susceptibility to TTS increasing with increasing frequency above 3 kHz (Finneran and Schlundt 2010, 2011; Finneran 2012). When beluga whales were exposed to fatiguing noise with sound levels of 165 dB re 1 \( \mu \)Pa 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\(_{\text{cum}}\) of 188 and 191 \( \mu \)Pa\(^2\)·s, respectively, significant TTS occurred at a hearing frequency of 4 kHz and not at lower hearing frequencies that were tested, despite the fact that most of the airgun energy was <1 kHz; recovery occurred within 12 min post exposure (Kastelein et al. 2017).

Popov et al. (2016) reported that TTS produced by exposure to a fatiguing noise was larger during the first session (or naïve subject state) with a beluga whale than TTS that resulted from the same sound in subsequent sessions (experienced subject state). Similarly, several other studies have shown that some marine mammals (e.g., bottlenose dolphins, false killer whales) can decrease their hearing sensitivity in order to mitigate the impacts of exposure to loud sounds (e.g., Nachtigall and Supin 2013, 2014, 2015, 2016; Nachtigall et al. 2018)

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

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

For the harbor porpoise, Tougaard et al. (2015) have suggested an exposure limit for TTS as an SEL of 100–110 dB above the pure tone hearing threshold at a specific frequency; they also suggested an exposure limit of $L_{eq\text{-fast}}$ (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. Mulson et al. (2015) suggested that basing weighting functions on equal latency/loudness contours may be more appropriate than M-weighting for marine mammals. Simulation modeling to assess the risk of sound exposure to marine mammals (gray seal and harbor porpoise) showed that SEL is most strongly influenced by the weighting function (Donovan et al. 2017). Houser et al. (2017) provide a review of the development and application of auditory weighting functions, as well as recommendations for future work.

Initial evidence from exposures to non-pulses has also suggested that some pinnipeds (harbor seals in particular) incur TTS at somewhat lower received levels than do most small odontocetes exposed for similar durations (Kastak et al. 1999, 2005, 2008; Ketten et al. 2001). Kastelein et al. (2012b) exposed two harbor seals to octave-band white noise centered at 4 kHz at three mean received SPLs of 124, 136, and 148 dB re 1 µPa; TTS >2.5 dB was induced at an SEL of 170 dB (136 dB SPL for 60 min), and the maximum TTS of 10 dB occurred after a 120-min exposure to 148 dB re 1 µPa or an SEL of 187 dB. Kastelein et al. (2013c) reported that a harbor seal unintentionally exposed to the same sound source with a mean received SPL of 163 dB re 1 µPa for 1 h induced a 44 dB TTS. For a harbor seal exposed to octave-band white noise centered at 4 kHz for 60 min with mean SPLs of 124–148 re 1 µPa, the onset of PTS would require a level of at least 22 dB above the TTS onset (Kastelein et al. 2013c). Reichmuth et al. (2016) exposed captive spotted and ringed seals to single airgun pulses with SELs of 165–181 dB and SPLs (peak to peak) of 190–207 re 1 µPa; no low-frequency TTS was observed. Harbor seals may be able to decrease their exposure to underwater sound by swimming just below the surface where sound levels are typically lower than at depth (Kastelein et al. 2018).

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 mammals close to an airgun array might incur at least mild TTS, there has been further speculation about the possibility that some individuals occurring very close to airguns might incur PTS (e.g., Richardson et al. 1995, p. 372ff; Gedamke et al. 2011). In terrestrial animals, exposure to sounds sufficiently strong to elicit a large TTS induces physiological and structural changes in the inner ear, and at some high level of sound exposure, these phenomena become non-recoverable (Le Prell 2012). At this level of sound exposure, PTS grades into TTS. 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 new noise exposure criteria for marine mammals that were recently 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 (SEL_{cum} over 24 hours) and Peak SPL_{flat}. Onset of PTS is assumed to be 15 dB higher when considering SEL_{cum} and 6 dB higher when considering SPL_{flat}. Different thresholds are provided for the various hearing groups, including LF cetaceans, MF cetaceans, HF cetaceans, phocids, and otariids.

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

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might (in theory) occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, and other types of organ or tissue damage. Gray and Van Waerebeek (2011) have suggested a cause-effect relationship between a seismic survey off Liberia in 2009 and the erratic movement, postural instability, and akesia in a pantropical spotted dolphin based on spatially and temporally close association with the airgun array. It is possible that some marine mammal species (i.e., beaked whales) are especially susceptible to injury and/or stranding when exposed to strong transient sounds (e.g., Southall et al. 2007). Ten cases of cetacean strandings in the general area where a seismic survey was ongoing have led to
speculation concerning a possible link between seismic surveys and strandings (Castellote and Llorens 2016). An analysis of stranding data found that the number of long-finned pilot whale strandings along Ireland’s coast increased with seismic surveys operating offshore (McGeady et al. 2106). However, there is no definitive evidence that any of these effects occur even for marine mammals in close proximity to large arrays of airguns. Morell et al. (2017) examined the inner ears of long-finned pilot whales after a mass stranding in Scotland and reported damage to the cochlea compatible with over-exposure from underwater noise; however, no seismic surveys were occurring in the vicinity in the days leading up to the stranding.

Since 1991, there have been 70 Marine Mammal Unusual Mortality Events (UME) in the U.S. (NOAA 2019). In a hearing to examine the Bureau of Ocean Energy Management’s 2017–2022 OCS Oil and Gas Leasing Program (https://www.energy.senate.gov/public/index.cfm/2016/5/hearing-is-examine-the-bureau-of-ocean-energy-management-s-2017-2022-ocs-oil-and-gas-leasing-program), 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. Similarly, the large whale UME Core Team found that seismic testing did not contribute to the 2015 UME involving humpbacks and fin whales from Alaska to B.C. (Savage 2017).

Non-auditory effects, if they occur at all, would presumably be limited to short distances and to activities that extend over a prolonged period. Marine mammals that show behavioral avoidance of seismic vessels, including most baleen whales, some odontocetes, and some pinnipeds, are especially unlikely to incur non-auditory physical effects. The brief duration of exposure of any given mammal and the planned monitoring and mitigation measures would further reduce the probability of exposure of marine mammals to sounds strong enough to induce non-auditory physical effects.

Possible Effects of Other Acoustic Sources

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

There has been some recent attention given to the effects of MBES on marine mammals, as a result of a report issued in September 2013 by an IWC independent scientific review panel linking the operation of an MBES to a mass stranding of melon-headed whales (Peponocephala electra; Southall et al. 2013) off Madagascar. During May–June 2008, ~100 melon-headed whales entered and stranded in the Loza Lagoon system in northwest Madagascar at the same time that a 12-kHz MBES survey was being conducted ~65 km away off the coast. In conducting a retrospective review of available information on the event, an independent scientific review panel concluded that the Kongsberg EM 120 MBES was the most plausible behavioral trigger for the animals initially entering the lagoon system and eventually stranding. The independent scientific review panel, however, identified that an unequivocal conclusion on causality of the event was not possible because of the lack of information about the event and a number of potentially contributing factors. Additionally, the independent review panel report indicated that this incident was likely the result of a complicated confluence of environmental, social, and other factors that have a very low probability of occurring again in the future, but recommended that the potential be considered in environmental planning. It should be noted that this event is the first known marine mammal mass stranding closely associated with the operation of an MBES. Leading scientific experts knowledgeable about MBES expressed concerns about the independent scientific review panel analyses and findings (Bernstein 2013).
Reference has also been made that two beaked whales stranded in the Gulf of California in 2002 were observed during a seismic survey in the region by the R/V *Ewing* (Malakoff 2002, Cox et al. 2006 in PEIS:3-136), which used a similar MBES system. As noted in the PEIS, however, “The link between the stranding and the seismic surveys was inconclusive and not based on any physical evidence” (Hogarth 2002, Yoder 2002 in PEIS:3-190).

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

There has only been one 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).

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

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

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

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

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

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

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

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

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

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

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

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

**Numbers of Marine Mammals that could be “Taken by Harassment”**

All takes would be anticipated to be Level B “takes by harassment” as described in § I, involving temporary changes in behavior. 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; takes for northern sea otter are not included here, as an
IHA application will be sought from USFWS. The main sources of distributional and numerical data used in deriving the estimates are described in the next subsection.

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

**Basis for Estimating “Takes”**

The Level B estimates are based on a consideration of the number of marine mammals that could be within the area around the operating airgun array where received levels of sound ≥160 dB re 1 μPa\textsubscript{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\textsubscript{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 4, estimates of the number of marine mammals that potentially could be exposed to ≥160 dB re 1 μPa\textsubscript{rms} during the proposed seismic survey of the Aleutian Arc if no animals moved away from the survey vessel are shown in Table 5. The Requested Take Authorization is given in the right-most column of Table 5.
TABLE 4. Densities of marine mammals (individuals/km²) 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).

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<tr>
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<th>Shallow Water</th>
<th>Intermediate Water</th>
<th>Deep Water</th>
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<td>&lt;100 m</td>
<td>100-1000 m</td>
<td>&gt;1000 m</td>
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<tr>
<td>LF Cetaceans</td>
<td></td>
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<tr>
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<td>0.12900</td>
<td>0.00100</td>
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<tr>
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<td>0.07100</td>
<td>0.02100</td>
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<td>0.00010</td>
<td>0.00010</td>
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<td>0.00060</td>
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<tr>
<td>Gray whale</td>
<td>0.04857</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>MF Cetaceans</td>
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<td></td>
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<tr>
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<td>0</td>
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<td>0.00500</td>
<td>0.00200</td>
</tr>
<tr>
<td>Pacific white-sided dolphin</td>
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<tr>
<td>Cuvier's beaked whale</td>
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<td>0.00050</td>
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</tr>
<tr>
<td>Stejneger's beaked whale</td>
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<td>Northern right whale dolphin</td>
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<td>N.A.</td>
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<tr>
<td>Risso’s dolphin</td>
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<td>0.00001</td>
<td>0.00001</td>
</tr>
<tr>
<td>HF Cetaceans</td>
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</tr>
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<td>Harbor Porpoise</td>
<td>0.04730</td>
<td>0.04730</td>
<td>0.00000</td>
</tr>
<tr>
<td>Dall’s porpoise</td>
<td>0.21800</td>
<td>0.21800</td>
<td>0.03700</td>
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<tr>
<td>Otariid Seals</td>
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<td></td>
</tr>
<tr>
<td>Steller sea lion</td>
<td>0.00980</td>
<td>0.00980</td>
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</tr>
<tr>
<td>Northern fur seal</td>
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<td>0.01700</td>
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<td>Phocid Seals</td>
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<td>Northern elephant seal</td>
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<td>0.00220</td>
<td>0.00220</td>
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<td>Harbor seal</td>
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<td>0.01000</td>
<td>0.00001</td>
</tr>
<tr>
<td>Spotted seal</td>
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<td>N.A.</td>
<td>N.A.</td>
</tr>
<tr>
<td>Ribbon seal</td>
<td>N.A.</td>
<td>N.A.</td>
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</tr>
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</table>

N.A. means not available.
TABLE 5. 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.

<table>
<thead>
<tr>
<th>Species</th>
<th>Calculated Take</th>
<th>Regional Population Size</th>
<th>% of Pop. (Level B Takes)</th>
<th>Requested Take Authorization</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Level B¹ Level A²</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LF Cetaceans</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>North Pacific right whale</td>
<td>1</td>
<td>0</td>
<td>400</td>
<td>0.1</td>
</tr>
<tr>
<td>Humpback whale</td>
<td>2,580</td>
<td>140</td>
<td>21,063</td>
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<td>Blue whale</td>
<td>25</td>
<td>2</td>
<td>1,647</td>
<td>1.6</td>
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<td>Fin whale</td>
<td>2,037</td>
<td>118</td>
<td>13,620</td>
<td>15.8</td>
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<td>Sei whale</td>
<td>5</td>
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<td>27,197</td>
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<td>Minke whale</td>
<td>30</td>
<td>2</td>
<td>20,000</td>
<td>0.2</td>
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<tr>
<td>Gray whale</td>
<td>226</td>
<td>3</td>
<td>26,960</td>
<td>0.8</td>
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<td>MF Cetaceans</td>
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<td>Sperm whale</td>
<td>39</td>
<td>3</td>
<td>26,300</td>
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<td>Killer whale</td>
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<td>9</td>
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<td>110</td>
<td>7</td>
<td>3,274</td>
<td>3.6</td>
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<td>Baird's beaked whale</td>
<td>25</td>
<td>2</td>
<td>2,697</td>
<td>1.0</td>
</tr>
<tr>
<td>Stejneger's beaked whale</td>
<td>43</td>
<td>3</td>
<td>3,044</td>
<td>1.5</td>
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<tr>
<td>Northern right whale dolphin</td>
<td>N.A.</td>
<td>N.A.</td>
<td>26,556</td>
<td>N.A.</td>
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<tr>
<td>Risso's dolphin</td>
<td>1</td>
<td>0</td>
<td>838,000</td>
<td>&lt;0.01</td>
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<tr>
<td>HF Cetaceans</td>
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<td></td>
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<tr>
<td>Harbor Porpoise</td>
<td>935</td>
<td>51</td>
<td>79,261</td>
<td>1.2</td>
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<td>Dall's porpoise</td>
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<tr>
<td>Otariid Seals</td>
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<tr>
<td>Steller sea lion</td>
<td>489</td>
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<tr>
<td>Phocid Seal</td>
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<td>Northern elephant seal</td>
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<td>210,000</td>
<td>0.1</td>
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<td>Harbor seal</td>
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<tr>
<td>Spotted seal</td>
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<td>N.A.</td>
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<tr>
<td>Ribbon seal</td>
<td>N.A.</td>
<td>N.A.</td>
<td>184,697</td>
<td>N.A.</td>
</tr>
</tbody>
</table>

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 3).
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 ~57 individuals from the Western North Pacific DPS, and ~299 whales from the Mexico DPS; the remainder are from the Hawaii DPS (see text).
⁷ Requested take includes 3 individuals from the Western North Pacific DPS (see text).
⁸ Requested take authorization is mean group size based on Barlow (2016).
⁹ In the absence of density information and as described in the associated text, requested take authorization was estimated as five individuals.
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. For ribbon and spotted seals, in the absence of density information and based on the authors experience, 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). 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 EZs) (Table 5). Those numbers likely overestimate actual Level A takes because the predicted Level A EZs are small and mitigation measures would further reduce the chances of, if not eliminate, any such takes. In addition, most marine mammals would move away from a sound source before they are exposed to sound levels that could result in a Level A take. Dall’s porpoise could be more susceptible to exposure to sound levels that exceed the PTS threshold than other marine mammals, as this species is known to approach vessels to bowride. However, Level A takes are considered highly unlikely for most marine mammal species that could be encountered in the proposed survey area.

The estimate of the number of marine mammals that could be exposed to seismic sounds with received levels ≥160 dB re 1 μPa rms in the GOA survey area is 13,388 cetaceans and 1705 pinnipeds (Table 5). That total includes 2588 cetaceans listed as threatened or endangered under the ESA: 42 sperm whales, 5 sei whales, 2155 fin whales, 27 blue whales, representing 0.2%, 0.02%, 15.8%, 1.6% of their regional populations, respectively, as well as 3 Western North Pacific gray whales, 57 Western
North Pacific humpback whales, and 299 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 520 endangered Steller sea lions from the Western DPS which represents 1% of the population. In addition, 189 beaked whales could be exposed. Approximately half of all cetaceans potentially exposed would be porpoise. Dalls’ porpoise is expected to be the most common marine mammal species in the area, with up to 5732 exposures to ≥160 dB re 1 μPa rms (0.5% of their regional population).

In addition, 189 beaked whales could be exposed. Approximately half of all cetaceans potentially exposed would be porpoise. Dalls’ porpoise is expected to be the most common marine mammal species in the area, with up to 5732 exposures to ≥160 dB re 1 μPa rms (0.5% 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.

Conclusions

The proposed seismic survey would involve towing a 36-airgun array, which introduces pulsed sounds into the ocean. Routine vessel operations, other than the proposed seismic operations, are conventionally assumed not to affect marine mammals sufficiently to constitute “taking”.

In §3.6.7, §3.7.7, §3.8.7, and §3.9.7, the PEIS concluded that airgun operations with implementation of the proposed monitoring and mitigation measures could result in a small number of Level B behavioral effects in some mysticetes, odontocetes, pinniped, and sea otters and that Level A effects were highly unlikely. 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 recently 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 (e.g., NMFS 2019b,c).

Estimates of the numbers of marine mammals that could be exposed to airgun sounds during the proposed program have been presented, together with the requested “take authorization”. The estimated numbers of animals potentially exposed to sound levels sufficient to cause Level A and/or B harassment are low percentages of the regional population sizes. However, the relatively short-term exposures are unlikely to result in any long-term negative consequences for the individuals or their populations. Therefore, no significant impacts on marine mammals would be anticipated from the proposed activities.

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

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

There is some sealing by indigenous groups in the proposed survey area in the Aleutian Islands. However, given the temporary nature of the proposed activities and the fact that all operations would occur more than 3 n.mi. from shore, the proposed activity would not be expected to have any impact on the availability of the species or stocks for subsistence users. However, indigenous groups will be consulted to confirm this conclusion. To avoid the potential spread and health impacts related to COVID-19, we will reach out via a letter to notify subsistence hunters of the Proposed Action, identify the measures taken and would be taken to minimize any effects on the availability of marine mammals for subsistence uses, and provide an opportunity for comment on these measures. Results of this effort will be shared with NMFS.

IX. **ANTICIPATED IMPACT ON HABITAT**

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

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

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

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

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

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

XI. **MITIGATION MEASURES**

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

Marine mammals are known to occur in the proposed survey area. To minimize the likelihood that impacts would occur to the species and stocks, airgun operations would be conducted in accordance with
mitigation measures that are an integral part of the planned activity. The procedures described here are based on protocols used during previous L-DEO seismic research cruises as approved by NMFS, and on best practices recommended in Richardson et al. (1995), Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013a), Wright (2014), Wright and Cosentino (2015), and Acosta et al. (2017). Ultimately, L-DEO would follow monitoring and mitigation measures required by the IHA and ITS.

### Planning Phase

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

1. **Energy Source**—Part of the considerations for the proposed marine seismic survey was to evaluate whether the research objectives could be met with a smaller energy source. The scientific objectives for the proposed survey could not be met using smaller sources, as 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.

2. **Survey Location and Timing**—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), 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 (summer and fall).

   The Andreanof segment of the Aleutian Arc is the best location to study the fundamental processes that form oceanic-arc crust. The crust at the segment 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.

3. **Mitigation Zones**—During the planning phase, mitigation zones for the proposed 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 proposed survey would acquire data with an 18- or 36-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.

4. The thresholds for permanent threshold shift (PTS) onset or Level A Harassment (injury) for marine mammals for impulsive sounds use dual metrics of cumulative sound exposure level (SEL$_{cum}$ over 24 hours) and peak sound pressure levels (SPL$_{flat}$). Different thresholds are provided for the various hearing groups, including low-frequency (LF) cetaceans (e.g., baleen whales), mid-frequency (MF) cetaceans (e.g., most delphinids), high-frequency (HF) cetaceans (e.g., harbor porpoise and *Kogia* spp.), phocids underwater (PW), and otariids/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). Enforcement of mitigation zones via shut downs would be implemented during operations, as noted below.

### Mitigation During Operations

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

**Shut-down Procedures**

The operating airgun(s) would be shut down if a marine mammal is seen within or approaching the EZ, except for designated animals for which shut down has been waived (e.g., bow-riding dolphins). Following a shut down, airgun activity would not resume until the marine mammal has cleared the EZ. The animal would be considered to have cleared the EZ if

- it is visually observed to have left the EZ, or
- it has not been seen within the EZ for 15 min in the case of small odontocetes and pinnipeds, or
- it has not been seen within the EZ for 30 min in the case of mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, and beaked whales.

The airgun array would be ramped up gradually after a shut down for a marine mammal. Ramp-up procedures are described below.

**Ramp-up Procedures**

A ramp-up procedure would be followed when the airgun array begins operating after a specified period without airgun operations. It is proposed that, for the present survey, this period would be 30 min, as long as PSOs have maintained constant visual and acoustic observations and no detections within the EZ have occurred. Ramp up would not occur if a marine mammal has not cleared the EZ as described earlier. Ramp up would begin with the smallest airgun in the array (40 in$^3$). Ramp-up would begin by activating a single airgun of the smallest volume in the array and shall continue in stages by doubling the number of active elements at the commencement of each stage, with each stage of approximately the same duration. Airguns would be added in a sequence such that the source level of the array would increase in steps not exceeding 6 dB per 5-min period.
During ramp up, the PSOs would monitor the EZ, and if marine mammals are sighted, a shut down would be implemented as though the full array were operational. Ramp up would not commence at night or during poor visibility unless the EZ has been monitored visually and PAM has occurred for 30 min prior to the start of operations and no marine mammal detections occurred during that period.

**XII. PLAN OF COOPERATION**

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

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

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

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

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

Not applicable. The proposed activity would take place in the North Pacific Ocean and southern Bering Sea, and no activities would take place in traditional Arctic subsistence hunting area.

**XIII. MONITORING AND REPORTING PLAN**

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

L-DEO proposes to sponsor marine mammal monitoring during the present project, in order to implement the proposed mitigation measures that require real-time monitoring and to satisfy the expected monitoring requirements of the IHA. L-DEO’s proposed Monitoring Plan is described below. L-DEO understands that this Monitoring Plan would be subject to review by NMFS and that refinements may be required. The monitoring work described here has been planned as a self-contained project independent of any other related monitoring projects that may be occurring simultaneously in the same regions. L-DEO is prepared to discuss coordination of its monitoring program with any related work that might be done by other groups insofar as this is practical and desirable.

**Vessel-based Visual Monitoring**

Observations by PSOs would take place during daytime airgun operations and nighttime start ups of the airguns. Airgun operations would be shut down when marine mammals are observed within, or about to enter, designated EZs [see § XI above] where there is concern about potential effects on hearing or other physical effects. PSOs would also watch for marine mammals near the seismic vessel for at least 30 min
XIII. Monitoring and Reporting Plan

prior to the planned start of airgun operations. Observations would also be made during daytime periods when R/V Langseth is underway without seismic operations, such as during transits. PSOs would also watch for any potential impacts of the acoustic sources on fish.

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

R/V Langseth is a suitable platform for marine mammal observations. When stationed on the observation platform, the eye level would be ~21.5 m above sea level, and the observer would have a good view around the entire vessel. During daytime, the PSVO(s) would scan the area around the vessel systematically with reticle binoculars (e.g., 7x50 Fujinon), Big-eye binoculars (25x150), and with the naked eye. During darkness, night vision devices (NVDs) would be available (ITT F500 Series Generation 3 binocular-image intensifier or equivalent), when required.

Passive Acoustic Monitoring

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

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

The towed hydrophones would ideally be monitored 24 h per day while at the seismic survey areas during airgun operations, and during most periods when R/V Langseth is underway while the airguns are not operating. However, PAM may not be possible if damage occurs to the array or back-up systems during operations. One PSO would monitor the acoustic detection system at any one time, by listening to the signals from two channels via headphones and/or speakers and watching the real-time spectrographic display for frequency ranges produced by cetaceans. The PSO monitoring the acoustical data referred to as the PSAO, would be on shift for 1–6 h at a time. All observers would be expected to rotate through the PAM position, although the most experienced with acoustics would be on PAM duty more frequently.
When a vocalization is detected while visual observations are in progress, the PSAO would contact the PSVO immediately, to alert him/her to the presence of cetaceans (if they have not already been seen), and to allow a shut down to be initiated, if required. The information regarding the call would be entered into a database. The data to be entered include an acoustic encounter identification number, whether it was linked with a visual sighting, date, time when first and last heard and whenever any additional information was recorded, position and water depth when first detected, bearing if determinable, species or species group (e.g., unidentified dolphin, sperm whale), types and nature of sounds heard (e.g., clicks, continuous, sporadic, whistles, creaks, burst pulses, strength of signal, etc.), and any other notable information. The acoustic detection could also be recorded for further analysis.

**PSO Data and Documentation**

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

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

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

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

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

Results from the vessel-based observations would provide

1. the basis for real-time mitigation (airgun shut down);
2. information needed to estimate the number of marine mammals potentially taken by harassment, which must be reported to NMFS;
3. data on the occurrence, distribution, and activities of marine mammals in the area where the seismic study is conducted;
4. information to compare the distance and distribution of marine mammals relative to the source vessel at times with and without seismic activity;
5. data on the behavior and movement patterns of marine mammals seen at times with and without seismic activity; and
6. any observations of fish potentially affected by the sound sources.
A report would be submitted to NMFS and NSF within 90 days after the end of the cruise. The report would describe the operations that were conducted and sightings of marine mammals near the operations. The report would provide full documentation of methods, results, and interpretation pertaining to all monitoring. The 90-day report would summarize the dates and locations of seismic operations, all marine mammal (dates, times, locations, activities, associated seismic survey activities), and any observations of fish potentially affected by the sound sources. The report would also include estimates of the number and nature of exposures that could result in “takes” of marine mammals by harassment or in other ways.

**XIV. COORDINATING RESEARCH TO REDUCE AND EVALUATE INCIDENTAL TAKE**

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

L-DEO and NSF would coordinate the planned marine mammal monitoring program associated with the seismic survey with other parties that may have interest in this area. L-DEO and NSF would coordinate with applicable U.S. agencies (e.g., NMFS and USFWS) and would comply with their requirements.

**XV. LITERATURE CITED**


XV. Literature Cited


Guerra, M., P.J. Dugan, D.W. Ponirakis, M. Popescu, Y. Shiu, and C.W. Clark. 2016. High-resolution analysis of seismic airgun impulses and their reverberant field as contributors to an acoustic environment.  *In:


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NMFS. 2013b. Effects of oil and gas activities in the Arctic Ocean: Supplemental draft environmental impact statement. U.S. Dept. of Commer. NOAA. NMFS, Office of Protected Resources.


NSF (National Science Foundation). 2012. Record of Decision for marine seismic research funded by the National Science Foundation.


LIST OF APPENDICES

APPENDIX A: DETERMINATION OF MITIGATION ZONES

APPENDIX B: MARINE MAMMAL DENSITIES

APPENDIX C: MARINE MAMMAL TAKE CALCULATIONS

APPENDIX D: ENSONIFIED AREAS FOR MARINE MAMMAL TAKE CALCULATIONS
APPENDIX A: DETERMINATION OF MITIGATION ZONES
APPENDIX A: DETERMINATION OF MITIGATION ZONES

During the planning phase, mitigation zones for the proposed marine seismic survey were calculated based on 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. 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, using 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 can be used to derive mitigation radii.

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\(^2\) 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 radii at 160 dB\(_{\text{rms}}\) are obtained directly from the empirical data from Crone et al. (2014) at 11 km (Table A-1; see Addendum). Likewise, the 175 dB\(_{\text{rms}}\) 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).

**Table A-3.** Level B. Predicted distances to which sound levels ≥160-dB and ≥175-dB re 1 μPa\(_{\text{rms}}\) 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, which is included for consistency with the Draft EA.

<table>
<thead>
<tr>
<th>Source and Volume</th>
<th>Tow Depth (m)</th>
<th>Water Depth (m)</th>
<th>Predicted distances (in m) to the 160-dB Received Sound Level</th>
<th>Predicted distances (in m) to the 175-dB Received Sound Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 strings, 18 airguns, 3300 in(^3)</td>
<td>9</td>
<td>&gt;1000 m</td>
<td>3,562(^1)</td>
<td>775(^1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;100 m</td>
<td>3,939(^2)</td>
<td>1,057(^2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;100 m</td>
<td>5,263(^2)</td>
<td>1,633(^2)</td>
</tr>
<tr>
<td>4 strings, 36 airguns, 6600 in(^3)</td>
<td>9</td>
<td>&gt;1000 m</td>
<td>5,629(^1)</td>
<td>1,618(^1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;100 m</td>
<td>8,233(^3)</td>
<td>2,210(^3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;100 m</td>
<td>11,000(^3)</td>
<td>3,412(^3)</td>
</tr>
</tbody>
</table>

\(^1\)Distance based on L-DEO model results. \(^2\)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. \(^3\)Based on empirical data from Crone et al. (2014); see Appendix A for details.

\(^2\)L-DEO surveys off the Yucatán Peninsula in 2004 (Barton et al. 2006; Diebold et al. 2006), in the Gulf of Mexico in 2008 (Tolstoy et al. 2009; Diebold et al. 2010), off Washington and Oregon in 2012 (Crone et al. 2014), and off New Jersey in 2014 and 2015 (Crone et al. 2017).
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.
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-3) 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.

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.
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<sub>sum</sub> 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 20log<sub>10</sub>(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).

**Figure A-3.** Auditory weighting functions for five marine mammal hearing groups from the NMFS Technical Guidance.
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_{cumm} threshold is the largest.

<table>
<thead>
<tr>
<th>SEL_{cumm} Threshold</th>
<th>LF</th>
<th>MF</th>
<th>HF</th>
<th>PW</th>
<th>OW</th>
<th>Turtles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radial Distance (m)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(no weighting function)</td>
<td>307.1047</td>
<td>241.9511</td>
<td>7789</td>
<td>241.9511</td>
<td>25.3278</td>
<td>22.5598</td>
</tr>
<tr>
<td>Modified Farfield SEL*</td>
<td>232.7457</td>
<td>232.6746</td>
<td>232.8296</td>
<td>232.6746</td>
<td>231.0719</td>
<td>231.0667</td>
</tr>
<tr>
<td>Radial Distance (m)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(with weighting function)</td>
<td>77.331</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
<tr>
<td>Adjustment (dB)</td>
<td>-11.98</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
</tbody>
</table>

* 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_{cumm}, and the distances to the PTS thresholds for the 36-airgun array are shown in Table A-3. Figure A-3 shows the impact of weighting functions by hearing group. Figure A-4 shows the modeled amplitude spectral density of the 36-airgun array farfield signature. Figures A-5–A-7 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure A-8 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans. The thresholds for Peak SPL_{flat} for the 36-airgun array, as well as the distances to the PTS thresholds, are shown in Table A-4. Figures A-9–A-11 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_{cumm}, and the distances to the PTS thresholds for the 18-airgun array are shown in Table A-7. Figure A-12 shows the modeled amplitude spectral density of the 36-airgun array farfield signature. Figures A-13–A-15 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure A-16 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans. The thresholds for Peak SPL_{flat} for the 18-airgun array, as well as the distances to the PTS thresholds, are shown in Table A-8. Figures A-17–A-19 show the modeled received sound levels to the Peak SPL_{flat} thresholds, for a single shot. A summary of the Level A threshold distances are shown in Table A-9.
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, 6,600 cu.in, 36 element airgun source array @ a 9 m tow depth

**PROJECT CONTACT**

### STEP 2: WEIGHTING FACTOR ADJUSTMENT

<table>
<thead>
<tr>
<th>Weighting Factor Adjustment (kHz)</th>
<th>NA</th>
<th>Override WFA: Using LDEO modeling</th>
</tr>
</thead>
<tbody>
<tr>
<td>† Broadband: 99% frequency contour percentile (kHz) OR Narrowband: frequency (kHz); For appropriate default WFA: See INTRODUCTION tab</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

† 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

#### SOURCE VELOCITY (meters/second)

- Wideband: 95% frequency contour percentile (kHz)
- Narrowband: frequency (kHz)

#### SOURCE VELOCITY (meters/second)

- Wideband: 95% frequency contour percentile (kHz)
- Narrowband: frequency (kHz)

#### RESULTANT ISOPLETHS*

<table>
<thead>
<tr>
<th>Hearing Group</th>
<th>SEL (dB)</th>
<th>PTS SEL (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-Frequency Cetaceans</td>
<td>9.0</td>
<td>0.9</td>
</tr>
<tr>
<td>Mid-Frequency Cetaceans</td>
<td>15.5</td>
<td>9.9</td>
</tr>
<tr>
<td>High-Frequency Cetaceans</td>
<td>0.0</td>
<td>0.0</td>
</tr>
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<td>Phocid Pinnipeds</td>
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</tr>
<tr>
<td>Otariid Pinnipeds</td>
<td>0.0</td>
<td>12.8</td>
</tr>
<tr>
<td>Sea Turtles</td>
<td>0.0</td>
<td>12.8</td>
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</table>

#### WEIGHTING FUNCTION CALCULATIONS

<table>
<thead>
<tr>
<th>Weighting Function Parameters</th>
<th>Low-Frequency Cetaceans</th>
<th>Mid-Frequency Cetaceans</th>
<th>High-Frequency Cetaceans</th>
<th>Phocid Pinnipeds</th>
<th>Otariid Pinnipeds</th>
<th>Sea Turtles</th>
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<tbody>
<tr>
<td>a</td>
<td>1</td>
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<td>c</td>
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<td>0.94</td>
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<td>Adjustment (dB)</td>
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<td>-66.22</td>
<td>-25.70</td>
<td>-32.77</td>
<td>-3.98</td>
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</table>

† 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 $20 \times \log_{10}$ (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-5).
FIGURE A-4. 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-5. 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 20log10(radial distance).
FIGURE A-6. Modeled received sound levels (SELS) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 183–185-dB SEL isopleths (307.1 and 242.0 m, respectively).

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 203-dB SEL isopleth (25.3 m) and 204-dB SEL isopleth (22.6 m).
FIGURE A-8. 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\(_{\text{peak}}\)) for impulsive sources for marine mammals and predicted distances to Level A thresholds for various marine mammal hearing groups that could be received from the 36-airgun array during the proposed survey of the Aleutian Arc.

<table>
<thead>
<tr>
<th>Hearing Group</th>
<th>Low-Frequency Cetaceans</th>
<th>Mid-Frequency Cetaceans</th>
<th>High-Frequency Cetaceans</th>
<th>Phocid Pinnipeds</th>
<th>Otariid Pinnipeds/Sea Otters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Threshold</td>
<td>219</td>
<td>230</td>
<td>202</td>
<td>218</td>
<td>232</td>
</tr>
<tr>
<td>Radial Distance to Threshold (m)</td>
<td>38.78</td>
<td>13.75</td>
<td>235.43</td>
<td>42.17</td>
<td>10.87</td>
</tr>
<tr>
<td>PTS Peak Isopleth (Radius) to Threshold (m)</td>
<td>38.78</td>
<td>13.75</td>
<td>229.15</td>
<td>42.12</td>
<td>10.87</td>
</tr>
</tbody>
</table>
FIGURE A-9. 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-10. 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).
Appendix A

FIGURE A-11. 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 m¹. 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.

<table>
<thead>
<tr>
<th>Hearing Group</th>
<th>LF Cetaceans</th>
<th>MF Cetaceans</th>
<th>HF Cetaceans</th>
<th>Phocid Pinnipeds</th>
<th>Otariid Pinnipeds/Otters</th>
<th>Sea Turtles</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTS SEL_{cum}</td>
<td>376.0</td>
<td>0</td>
<td>0.9</td>
<td>9.9</td>
<td>0</td>
<td>12.8</td>
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<tr>
<td>PTS Peak</td>
<td>38.8</td>
<td>13.8</td>
<td>229.2</td>
<td>42.1</td>
<td>10.9</td>
<td>10.9</td>
</tr>
</tbody>
</table>

TABLE A-6. Results for single shot SEL source level modeling for the 18-airgun with and without applying weighting function to the various hearing groups. The modified farfield signature is estimated using the distance from the source array geometrical center to where the SEL_{cum} threshold is the largest. A propagation of 20 log_{10} (Radial distance) is used to estimate the modified farfield SEL.

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

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

<table>
<thead>
<tr>
<th>PROJECT TITLE</th>
<th>R/V Langseth</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROJECT/SOURCE INFORMATION</td>
<td>R/V Langseth - 2 strings 3300 cu.in 18 airgun array @ a 9 m tow depth</td>
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<tr>
<td>PROJECT CONTACT</td>
<td></td>
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</tbody>
</table>

STEP 2: WEIGHTING FACTOR ADJUSTMENT

<table>
<thead>
<tr>
<th>Weighting Factor Adjustment (kHz)^†</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Override WFA: Using LDEO modeling</td>
<td></td>
</tr>
</tbody>
</table>

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

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-12).

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FIGURE A-12. Modeled amplitude spectral density of the 18-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), Otariid Pinnipeds (OP), and sea turtles.

FIGURE A-13. Modeled received sound levels (SEls) in deep water from the 18-airgun array 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 (3970 m).
FIGURE A-14. Modeled received sound levels (SELs) in deep water from the 18-airgun array at a 9-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183–185 dB isopleths.

FIGURE A-15. Modeled received sound levels (SELs) in deep water from the 18-airgun array at a 9-m tow depth. The plot provides the distance from the geometrical center of the source array to the 203 dB isopleth.
Figure A-16. 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 the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL cum isopleth for one shot.

Figure A-17. Modeled deep-water received Peak SPL from the 18-airgun array at a 9-m tow depth. The plot provides the radial distance from the source geometrical center to the 202-dB Peak isopleth.
FIGURE A-18. Modeled deep-water received Peak SPL from the 18-airgun array at a 9-m tow depth. The plot provides the radial distances from the source geometrical center to the 218- and 219 dB Peak isopleths.

FIGURE A-19. Modeled deep-water received Peak SPL from the 18-airgun array at a 9-m tow depth. The plot provides the radial distances from the source geometrical center to the 230- and 232-dB Peak isopleths.
TABLE A-8. NMFS Level A acoustic thresholds (Peak SPL\textsubscript{flat}) for impulsive sources for marine mammals and predicted distances to Level A thresholds for various marine mammal hearing groups that could be received from the 18-airgun array during the proposed seismic survey of the Aleutian Arc.

<table>
<thead>
<tr>
<th>Hearing Group</th>
<th>LF Cetaceans</th>
<th>MF Cetaceans</th>
<th>HF Cetaceans</th>
<th>Phocid Pinnipeds</th>
<th>Otariid Pinnipeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Threshold</td>
<td>219</td>
<td>230</td>
<td>202</td>
<td>218</td>
<td>232</td>
</tr>
<tr>
<td>Radial Distance to Threshold (m)</td>
<td>23.268</td>
<td>11.198</td>
<td>118.955</td>
<td>25.217</td>
<td>9.919</td>
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<tr>
<td>PTS Peak Isopleth (Radius) to Threshold (m)</td>
<td>246.335</td>
<td>250.983</td>
<td>243.641</td>
<td>246.034</td>
<td>251.929</td>
</tr>
</tbody>
</table>

TABLE A-9. Level A threshold distances for different hearing groups for the 18-airgun array and a shot interval of 50 m\textsuperscript{1}. As required by NMFS (2016a, 2018), the largest distance (in bold) of the dual criteria (SEL\textsubscript{cum} or Peak SPL\textsubscript{flat}) was used to calculate Level A takes and threshold distances.

<table>
<thead>
<tr>
<th>Level A Threshold Distances (m) for Various Hearing Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>PTS SEL\textsubscript{cum}</td>
</tr>
<tr>
<td>PTS Peak</td>
</tr>
</tbody>
</table>

Literature Cited


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\(_{\text{RMS}}\) and 160 dB\(_{\text{SEL}}\) 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.

********

*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 (\(T_w\)), 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.

*******

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The entire 160 dBSEL 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 160 dBSEL mitigation radius distance would be well defined at a maximum of 8192 m, but that the 160 dBRMS would be close to ~11 km (Fig. 1). For a few shots along this profile, the 160 dBRMS 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 dBRMS levels up to a distance of ~11 km (~133% of the length of the streamer). However, the stable 160 dBSEL levels across this interval would support an extrapolated value of not much more than 11 km for the 160 dBRMS level given that the 160 dBRMS and 160 dBSEL 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 in³ 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 dBRMS measured radii for intermediate waters is 4291 m to 8233 m. The maximum 160 dBRMS measured radii, 8233 m (represented by a single shot at ~33750 from Figure 1), was selected for the 160 dBRMS 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 dBRMS and 160 dBSEL 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 dBRMS 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.

<table>
<thead>
<tr>
<th>Array</th>
<th>Water Depth (m)</th>
<th>Radii using L-DEO Modeling</th>
<th>Radii using Empirical Data (Crone et al. 2014)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Distance (m) to 160-dB_{rms} at 9 m tow depth</td>
<td>Distance (m) to 160-dB_{SEL} at 9 m tow depth</td>
</tr>
<tr>
<td>4 strings 36 airguns 6600 in³</td>
<td>&lt;100</td>
<td>22,102</td>
<td>8,192</td>
</tr>
<tr>
<td></td>
<td>100-1000</td>
<td>8,444</td>
<td>5,487</td>
</tr>
</tbody>
</table>

*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.

Literature Cited


APPENDIX B: MARINE MAMMAL DENSITIES
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). 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.

**Literature Cited**


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

<table>
<thead>
<tr>
<th>Species</th>
<th>Inshore (&lt;1000 m)</th>
<th>Slope (1000 m to Aleutian Trench)</th>
<th>Offshore (Offshore of Aleutian Trench)</th>
<th>Seamount (In Defined Seamount Areas)</th>
<th>Source</th>
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<td><strong>LF Cetaceans</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Pacific right whale</td>
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<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>DoN (2014)</td>
</tr>
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<td>Humpback whale</td>
<td>129.00</td>
<td>0.20</td>
<td>1.00</td>
<td>1.00</td>
<td>Rone et al. (2014)</td>
</tr>
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<td>Blue whale</td>
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<td>0.50</td>
<td>0.50</td>
<td>2.00</td>
<td>Rone et al. (2014)</td>
</tr>
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<td>Fin whale</td>
<td>71.00</td>
<td>14.00</td>
<td>21.00</td>
<td>5.00</td>
<td>Rone et al. (2014)</td>
</tr>
<tr>
<td>Sei whale</td>
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</tr>
<tr>
<td>Minke whale</td>
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<td>0.60</td>
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<tr>
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<tr>
<td>Sperm whale</td>
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<td>2.00</td>
<td>Rone et al. (2014)</td>
</tr>
<tr>
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<td>2.20</td>
<td>2.20</td>
<td>Waite (2003) in DoN (2009)</td>
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<td>1.42</td>
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<td>0.01</td>
<td>0.01</td>
<td>DoN (2014)</td>
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<td><strong>HF Cetaceans</strong></td>
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<td>0.00</td>
<td>0.00</td>
<td>Hobbs and Waite (2010) in DoN (2014)</td>
</tr>
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<td>Dall's porpoise</td>
<td>218.00</td>
<td>196.00</td>
<td>37.00</td>
<td>24.00</td>
<td>Rone et al. (2017)</td>
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<tr>
<td><strong>Otariid Seals</strong></td>
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<td>California sea lion</td>
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<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
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<tr>
<td>Northern fur seal</td>
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<td>4.00</td>
<td>17.00</td>
<td>6.00</td>
<td>Rone et al. (2014)</td>
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<td><strong>Phocid Seal</strong></td>
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<td>Northern elephant seal</td>
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<td>2.20</td>
<td>2.20</td>
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<td>DoN (2014)</td>
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<td>0.01</td>
<td>0.01</td>
<td>DoN (2014)</td>
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</table>
APPENDIX C: MARINE MAMMAL TAKE CALCULATIONS
# 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.

<table>
<thead>
<tr>
<th>Marine Mammal</th>
<th>Estimated Density (#/km²)</th>
<th>Level B (160 dB) Daily Ensonified Area (km²)</th>
<th>Level A Daily Ensonified Area (km²)</th>
<th>% of Pop. (Level B + Level A Takes)</th>
<th>Requested Take Authorization¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species</td>
<td>Shallow &lt;100 m</td>
<td>Intermediate 100-1000 m</td>
<td>Deep &gt;1000 m</td>
<td>Regional Population Size</td>
<td>Shallow &lt;100 m</td>
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<td>LF Cetaceans</td>
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</tr>
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<td>Humpback whale</td>
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<td>Blue whale</td>
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<td>0.0005000</td>
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<tr>
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<td>0.0710000</td>
<td>0.0210000</td>
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</tr>
<tr>
<td>Sei whale</td>
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<td>0.0001000</td>
<td>0.0001000</td>
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<tr>
<td>Minke whale</td>
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<td>0.0006000</td>
<td>0.0006000</td>
<td>20,000</td>
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</tr>
<tr>
<td>Gray whale</td>
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<td>0.0485700</td>
<td>0.0485700</td>
<td>26,960</td>
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<tr>
<td>MF Cetaceans</td>
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</tr>
<tr>
<td>Sperm whale</td>
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<td>0.0001000</td>
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<tr>
<td>Killer whale</td>
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<td>0.0050000</td>
<td>0.0020000</td>
<td>5,000</td>
<td>289</td>
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<tr>
<td>Pacific white-sided dolphin</td>
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<tr>
<td>Cuvier’s beaked dolphin</td>
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<td>3,274</td>
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<tr>
<td>Baird’s beaked dolphin</td>
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<td>0.0005000</td>
<td>0.0005000</td>
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<td>Stejneger’s beaked whale</td>
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<td>0.0000100</td>
<td>0.0001420</td>
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<td>Northern right whale dolphin</td>
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<td>Risso’s dolphin</td>
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<td>0.0000100</td>
<td>0.0000100</td>
<td>838,000</td>
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<tr>
<td>HF Cetaceans</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Harbor Porpoise</td>
<td>0.0473000</td>
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<td>0.0000000</td>
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<tr>
<td>Dall’s porpoise</td>
<td>0.2180000</td>
<td>0.2180000</td>
<td>0.0370000</td>
<td>1,186,000</td>
<td>289</td>
</tr>
<tr>
<td>Otariid Seals</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steller sea lion</td>
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<td>0.0098000</td>
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<td>Northern fur seal</td>
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<td>0.0150000</td>
<td>0.0170000</td>
<td>1,100,000</td>
<td>289</td>
</tr>
<tr>
<td>Phocid Seal</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northern elephant seal</td>
<td>0.0022000</td>
<td>0.0022000</td>
<td>0.0022000</td>
<td>210,000</td>
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</tr>
<tr>
<td>Harbor seal</td>
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<td>0.0010000</td>
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<td>N.A.</td>
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<tr>
<td>Ribbon seal</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>184,697</td>
<td>289</td>
</tr>
</tbody>
</table>

¹ Takes in bold adjusted to mean group size.
Appendix D

APPENDIX D: ENSONIFIED AREAS FOR MARINE MAMMAL TAKE CALCULATIONS
**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.

<table>
<thead>
<tr>
<th>Survey Zone</th>
<th>Criteria</th>
<th>All Lines - 1 Pass</th>
<th>2nd Pass for Dip/Strike Lines</th>
<th>25% Increase</th>
<th>Relevant Isopleth (m)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Daily Ensonified Area (km²)</td>
<td>Total Survey Days</td>
<td>Daily Ensonified Area (km²)</td>
<td>Total Survey Days</td>
</tr>
<tr>
<td>Shallow (&lt;100 m)</td>
<td>160 dB</td>
<td>193.4</td>
<td>10.1</td>
<td>292.2</td>
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<tr>
<td>Intermediate (100-1000 m)</td>
<td>160 dB</td>
<td>701.5</td>
<td>10.1</td>
<td>937.3</td>
<td>6.2</td>
</tr>
<tr>
<td>Deep (&gt;1000 m)</td>
<td>160 dB</td>
<td>1,648.9</td>
<td>10.1</td>
<td>1,470.9</td>
<td>6.2</td>
</tr>
<tr>
<td>Overall</td>
<td>160 dB</td>
<td>2,543.7</td>
<td>10.1</td>
<td>2,700.4</td>
<td>6.2</td>
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</tbody>
</table>

All zones LF Cetacean 151.8 10.1 150.5 6.2 1.25 3,080.6 376.0
All zones MF Cetacean 5.5 10.1 5.5 6.2 1.25 112.4 13.8
All zones HF Cetacean 92.5 10.1 92.5 6.2 1.25 1,883.0 229.2
All zones Otariid 4.4 10.1 8.7 6.2 1.25 122.8 10.9
All zones Phocid 16.9 10.1 30.7 6.2 1.25 450.9 42.1
All zones Sea Turtle 5.1 10.1 5.1 6.2 1.25 104.3 12.8