# Draft Environmental Assessment of a Low-Energy Marine Geophysical Survey by the R/V *Roger Revelle* in the Northeastern Pacific Ocean, September 2017

Prepared for

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# ABSTRACT

Researchers from Texas A&M University (TAMU), Oregon State University (OSU), and Rutgers University (Rutgers), with funding from the U.S. National Science Foundation (NSF), propose a chief scientist training cruise that would involve low-energy seismic surveys in the northeastern Pacific Ocean off the coasts of Oregon and Washington during September 2017. The surveys would be conducted on the R/V *Roger Revelle* (Revelle), which is operated by Scripps Institution of Oceanography (SIO). The seismic surveys would use a pair of low-energy Generator-Injector (GI) airguns with a total discharge volume of ~90 in$^3$. The seismic survey would take place outside of U.S. territorial waters within the Exclusive Economic Zone (EEZ) in water depths 130–2600 m.

NSF, as the research funding and action agency, has a mission to "promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense…". The Proposed Action involves the training of early career seismic chief scientists and the collection of data to address questions about earthquake hazards and paleoclimate records in basins. The Proposed Action has been identified as a NSF program priority.

This Draft Environmental Assessment (EA) addresses NSF's requirements under the National Environmental Policy Act (NEPA) for the proposed NSF federal action. SIO, on behalf of itself, NSF, TAMU, OSU, and Rutgers, is requesting an Incidental Harassment Authorization (IHA) from the U.S. National Marine Fisheries Service (NMFS) to authorize the incidental, i.e., not intentional, harassment of small numbers of marine mammals should this occur during the seismic survey. The analysis in this document also supports the IHA application process and provides information on marine species that are not addressed by the IHA application, including seabirds, sea turtles, and fish that are listed under the U.S. Endangered Species Act (ESA), including candidate species. As analysis on endangered/threatened species was included, this document will be used to support ESA Section 7 consultations with NMFS and U.S. Fish and Wildlife Service (USFWS). Alternatives addressed in this Draft EA consist of a corresponding program at a different time with issuance of an associated IHA and the no action alternative, with no IHA and no seismic survey. This document tiers to the Programmatic Environmental Impact Statement/Overseas Environmental Impact Statement for Marine Seismic Research Funded by the National Science Foundation or Conducted by the U.S. Geological Survey (NSF-USGS 2011) and Record of Decision (NSF 2012), referred to herein as the PEIS.

Numerous species of marine mammals inhabit the proposed project area in the northeastern Pacific. Under the U.S. ESA, several of these species are listed as ***endangered***, including the North Pacific right, humpback (Central America Distinct Population Segment or DPS), sei, fin, blue, sperm, and killer whales (Southern Resident DPS). The Mexico DPS of the humpback whale could also occur in the proposed project area and is listed as ***threatened*** under the ESA. ESA-listed sea turtle species that could occur in the project area include the ***endangered*** leatherback and loggerhead turtles, and the ***threatened*** green and olive ridley turtles. ESA-listed seabirds that could be encountered in the area include the ***endangered*** short-tailed albatross and the ***threatened*** marbled murrelet and western snowy plover. In addition, several ESA-listed fish species occur in the area, including the ***threatened*** Pacific eulachon Southern DPS), the ***threatened*** green sturgeon (Southern DPS), and numerous DPSs or evolutionarily significant units (ESU) of chinook, chum, coho, and sockeye salmon, and steelhead trout.

Potential impacts of the seismic survey on the environment would be primarily a result of the operation of the pair of GI airguns. A multibeam echosounder and a sub-bottom profiler would also be operated during the surveys. Impacts from the Proposed Action would be associated with increased

underwater sound, which could result in avoidance behavior by marine mammals, sea turtles, seabirds, and fish, and other forms of disturbance. An integral part of the planned survey is a monitoring and mitigation program designed to minimize potential impacts of the proposed activities on marine animals present during the proposed cruise, and to document as much as possible, the nature and extent of any effects. Injurious impacts to marine mammals, sea turtles, and seabirds have not been proven to occur near airguns including high-energy airgun arrays, and also are not likely to be caused by the other types of sound sources to be used. However, despite the relatively low levels of sound emitted by a pair of GI airguns, a precautionary approach would still be taken. The planned monitoring and mitigation measures would reduce the possibility of injurious effects.

Protection measures designed to mitigate the potential environmental impacts to marine mammals, sea turtles, and seabirds would include the following: ramp ups; typically two, but a minimum of one dedicated observer maintaining a visual watch during all daytime airgun operations; two observers 30 min before and during ramp ups during the day; no start ups during poor visibility or at night unless at least one airgun has been operating; and shut downs when marine mammals or sea turtles are detected in or about to enter designated exclusion zones. The acoustic source would also be powered or shut down in the event an ESA-listed seabird were observed diving or foraging within the designated exclusion zones. Observers would also watch for any impacts the acoustic sources may have on fish. SIO and its contractors are committed to applying these measures in order to minimize effects on marine mammals, sea turtles, seabirds, and fish, and other environmental impacts. Survey operations would be conducted in accordance with all applicable U.S. federal regulations, including IHA and Incidental Take Statement (ITS) requirements.

With the planned monitoring and mitigation measures, unavoidable impacts to each species of marine mammal and turtle that could be encountered would be expected to be limited to short-term, localized changes in behavior and distribution near the seismic vessel. At most, effects on marine mammals may be interpreted as falling within the U.S. MMPA definition of "Level B Harassment" for those species managed by NMFS; however, NSF is required to request, and NMFS may issue, Level A take for some marine mammal species. No long-term or significant effects would be expected on individual marine mammals, sea turtles, seabirds, fish, the populations to which they belong, or their habitats.

# LIST OF ACRONYMS

| | |
|---|---|
| ~ | approximately |
| AMVER | Automated Mutual-Assistance Vessel Rescue |
| BC | British Columbia (Canada) |
| BIA | Biologically Important Areas |
| CFR | Code of Federal Regulations |
| CITES | Convention on International Trade in Endangered Species |
| CPS | Coastal Pelagic Species |
| dB | decibel |
| DPS | Distinct Population Segment |
| EA | Environmental Assessment |
| EEZ | Exclusive Economic Zone |
| EFH | Essential Fish Habitat |
| EHV | Endeavour Hydrothermal Vents |
| EIS | Environmental Impact Statement |
| ESA | (U.S.) Endangered Species Act |
| ESU | Evolutionarily Significant Units |
| EZ | Exclusion Zone |
| FM | Frequency-Modulated |
| FMP | Fishery Management Plan |
| GI | Generator-Injector |
| GIS | Geographic Information System |
| h | hour |
| HF | high frequency |
| hp | horsepower |
| Hz | Hertz |
| IHA | Incidental Harassment Authorization (under MMPA) |
| in | inch |
| ISRP | Independent Scientific Review Panel |
| ITS | Incidental Take Statement |
| IUCN | International Union for the Conservation of Nature |
| IWC | International Whaling Commission |
| kHz | kilohertz |
| km | kilometer |
| kt | knot |
| L-DEO | Lamont-Doherty Earth Observatory of Columbia University |
| LF | low frequency |
| LFA | Low-Frequency Active (Sonar) |
| m | meter |
| MBES | multibeam echosounder |
| MCS | multi-channel seismic |
| MF | mid frequency |
| MFA | Mid-Frequency Active (Sonar) |
| min | minute |
| MMPA | (U.S.) Marine Mammal Protection Act |

| | |
|---|---|
| MPA | Marine Protected Area |
| ms | millisecond |
| M/V | motor vessel |
| n.mi. | nautical mile |
| NEPA | (U.S.) National Environmental Policy Act |
| NMFS | (U.S.) National Marine Fisheries Service |
| NOAA | National Oceanic and Atmospheric Administration |
| NRC | (U.S.) National Research Council |
| NSF | National Science Foundation |
| NWR | National Wildlife Refuge |
| OAWRS | Ocean Acoustic Waveguide Remote Sensing |
| OCNMS | Olympic Coast National Marine Sanctuary |
| OEIS | Overseas Environmental Impact Statement |
| OINWR | Oregon Islands National Wildlife Refuge |
| OSU | Oregon State University |
| OW | otariid underwater |
| p or pk | peak |
| PEIS | Programmatic Environmental Impact Statement |
| PI | Principal Investigator |
| PTS | Permanent Threshold Shift |
| PSO | Protected Species Observer |
| PSVO | Protected Species Visual Observer |
| PW | phocid underwater |
| RL | Received level |
| rms | root-mean-square |
| R/V | research vessel |
| s | second |
| SBP | Sub-Bottom Profiler |
| SEL | Sound Exposure Level |
| SIO | Scripps Institution of Oceanography |
| SPL | Sound Pressure Level |
| SST | Sea Surface Temperature |
| SWFSC | Southwest Fisheries Science Center |
| TAMU | Texas A&M University |
| TTS | Temporary Threshold Shift |
| UNEP | United Nations Environment Programme |
| U.S. | United States of America |
| USC | United States Code |
| USCG | U.S. Coast Guard |
| USFWS | U.S. Fish and Wildlife Service |
| USGS | U.S. Geological Survey |
| USIO | U.S. Implementing Organization |
| USN | U.S. Navy |
| μPa | microPascal |
| vs. | versus |

# I. PURPOSE AND NEED

The purpose of this Environmental Assessment (EA) is to provide the information needed to assess the potential environmental impacts associated with the Proposed Action, which includes the use of a pair of 45-$in^3$ Generator-Injector (GI) airguns during seismic surveys. This Draft EA was prepared under the National Environmental Policy Act (NEPA) and tiers to the Final Programmatic Environmental Impact Statement (EIS)/Overseas Environmental Impact Statement (OEIS) for Marine Seismic Research funded by the National Science Foundation or Conducted by the U.S. Geological Survey (NSF and USGS 2011) and Record of Decision (NSF 2012), referred to herein as the PEIS. The Draft EA provides details of the Proposed Action at the site-specific level and addresses potential impacts of the proposed seismic surveys on marine mammals, as well as other species of concern in the area, including sea turtles, seabirds, fish, and marine invertebrates. The Draft EA will also be used in support of an application for an Incidental Harassment Authorization (IHA) from the National Marine Fisheries Service (NMFS) and Section 7 consultations under the Endangered Species Act (ESA). The requested IHA would, if issued, allow the non-intentional, non-injurious "take by harassment" of small numbers of marine mammals during the proposed seismic surveys conducted on the R/V *Revelle* by Scripps Institution of Oceanography (SIO) in the northeastern Pacific off Oregon and Washington during September 2017. Per NMFS requirement, small numbers of Level A takes will be requested for the remote possibility of low-level physiological effects; however, because of the characteristics of the Proposed Action and proposed monitoring and mitigation measures, in addition to the general avoidance by marine mammals of loud sounds, Level A takes are considered highly unlikely.

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

## Mission of NSF

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

## Purpose of and Need for the Proposed Action

As noted in the PEIS, § 1.3, NSF has a continuing need to fund seismic surveys that enable scientists to collect data essential to understanding the complex Earth processes beneath the ocean floor. The Proposed Action involves an Early Career Seismic Chief Scientist Training Cruise which aims to train scientists on how to effectively plan seismic surveys, acquire data, and manage activities at sea, and to understand the sediment and crustal structure within the Cascadia continental margin. During the cruise, high-resolution multi-channel seismic (MCS) profiles would be collected off the coast of Oregon and Washington in the northeastern Pacific. The survey region is on the active continental margin of the west coast of the U.S., where a variety of sedimentary and tectonic settings are available, which would provide many targets of geologic interest to a wide range of research cruise participants. Potential targets are the subducting plate and overlying accretionary prism offshore Oregon and Washington, as well as accretionary ridges hosting gas hydrate, the sedimentary cover around seamounts, and hemipelagic sediment containing paleo-oceanographic information on the Juan de Fuca plate. All of these targets have implications for addressing important societally relevant questions, such as earthquake hazards and the long-term history of climate change as recorded in the ocean. In addition to a training cruise and providing a critical data set for understanding the Cascadia margin, the data collected during the survey would support NSF's need to foster a better understanding of Earth processes. The Proposed Action has been identified as an NSF program priority.

## Background of NSF-funded Marine Seismic Research

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

## Regulatory Setting

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

- National Environmental Protection Act (NEPA);
- Marine Mammal Protection Act (MMPA); and
- Endangered Species Act (ESA).

# II. ALTERNATIVES INCLUDING PROPOSED ACTION

In this EA, three alternatives are evaluated: (1) the proposed seismic surveys and issuance of an associated IHA, (2) corresponding seismic surveys at an alternative time, along with issuance of an associated IHA, and (3) no action alternative. Additionally, two Alternatives were considered but were eliminated from further analysis. A summary table of the proposed action, alternatives, and alternatives eliminated from further analysis is provided at the end of this section.

## Proposed Action

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

### (1) Project Objectives and Context

Researchers from Texas A&M University (TAMU), Oregon State University (OSU), and Rutgers University (Rutgers) propose to conduct an Early Career Seismic Chief Scientist Training Cruise involving low-energy seismic surveys on the *Revelle* in the northeastern Pacific off the coasts of Oregon and Washington (Fig. 1). The proposed surveys would take place on the active continental margin of the west coast of the U.S. where a variety of sedimentary and tectonic settings are available, providing many targets of geologic interest to a wide range of research cruise participants. To achieve the program's goals, the Principal Investigators (PIs), Drs. M. Tominaga (TAMU), Drs. A. Trehu and M. Lyle (OSU), and G. Mountain (Rutgers), propose to collect low-energy, high-resolution MCS profiles. In addition to the PIs, a number of early career researchers and students would participate in the survey activities.

### (2) Proposed Activities

#### (a) Location of the Survey Activities

The surveys would take place off the Oregon continental margin out to 127.5°W and between ~43 and 46.5°N (see Fig. 1). Although the proposed activities could take place anywhere within the project area as shown in Figure 1, two survey sites have been proposed within this area—the Astoria Fan and the

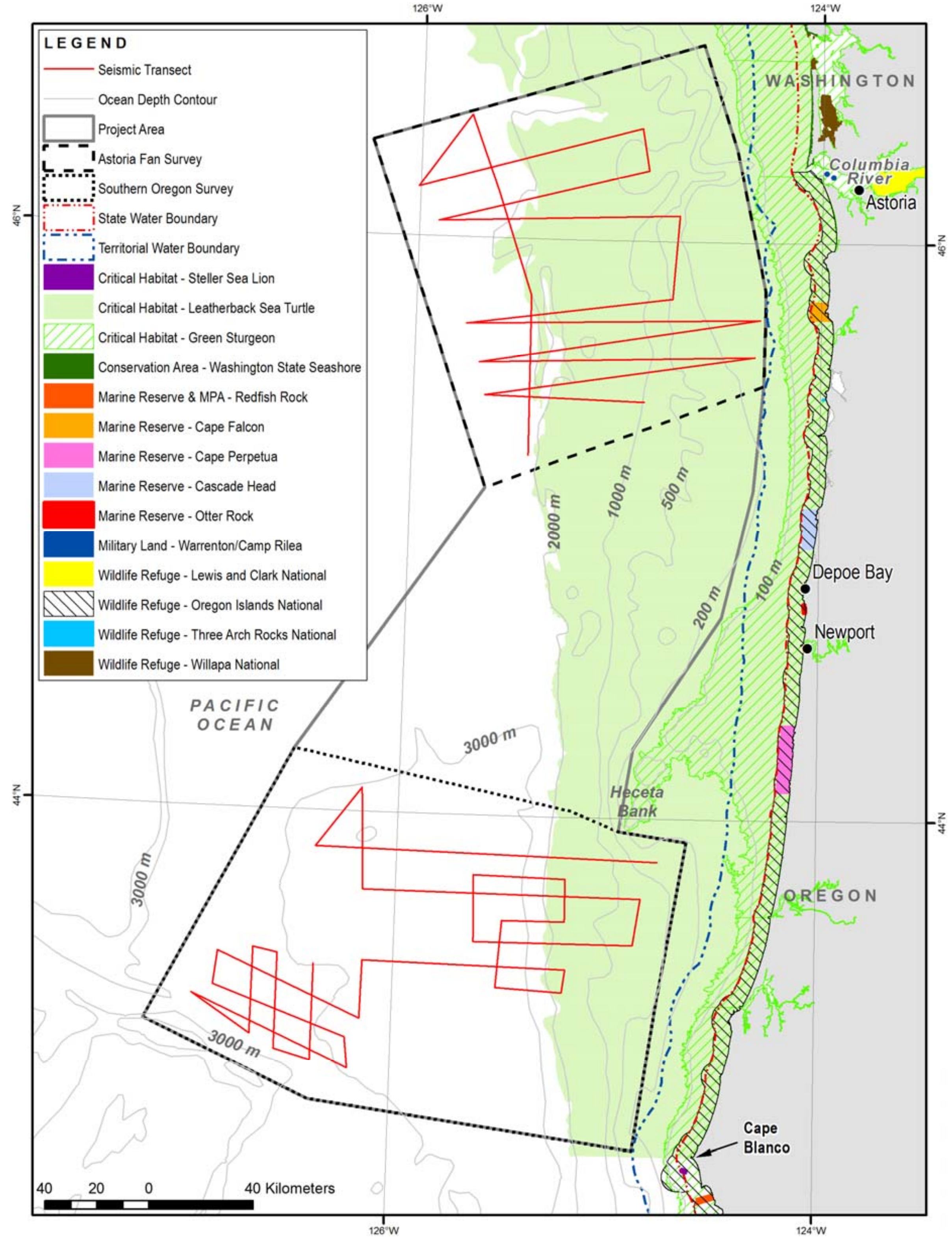

FIGURE 1. Locations of the proposed low-energy seismic surveys in the northeastern Pacific Ocean, September 2017.

Southern Oregon survey areas. Representative survey tracklines are shown in Figure 1; however, some deviation in actual track lines could be necessary for reasons such as science drivers, poor data quality, inclement weather, or mechanical issues with the research vessel and/or equipment. The seismic surveys would be conducted within the EEZ of the U.S., in water depths ranging from ~130 to 2600 m.

### (b) Description of the Activities

The procedures to be used for the seismic surveys would be similar to those used during previous seismic surveys conducted by SIO and would use conventional seismic methodology. The surveys would involve one source vessel, the *Revelle*. The *Revelle* would deploy a pair of 45-$in^3$ GI airguns as an energy source with a total volume of ~90 $in^3$. The receiving system would consist of one 800-m hydrophone streamer. As the airguns are towed along the survey lines, the hydrophone streamer would receive the returning acoustic signals and transfer the data to the on-board processing system.

Two potential survey sites off the Oregon continental margin have been proposed, and are depicted by the boxes in Fig. 1. One survey option (Astoria Fan) is located off northern Oregon off the mouth of the Columbia River and near the Astoria Canyon; the other (southern Oregon) is located off the southern Oregon margin. Each of the proposed surveys has several science targets. The southern Oregon survey includes the paleo objectives, a long plate transect that crosses Diebold Knoll, and a detailed survey of the megaslump segment of the Cascadia subduction zone, which has no previous seismic data. The Astoria Fan survey includes flexure, accretionary wedge mechanisms and gas hydrates as objectives; it covers a major seismic gap. The scientists on board would be responsible for modifying the survey to fit the allocated cruise length while meeting the project objectives, including choosing which survey or what portion of each survey to conduct.

The total line km for the Southern Oregon survey is 1013 km, ~5% of which are in intermediate water (100–1000 m), with the remainder in water deeper than 1000 m. The total length for the Astoria Fan survey is 1057 km, with ~23% of line km in intermediate water and the remainder in water >1000 m. No effort during either survey would occur in shallow water <100 m deep. The total track distance to be surveyed is estimated to be no greater than ~1057 km which is the line km of the longest survey. There would be additional seismic operations in the survey area associated with airgun testing and repeat coverage of any areas where initial data quality is sub-standard. In our calculations [see § IV(3)], 25% has been added for those additional operations.

In addition to the operations of the airgun array, a multibeam echosounder (MBES) and a sub-bottom profiler (SBP) would also be operated from the *Revelle* continuously throughout the seismic survey, but not during transits to and from the survey areas. All planned data acquisition and sampling activities would be conducted by SIO with on-board assistance by the scientists who have proposed the project. The vessel would be self-contained, and the crew would live aboard the vessel for the entire cruise.

### (c) Schedule

The *Revelle* would likely depart from Newport, OR, on or about 22 September 2017 and would return to Newport on or about 29 September. Some deviation in timing could result from unforseen events such as weather or logistical issues. Seismic operations would take ~4 to 5 days, and the transit to and from Newport would take ~2 days.

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

#### (d) Vessel Specifications

The *Revelle* has a length of 83 m, a beam of 16.0 m, and a maximum draft of 5.2 m. The ship is powered by two 3000-hp Propulsion General Electric motors and a 1180-hp azimuthing jet bow thruster. An operation speed of ~8.3–9.3 km/h (~4.5–5 kt) would be used during seismic acquisition. When not towing seismic survey gear, the *Revelle* cruises at 22.2–23.1 km/h (12–12.5 kt) and has a maximum speed of 27.8 km/h (15 kt). It has a normal operating range of ~27,780 km.

The *Revelle* would also serve as the platform from which vessel-based protected species visual observers (PSVO) would watch for marine mammals and sea turtles before and during airgun operations. The characteristics of the *Revelle* that make it suitable for visual monitoring are described in § II(3)(a).

Other details of the *Revelle* include the following:

| | |
|---|---|
| Owner: | U.S. Navy |
| Operator: | Scripps Institution of Oceanography of the University of California |
| Flag: | United States of America |
| Date Built: | 1996 |
| Gross Tonnage: | 3180 |
| Compressors for Air Guns: | Price Air Compressors, 300 cfm at 1750 psi |
| Accommodation Capacity: | 22 crew plus 37 scientists |

#### (e) Airgun Description

The *Revelle* would tow a pair of 45-in$^3$ GI airguns and an 800-m streamer containing hydrophones along predetermined lines. Seismic pulses would be emitted at intervals of ~8–10 s (20–25 m).

The generator chamber of each GI gun, the one responsible for introducing the sound pulse into the ocean, is 45 in$^3$. The larger (105 in$^3$) injector chamber injects air into the previously generated bubble to maintain its shape, and does not introduce more sound into the water. The two 45-in$^3$ GI guns would be towed 21 m behind the *Revelle*, 2 m apart side by side, at a depth of 3 m.

#### GI Airgun Specifications

| | |
|---|---|
| Energy Source | Two GI guns of 45 in$^3$ |
| Source output (downward) | 0-peak is 3.6 bar-m (230.8 dB re 1 µPa·m);<br>peak-peak is 6.6 bar-m (236.4 dB re 1 µPa·m) |
| Towing depth of energy source | 3 m |
| Air discharge volume | Approx. 90 in$^3$ |
| Dominant frequency components | 0–188 Hz |
| Gun positions used | Two inline airguns 2 m apart |
| Gun volumes at each position (in$^3$) | 45, 45 |

As the airguns are towed along the survey lines, the towed hydrophone array in the 800-m streamer would receive the reflected signals and transfer the data to the on-board processing system. Given the relatively short streamer length behind the vessel, the turning rate of the vessel with gear deployed would be much higher than the limit of 5º per minute for a seismic vessel towing a streamer of more typical length (>>l km), ~20º. Thus, the maneuverability of the vessel would not be limited much during operations.

As the dimension of the source is small (2 airguns separated by 2 m), the array can be considered as a point source. Thus, we do not expect source array effects in the near field. The source levels can thus be directly derived from the modeled farfield source signature, which is estimated using the PGS Nucleus software. In the case of small source dimension, the source levels obtained from the farfield source signature and maximum modeled source level in the near field are nearly identical.

The nominal downward-directed source levels indicated above do not represent actual sound levels that can be measured at any location in the water. Rather, they represent the level that would be found 1 m from a hypothetical point source emitting the same total amount of sound as is emitted by the combined GI airguns. The actual received level at any location in the water near the GI airguns would not exceed the source level of the strongest individual source. Actual levels experienced by any organism more than 1 m from either GI airgun would be significantly lower.

A further consideration is that the rms[1] (root mean square) received levels that are used as impact criteria for marine mammals are not directly comparable to the peak (p or 0–p) or peak to peak (p–p) values normally used to characterize source levels of airgun arrays. The measurement units used to describe airgun sources, peak or peak-to-peak decibels, are always higher than the rms decibels referred to in biological literature. A measured received sound pressure level (SPL) of 160 dB re 1 $\mu Pa_{rms}$ in the far field would typically correspond to ~170 dB re 1 $\mu Pa_{p}$ or 176–178 dB re 1 $\mu Pa_{p\text{-}p}$, as measured for the same pulse received at the same location (Greene 1997; McCauley et al. 1998, 2000). The precise difference between rms and peak or peak-to-peak values depends on the frequency content and duration of the pulse, among other factors. However, the rms level is always lower than the peak or peak-to-peak level for an airgun-type source.

### (f) Multibeam Echosounder and Sub-bottom Profilers

Along with the airgun operations, two additional acoustical data acquisition systems would be operated during the seismic survey, but not during transits. The ocean floor would be mapped with the Kongsberg EM 122 MBES and a Knudsen Chirp 3260 SBP. These sources are described in § 2.2.3.1 of the PEIS.

## (3) Monitoring and Mitigation Measures

Standard monitoring and mitigation measures for seismic surveys are described in § 2.4.4.1 of the PEIS and would occur in two phases: pre-cruise planning and during operations. The following sections describe the efforts during both stages for the proposed action.

---

[1] The rms (root mean square) pressure is an average over the pulse duration.

### (a) 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 activities. Several factors were considered during the planning phase of the proposed activities, including

***Energy Source*.—**Part of the considerations for the proposed survey was to evaluate what source level was necessary to meet the research objectives. It was decided that the scientific objectives could be met using a low-energy source consisting of two 45-$in^3$ GI guns (total volume of 90 $in^3$) at a tow depth of ~3 m. The SIO portable MCS system's energy source level is one of the smallest source levels used by the science community for conducting seismic research.

***Survey Timing*.—**The PIs worked with SIO and NSF to identify potential times to carry out the survey, taking into consideration key factors such as environmental conditions (e.g., the seasonal presence of marine mammals), weather conditions, equipment, and optimal timing for other proposed research cruises. Some marine mammal species are expected to occur in the area year-round, so altering the timing of the proposed project likely would result in no net benefits for those species.

***Mitigation Zones*.—**During the planning phase, mitigation zones for the proposed marine seismic surveys were not dervied from the farfield siganture but calculated based on modeling by Lamont-Doherty Earth Observatory (L-DEO) for both the exclusion zones (EZ) for Level A takes and safety zones (160 dB re 1µ$Pa_{rms}$) for Level B takes. Received sound levels have been predicted by L-DEO's model (Diebold et al. 2010, provided as Appendix H in the PEIS), as a function of distance from the airguns, for the two 45-$in^3$ GI guns. This modeling approach uses ray tracing for the direct wave traveling from the array to the receiver and its associated source ghost (reflection at the air-water interface in the vicinity of the array), in a constant-velocity half-space (infinite homogeneous ocean layer, unbounded by a seafloor). In addition, propagation measurements of pulses from a 36-airgun array at a tow depth of 6 m have been reported in deep water (~1600 m), intermediate water depth on the slope (~600–1100 m), and shallow water (~50 m) in the Gulf of Mexico (GoM) in 2007–2008 (Tolstoy et al. 2009; Diebold et al. 2010).

For deep and intermediate-water cases, the field measurements cannot be used readily to derive mitigation radii, as at those sites the calibration hydrophone was located at a roughly constant depth of 350–500 m, which may not intersect all the sound pressure level (SPL) isopleths at their widest point from the sea surface down to the maximum relevant water depth (~2000 m) for marine mammals. 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.

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

The proposed surveys would acquire data with two 45-in$^3$ GI guns at a tow depth of 3 m. For deep water (>1000 m), we use the deep-water radii obtained from L-DEO model results down to a maximum water depth of 2000 m (Fig. 2). The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor (multiplication) of 1.5, such that observed levels at very near offsets fall below the corrected mitigation curve (Fig. 16 in Appendix H of the PEIS). Table 1 shows the distances at which the 160- and 175-dB re 1µPa$_{\text{rms}}$ sound levels are expected to be received for the two 45-in$^3$ GI guns at 3-m tow depth. The 160-dB level is the behavioral disturbance criterion that is used to estimate anticipated Level B takes for marine mammals; a 175-dB level is used by NMFS to determine behavioral disturbance for sea turtles.

A recent retrospective analysis of acoustic propagation of *Langseth* sources in a coastal/shelf environment from the Cascadia Margin off Washington suggests that predicted (modeled) radii (using an approach similar to that used here) for *Langseth* sources were 2–3 times larger than measured in shallow water, so in fact, as expected, were very conservative (Crone et al. 2014). Similarly, preliminary analysis by Crone (2017, L-DEO, pers. comm.) of data collected during a survey off New Jersey in 2014 and 2015 confirmed that *in situ* measurements and estimates of the 160- and 180-dB distances collected by the *Langseth* hydrophone streamer were similarly 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 exclusion zones, resulting in significantly larger safety zones than necessary.

In July 2016, the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) released new technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (NMFS 2016a). The new guidance established new thresholds for permanent threshold shift (PTS) onset or Level A Harassment (injury), for marine mammal species. The new noise exposure criteria for marine mammals (Table 2) 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. Onset of PTS was assumed to be 15 dB or 6 dB higher when considering SEL$_{\text{cum}}$ and SPL$_{\text{flat}}$, respectively. For impulsive sounds, such airgun pulses, the new guidance incorporates marine mammal auditory weighting functions and dual metrics of cumulative sound exposure level (SEL$_{\text{cum}}$ over 24 hours)

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[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 2017, L-DEO, pers. comm.)

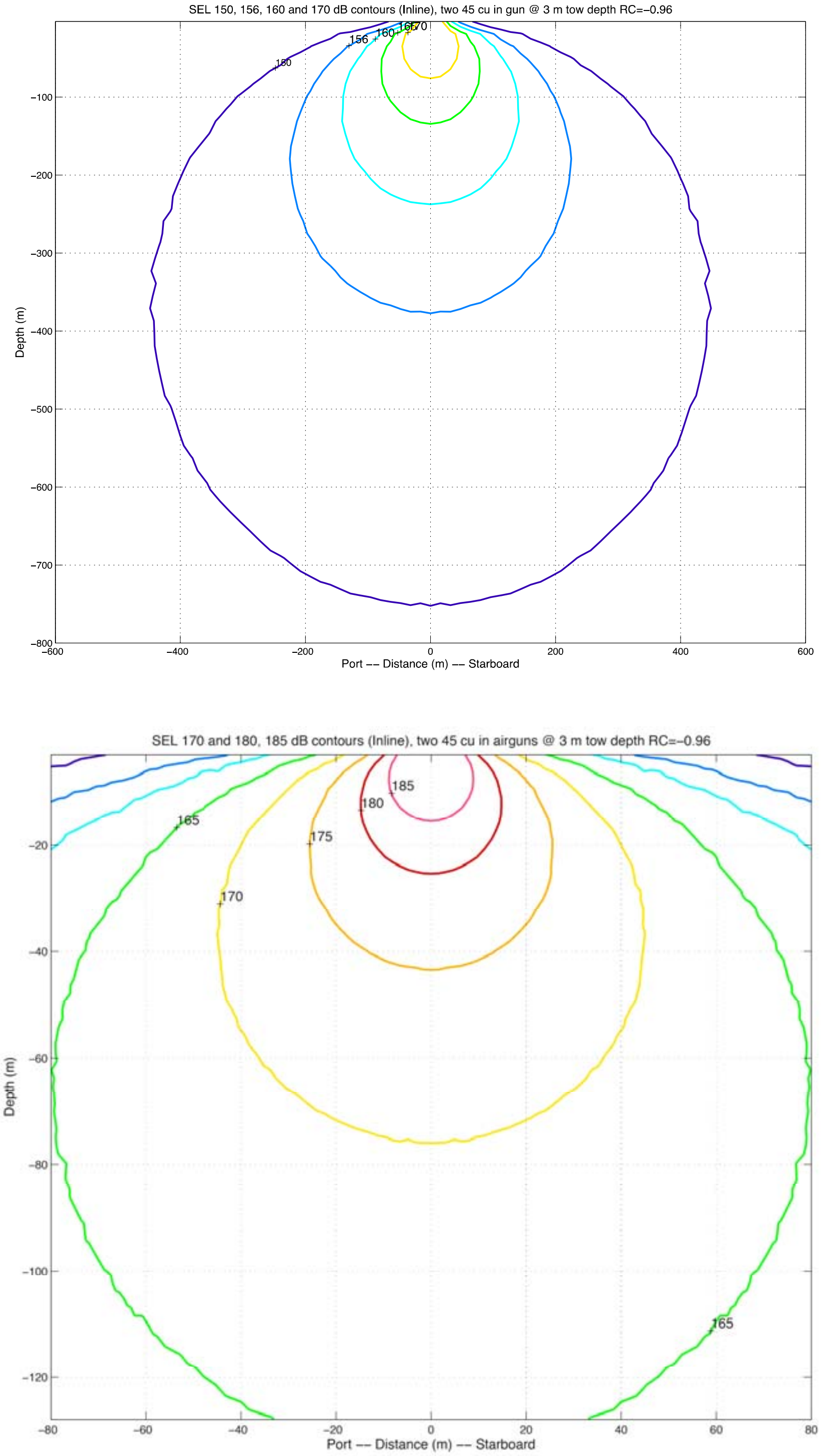


FIGURE 2. Modeled deep-water received sound exposure levels (SELs) from the two 45-in$^3$ GI guns planned for use during the proposed surveys in the northeast Pacific Ocean at a 3-m tow depth. Received rms levels (SPLs) are expected to be ~10 dB higher. The radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The lower plot is a zoomed-in version of the upper plot.

TABLE 1. Level B. Predicted distances to the 160 dB re 1 µPa$_{rms}$ and 175-dB sound levels that could be received from two 45-in$^3$ GI guns (at a tow depth of 3 m) that would be used during the seismic surveys in the northeastern Pacific during September 2017 (model results provided by L-DEO). The 160-dB criterion applies to all marine mammals; the 175-dB criterion applies to sea turtles.

| Water depth | Predicted distances (in m) to various received sound levels | |
|---|---|---|
| | **160 dB re 1 µPa$_{rms}$** | **175 dB re 1 µPa$_{rms}$** |
| >1000 m | 448[1] | 80[1] |
| 100–1000 m | 672[2] | 120[2] |

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

[2] Distance is based on L-DEO model results with a 1.5 x correction factor between deep and intermediate water depths.

and peak sound pressure levels (SPL$_{flat}$). Different thresholds are provided for the various hearing groups, including low-frequency (LF) cetaceans (e.g., baleen whales), mid-frequency (MF) cetaceans (e.g., most delphinids), high-frequency (HF) cetaceans (e.g., porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW). The distances to the PTS thresholds for the various marine mammal hearing groups have been calculated using the NMFS Techincal Guidance's companion User Spreadsheet, using simple (default) weighting factor adjustments (Table 2). As required by NMFS (2016a), the largest distance of the dual criteria (SEL$_{cum}$ or Peak SPL$_{flat}$) would be used as the EZ and for calculating takes. The new guidance did not alter the current threshold, 160 dB re 1µPa$_{rms}$, for Level B harassment (behavior).

The NSF/USGS PEIS defined a low-energy source as any towed acoustic source whose received level is ≤180 dB re 1 µPa$_{rms}$ (the Level A threshold under the former NMFS acoustic guidance) at 100 m, including any single or any two GI airguns and a single pair of clustered airguns with individual volumes of ≤250 in$^3$. In § 2.4.2 of the PEIS, Alternative B (the Preferred Alternative) conservatively applied a 100-m EZ for all low-energy acoustic sources in water depths >100 m. Consistent with the PEIS, that approach would be used here for the pair of 45-in$^3$ GI airguns. The 100-m EZ would also be used as the EZ for sea turtles, although current guidance by NMFS suggests a Level A criterion of 195 dB re 1 µPa$_{rms}$ or an EZ <14 m (9 m in deep water; 13.5 m in intermediate water) for the pair of 45-in$^3$ GI airguns (see Fig. 2). If marine mammals or sea turtles are detected in or about to enter the appropriate EZ, the airguns would be shut down immediately. Enforcement of mitigation zones via shut downs would be implemented in the Operational Phase, as noted below. A fixed 160-dB "Safety Zone" was not defined for the same suite of low-energy sources in the NSF/USGS PEIS; therefore, L-DEO model results for 45-in$^3$ GI guns are used here to determine the 160-dB radius for the pair of 45-in$^3$ GI airguns (see Table 1).

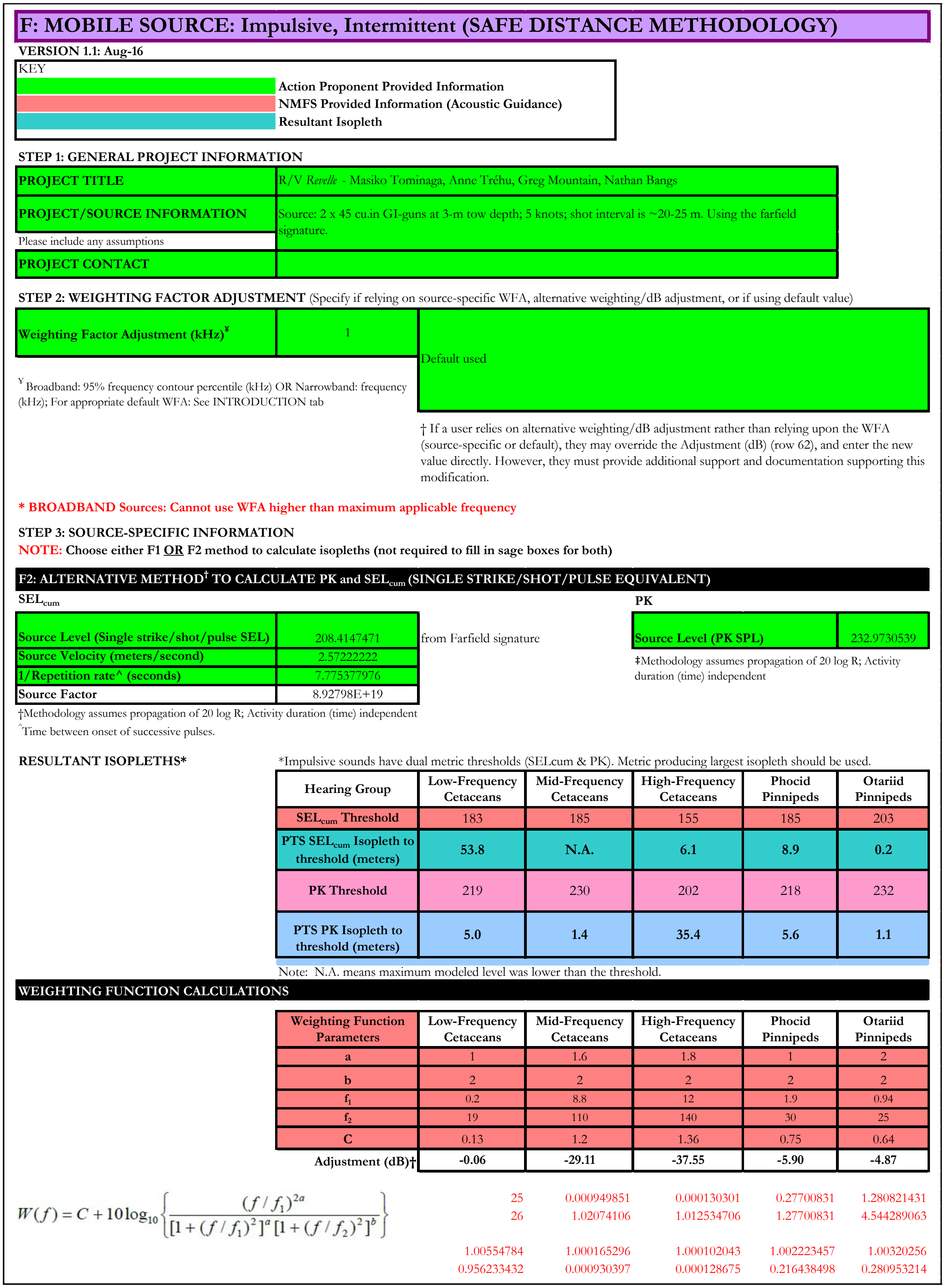
The Draft EA has been prepared in accordance with the current NOAA acoustic practices, and the procedures are based on best practices noted by Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013a), Wright (2014), and Wright and Cosentino (2015).

### (b) Operational Phase

SIO's operational mitigation measures are described in § 2.4.1.1 of the PEIS and include

- monitoring by PSVOs for marine species (including marine mammals, sea turtles, ESA-listed seabirds diving near the vessel, and observing for potential impacts of acoustic sources on fish);

TABLE 2. Level A. NMFS Level A acoustic thresholds 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 airgun arrays during the proposed seismic surveys in the southwest Pacific Ocean.



**F: MOBILE SOURCE: Impulsive, Intermittent (SAFE DISTANCE METHODOLOGY)**

**VERSION 1.1: Aug-16**

KEY

| | |
|---|---|
| 🟩 | **Action Proponent Provided Information** |
| 🟥 | **NMFS Provided Information (Acoustic Guidance)** |
| 🟦 | **Resultant Isopleth** |

**STEP 1: GENERAL PROJECT INFORMATION**

| | |
|---|---|
| **PROJECT TITLE** | R/V *Revelle* - Masiko Tominaga, Anne Tréhu, Greg Mountain, Nathan Bangs |
| **PROJECT/SOURCE INFORMATION**<br>Please include any assumptions | Source: 2 x 45 cu.in GI-guns at 3-m tow depth; 5 knots; shot interval is ~20-25 m. Using the farfield signature. |
| **PROJECT CONTACT** | |

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

| | | |
|---|---|---|
| **Weighting Factor Adjustment (kHz)¥** | 1 | Default used |

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

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

*** BROADBAND Sources: Cannot use WFA higher than maximum applicable frequency**

**STEP 3: SOURCE-SPECIFIC INFORMATION**

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

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

**SEL$_{cum}$**

| | | |
|---|---|---|
| **Source Level (Single strike/shot/pulse SEL)** | 208.4147471 | from Farfield signature |
| **Source Velocity (meters/second)** | 2.57222222 | |
| **1/Repetition rate^ (seconds)** | 7.775377976 | |
| **Source Factor** | 8.92798E+19 | |

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

^Time between onset of successive pulses.

**PK**

| | |
|---|---|
| **Source Level (PK SPL)** | 232.9730539 |

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

**RESULTANT ISOPLETHS***

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

| **Hearing Group** | **Low-Frequency Cetaceans** | **Mid-Frequency Cetaceans** | **High-Frequency Cetaceans** | **Phocid Pinnipeds** | **Otariid Pinnipeds** |
|---|---|---|---|---|---|
| **SEL$_{cum}$ Threshold** | 183 | 185 | 155 | 185 | 203 |
| **PTS SEL$_{cum}$ Isopleth to threshold (meters)** | **53.8** | **N.A.** | **6.1** | **8.9** | **0.2** |
| **PK Threshold** | 219 | 230 | 202 | 218 | 232 |
| **PTS PK Isopleth to threshold (meters)** | **5.0** | **1.4** | **35.4** | **5.6** | **1.1** |

Note: N.A. means maximum modeled level was lower than the threshold.

**WEIGHTING FUNCTION CALCULATIONS**

| **Weighting Function Parameters** | **Low-Frequency Cetaceans** | **Mid-Frequency Cetaceans** | **High-Frequency Cetaceans** | **Phocid Pinnipeds** | **Otariid Pinnipeds** |
|---|---|---|---|---|---|
| **a** | 1 | 1.6 | 1.8 | 1 | 2 |
| **b** | 2 | 2 | 2 | 2 | 2 |
| **f$_1$** | 0.2 | 8.8 | 12 | 1.9 | 0.94 |
| **f$_2$** | 19 | 110 | 140 | 30 | 25 |
| **C** | 0.13 | 1.2 | 1.36 | 0.75 | 0.64 |
| **Adjustment (dB)†** | **-0.06** | **-29.11** | **-37.55** | **-5.90** | **-4.87** |

$$W(f) = C + 10\log_{10}\left\{\frac{(f/f_1)^{2a}}{[1+(f/f_1)^2]^a[1+(f/f_2)^2]^b}\right\}$$

| | | | | |
|---|---|---|---|---|
| 25 | 0.000949851 | 0.000130301 | 0.27700831 | 1.280821431 |
| 26 | 1.02074106 | 1.012534706 | 1.27700831 | 4.544289063 |
| 1.00554784 | 1.000165296 | 1.000102043 | 1.002223457 | 1.00320256 |
| 0.956233432 | 0.000930397 | 0.000128675 | 0.216438498 | 0.280953214 |

- PSVO data and documentation; and
- mitigation during operations (speed or course alteration; shut-down and ramp-up procedures; and avoidance of concentrations of large whales).

The proposed operational mitigation measures are standard for all low energy seismic cruises, per the PEIS, and therefore are not discussed further here. Special mitigation measures were considered for this cruise. It is unlikely that concentrations of large whales would be encountered, but if so, they would be avoided.

Marine mammals and sea turtles are known to occur in the proposed survey area. However, the number of individual animals expected to be approached closely during the proposed activities would be relatively small in relation to regional population sizes. With the proposed monitoring and mitigation provisions, potential effects on most if not all individuals would be expected to be limited to minor behavioral disturbance. Those potential effects would be expected to have negligible impacts both on individual marine mammals and on the associated species and stocks. Survey operations would be conducted in accordance with all applicable U.S. federal regulations, including IHA and ITS requirements.

## Alternative 1: Alternative Survey Timing

An alternative to issuing the IHA for the period requested and to conducting the project then would be to conduct the project at an alternative time, implementing the same monitoring and mitigation measures as under the Proposed Action, and requesting an IHA to be issued for that alternative time (Table 3). The proposed time for the cruise in September 2017 is the most suitable time logistically for the *Revelle* and the participating scientists. If the IHA is issued for another period, it could result in significant delay and disruption not only of this cruise, but also of additional studies that are planned on the *Revelle* for 2017 and beyond. An evaluation of the effects of this Alternative Action is given in § IV.

## Alternative 2: No Action Alternative

An alternative to conducting the proposed activities is the "No Action" alternative, i.e., do not issue an IHA and do not conduct the research operations (Table 3). If the research was not conducted, the "No Action" alternative would result in no disturbance to marine mammals from the proposed activities. The purpose of the proposed action is to train early career chief seismic scientists and to cover seismic data gaps and address questions about earthquake hazards and paleoclimate records in basins off the Oregon continental margin.

The "No Action" alternative could also, in some circumstances, result in schedule impacts of other studies that would be planned on the *Revelle* for 2017 and beyond, depending on the timing of the decision. Not conducting this cruise (no action) would result in less data and support for the academic institutions involved. Data collection would be an essential first step for a much greater effort to analyze and report information for the significant topics indicated. The field effort provides material for years of analyses involving multiple professors, students, and technicians. The lost opportunity to collect valuable scientific information would be compounded by lost opportunities for support of research infrastructure, training, and professional career growth. Effects of this Alternative Action are evaluated in § IV.

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

| Proposed Action | Description/Analysis |
|---|---|
| Proposed Action: Conduct marine geophysical surveys and associated activities in the northeastern Pacific Ocean | Under this action, the use of a low-energy seismic source is proposed. When considering mobilization, demobilization, equipment maintenance, weather, marine mammal activity, and other contingencies, the proposed activities would be expected to be completed in ~8 days. The affected environment, environmental consequences, and cumulative impacts of the proposed activities are described in Sections III, IV, and V, respectively. The standard monitoring and mitigation measures identified in the PEIS would apply, along with any additional requirements identified by regulating agencies. All necessary permits and authorizations, including an IHA, would be requested from regulatory bodies. |
| Alternatives | Description/Analysis |
| Alternative 1: Alternative Survey Timing | Under this Alternative, SIO would conduct survey operations at a different time of the year to reduce potential impacts on marine resources and users, and improve monitoring capabilities. However, except for some baleen whales, most marine mammal species are likely year-round residents in the survey area, so altering the timing of the proposed project likely would result in no net benefits for those species. Further, consideration would be needed for constraints for vessel operations and availability of equipment (including the vessel) and personnel. Limitations on scheduling the vessels include the additional research studies planned on the vessel for 2017 and beyond. The standard monitoring and mitigation measures identified in the PEIS would apply and are described in further detail in this document (Section II [3]) along with any additional requirements identified by regulating agencies. All necessary permits and authorizations, including an IHA, would be requested from regulatory bodies. |
| Alternative 2: No Action | Under this Alternative, no proposed activities would be conducted and seismic data would not be collected. Whereas this alternative would avoid impacts to marine resources, it would not meet the purpose and need for the proposed action. The training of scientists, collection of new data, interpretation of these data, and introduction of new results into the greater scientific community would not be achieved. Geological data of scientific value and relevance to increasing our understanding of Earth processes would not be collected. No permits and authorizations, including an IHA, would be requested from regulatory bodies as the proposed action would not be conducted. |
| Alternatives Eliminated from Further Analysis | Description/Analysis |
| Alternative E1: Alternative Location | The study sites off the Oregon continental margin have been specifically selected as key locations to address seismic data gaps and to address questions about earthquake hazards and paleoclimate records in basins. The survey locations would allow the PIs, early career scientists, and students involved to reach sites of high scientific interest in a cost effective and timely manner, allowing more time and effort to focus on the research and training aspects of the proposed activities. |
| Alternative E2: Alternative Survey Techniques | Under this alternative, SIO would use alternative survey techniques, e.g., marine vibroseis, that could potentially reduce impacts on the marine environment. Alternative technologies were evaluated in the PEIS, § 2.6. At the present time, however, these technologies are still not feasible, commercially viable, or appropriate to meet the Purpose and Need. |

## Alternatives Considered but Eliminated from Further Analysis

### (1) Alternative E1: Alternative Location

The Astoria Fan and southern Oregon survey sites have been specifically selected as key locations to cover seismic data gaps and to collect data to address questions about earthquake hazards and paleoclimate records in basins. The survey locations would also allow the PIs, early career scientists, and students involved to reach sites of high scientific interest in a cost effective and timely manner, allowing more time and effort to focus on the research and training aspects of the proposed activities.

### (2) Alternative E2: Use of Alternative Technologies

As described in § 2.6 of the PEIS, alternative technologies to the use of airguns were investigated to conduct marine geophysical research. At the present time, these technologies are still not feasible, commercially viable, or appropriate to meet the Purpose and Need. Additional details about these technologies are given in the Final USGS EA (RPS 2014a). Table 3 provides a summary of the proposed action, alternatives, and alternatives eliminated from further analysis.

# III. AFFECTED ENVIRONMENT

As described in the PEIS, Chapter 3, the description of the affected environment focuses only on those resources potentially subject to impacts. Accordingly, the discussion of the affected environment (and associated analyses) has focused mainly on those related to marine biological resources, as the proposed short-term activities have the potential to impact marine biological resources within the project area. These resources are identified in Section III, and the potential impacts to these resources are discussed in Section IV. Initial review and analysis of the proposed Project activities determined that the following resource areas did not require further analysis in this Draft EA:

- *Transportation*—Only one vessel, the *Revelle*, would be used during the marine seismic survey. Therefore, projected increases in vessel traffic attributable to implementation of the proposed activities would constitute only a negligible portion of the total existing vessel traffic in the analysis area;
- *Air Quality/Greenhouse Gases*—Project vessel emissions would result from the proposed activities; however, these short-term emissions would not result in any exceedance of Federal Clean Air standards. Emissions would be expected to have a negligible impact on the air quality within the survey area;
- *Land Use*—All activities are proposed to occur in the marine environment. Therefore, no changes to current land uses or activities within the project area would result from the proposed Project;
- *Safety and Hazardous Materials and Management*—No hazardous materials would be generated or used during proposed activities. All Project-related wastes would be disposed of in accordance with Federal and international requirements;
- *Geological Resources (Topography, Geology and Soil)*—The proposed project would not result in any disturbances to seafloor sediments. The proposed activities, therefore, would not adversely affect geologic resources;

- *Water Resources*—No discharges to the marine environment are proposed within the project area that would adversely affect marine water quality. Therefore, there would be no impacts to water resources resulting from the proposed Project activities;
- *Terrestrial Biological Resources*—All proposed project activities would occur in the marine environment and would not impact terrestrial biological resources;
- *Socioeconomic and Environmental Justice*—Implementation of the proposed project would not affect, beneficially or adversely, socioeconomic resources, environmental justice, or the protection of children. No changes in the population or additional need for housing or schools would occur. Although there are a number (at least 17) of shore-accessible SCUBA diving sites along the Oregon coast (ShoreDiving.com 2017), the proposed activities would occur in water depths >130 m, outside the range for recreational SCUBA diving. Human activities in the area around the survey vessel would be limited to fishing activities, other vessel traffic, and possibly whale watching; however, no significant impacts on fishing would be anticipated particularly because of the short duration of the proposed activities (~1 week). Fishing and potential impacts to fishing are described in further detail in Sections III and IV, respectively. No other socioeconomic impacts would be anticipated as result of the proposed activities;
- *Visual Resources*—No visual resources would be anticipated to be negatively impacted as the area of operation is outside of the land and coastal view shed; and
- *Cultural Resources*—Although the Columbia River Bar is nicknamed the *Graveyard of the Pacific* with ~2000 shipwrecks (TheOregonCoast.info 2017), the Astoria Fan survey area is located >50 km from the mouth of the Columbia River and would occur beyond 12 n.mi. from the coastline; thus, there are no known cultural resources within the proposed project area. Furthermore, the proposed activities would not involve seafloor disturbances, including placement of equipment on the seafloor. Therefore, no impacts to cultural resources, including shipwrecks, would be anticipated.

## Oceanography

The proposed survey area occurs in the northeastern Pacific Ocean off the coasts of Oregon and Washington. In the North Pacific Ocean, there is a clockwise flow of the central subtropical gyre, and to the north of it, the subarctic gyre flows counterclockwise (Escorza-Treviño 2009). The convergence zone of the subarctic and central gyres, known as the Subarctic Boundary, crosses the western and central North Pacific Ocean at 42ºN (Escorza-Treviño 2009). It is in that area that the change in abundance of cold-water *vs*. warm-water species is the greatest (Escorza-Treviño 2009). Along the U.S. west coast, the Alaska Current flows north along the southeastern coast of Alaska and the Aleutian Peninsula, and the California Current flows south along the coast of California (Escorza-Treviño 2009). The California Current system nutrifies offshore waters by mixing with water from the shelf edge (Buchanan et al. 2001).

Acoustic backscatter surveys within ~550 km of the U.S. west coast showed that fish and zooplankton are associated with shallow bathymetry in this area; the highest densities were located in waters <4000 m deep (Philbrick et al. 2003). During winter through fall, 2015–2016, average sea surface temperatures within the survey area were 9.6, 11.3, 13.6 and 12.0ºC, respectively, with minimum and maximum values of 8.8ºC and 17.0ºC (data unavailable for June and October–December 2016) (ERDDAP 2017a). From July to December 2001, offshore primary productivity ranged up to ~250 $\mathrm{mgC \cdot m^{-2} \cdot d^{-1}}$ in the euphotic zone (Philbrick et al. 2003). Overall, primary production within the survey area is highest from May through September; the chlorophyll concentration in sea water peaked at 280,764 $\mathrm{mg \cdot m^{-3} \cdot d^{-1}}$ during August 2016 (ERDDAP 2017b,c).

A climatic phenomenon called the "Pacific Decadal Oscillation" (PDO) is evident in the Pacific Ocean (Mantua 1999). The PDO is similar to a long-lived El Niño-like pattern of climate variability; it is mainly evident in the North Pacific/North American area, whereas El Niños are typical in the tropics (Mantua 1999). El Niño events do not always influence conditions as far north as Oregon and Washington; during less intense episodes, California is the northern limit of El Niño conditions (Buchanan et al. 2001). PDO "events" persist for 20–30 years, whereas typical El Niño events persist for 6–18 months (Mantua 1999). In the past century, there have been two PDO cycles: "cool" PDO regimes during 1890–1924 and 1947–1976, and "warm" PDO regimes during 1925–1946 and 1977–the mid 1990s (Mantua et al. 1997; Minobe 1997).

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

## Protected Areas

### (1) Critical Habitat for ESA-listed Species

Several areas near the proposed survey area have been specifically identified as important to ESA-listed species, including critical habitat for marine mammals, sea turtles, seabirds, and fish. Only those areas within 50 km of the proposed survey area are shown on Figure 1.

***Steller Sea Lion Critical Habitat.***—Federally designated critical habitat for Steller sea lions includes all rookeries and major haulouts including those in southern Oregon (NMFS 1993). Although the Eastern Distinct Population Segment (DPS) was delisted from the ESA in 2013, the designated critical habitat remains valid (NOAA 2017a). The designated critical habitats in Oregon are located along the coast at Rogue Reef (Pyramid Rock) and Orford Reef (Long Brown Rock and Seal Rock; see Fig. 1). The critical habitat areas include aquatic zones that extend 0.9 km seaward and air zones extending 0.9 km above these terrestrial and aquatic zones (NMFS 1993). The southeastern boundary of the Southern Oregon survey area is located ~20 km and ~55 km from Orford Reef and Rogue Reef critical habitats, respectively.

***Southern Resident Killer Whale Critical Habitat.***—Critical habitat for the Eastern North Pacific Southern Resident Stock of killer whales is defined in detail in the Code of Federal Regulations (see NMFS 2006). Critical habitat currently includes three specific marine areas of Puget Sound, Washington: the Summer Core Area, Puget Sound, and the Strait of Juan de Fuca. The critical habitat includes all waters relative to a contiguous shoreline delimited by the line at a depth of 6.1 m relative to extreme high water. The western boundary of the Strait of Juan de Fuca Area is Cape Flattery, Washington (48.38°N; 124.72°W), located ~190 km from the northern portion of the Astoria Fan survey area. In January 2014 the NMFS received a petition requesting an expansion to the Southern Resident killer whale critical habitat to include Pacific Ocean marine waters along the US west coast from Cape Flattery, WA to Point Reyes, CA, extending ~76 km offshore; the NMFS released a 12-month finding in February 2015 accepting the validity of a critical habitat expansion and anticipates developing a new proposed rule during 2017 (NMFS 2015a).

***Critical Habitat for Leatherback Turtles.***—In January 2012, NMFS designated critical habitat for leatherback sea turtles along the west coast of the U.S. (NMFS 2012a). The critical habitat includes marine areas of ~43,798 km$^2$ off California and ~64,760 km$^2$ from Cape Flattery, Washington, to Cape Blanco, Oregon (NMFS 2012a). The Astoria Fan and Southern Oregon survey areas east of the 2000-m contour occur in the critical habitat (see Fig. 1). The majority of the Astoria Fan survey area and the eastern portion of the Southern Oregon survey area occur in the critical habitat (see Fig. 1).

***Western Snowy Plover Critical Habitat.***—Critical habitat for the Pacific Coast population of the western snowy plover includes sandy beaches and dune systems immediately inland from the active beach face as well as salt flats, mud flats, and gravel bars. These areas should be above high tides and below the heavily vegetated areas, and have minimal disturbance from humans (USFWS 2011). Critical habitat in Washington and Oregon covers 2460 ha and 856 ha, respectively (see Fig. 1). (NMFS 2012b). Segments of this critical habitat are located ~20 km to the east of the proposed survey areas (Fig. 3).

***Marbled Murrelet Critical Habitat.***—Federally designated critical habitat for marbled murrelets includes nesting habitat with the presence of suitable nesting platforms (including large branches, deformities, mistletoe infestations), canopy cover, landscape condition, and distance to the ocean; nesting platforms are typically at least 10 m off the ground (USFWS 2016a). The critical habitat includes 3,698,100 acres in Washington, Oregon, and California (USWFS 2016a). The nearest segments of this critical habitat are ~23 km to the east of the survey areas (see Fig. 3).

***Green Sturgeon Critical Habitat.***—Coastal U.S. marine Critical Habitat for the ***Threatened*** Southern DPS of North American green sturgeon includes waters within ~109 m (60 fathoms) depth from Monterey Bay, California, north to Cape Flattery, Washington, to its U.S. boundary, encompassing 29,581 km$^2$ of marine habitat (NMFS 2009). Although this critical habitat is adjacent to the proposed project area, no critical habitat occurs within the survey areas (see Fig. 1).

Freshwater critical habitats have been designated for a number of ESA-listed fish species within Washington and Oregon, east or northeast of the proposed survey area; however, none of these habitats extend into marine waters. The species include:

- Pacific eulachon/smelt (Southern DPS; ***Threatened*)**
- Chinook salmon
    - Lower Columbia River Evolutionary Significant Unit (ESU; ***Threatened***)
    - Puget Sound ESU (***Threatened***)
    - Upper Columbia River ESU (spring-run; ***Endangered***)
    - Upper Willamette River ESU (***Threatened***)

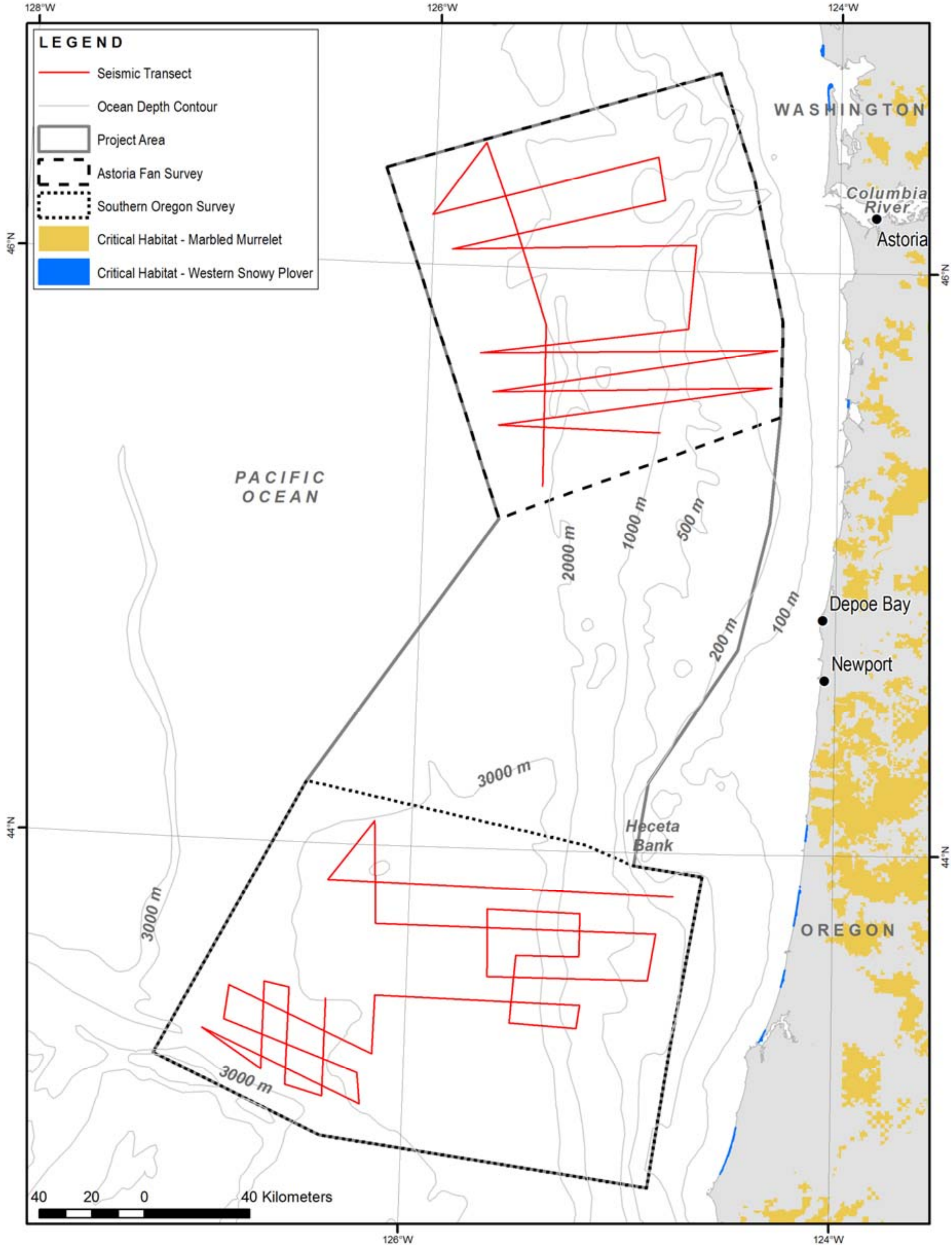


FIGURE 3. Critical habitat for ESA-listed seabirds near the proposed project area in the northeastern Pacific.

- Chum salmon
    - Columbia River ESU (***Threatened***)
    - Hood Canal (summer-run; ***Threatened***)
- Coho salmon
    - Lower Columbia River ESU (***Threatened***)
    - Oregon Coast (***Threatened***)
- Sockeye salmon (Ozette Lake ESU; ***Threatened***)
- Steelhead
    - Lower Columbia River DPS (***Threatened***)
    - Middle Columbia River DPS (***Threatened***)
    - Puget Sound DPS (***Threatened***)
    - Snake River Basin DPS (***Threatened***)
    - Upper Columbia River DPS (***Endangered***)
    - Upper Willamette River DPS (***Threatened***)
- Yelloweye rockfish (Puget Sound/Georgia Basin DPS; ***Threatened***); includes marine portions within Puget Sound/Georgia Basin

### (2) Other Protected Areas

There are two portions of U.S. military land which are closed to access near the mouth of the Columbia River, referred to as Warrenton/Camp Rilea (USGS 2016). The nearest of these two areas is ~30 km east of the Astoria Fan survey area (see Fig. 1).

***Endeavour Hydrothermal Vents Marine Protected Area.—***The Endeavour Hydrothermal Vents (EHV) were designated as the first Marine Protected Area under Canada's Oceans Act in 2003. The EHV area is located on the Juan de Fuca Ridge, 250 km offshore from Vancouver Island, 2250 m below the ocean's surface. Under the Canadian Oceans Act, underwater activities that may result in the disturbance, damage, destruction, or removal of the seabed, or any living marine organism or any part of its habitat, are prohibited (SOR 2003-87). The EHV area is located ~280 km from the northwestern portion of the Astoria Fan survey area.

***Washington Island National Wildlife Refuges.—***The Washington Islands National Wildlife Refuges (NWRs) are located along 161 km of the outer coast of the Olympic Peninsula, encompassing more than 600 islands, sea stacks, rocks, and reefs. The area is comprised of three NWRs: Copalis NWR (47.13–47.48°N), Quillayute Needles NWR (47.63–48.03°N), and Flattery Rocks NWR (48.03–48.38°N). The refuges do not include islands that are part of designated Native American reservations. Along much of the coastline adjacent to the islands lies the ONP. In 1970, all three of the Washington Islands NWRs were designated as Wilderness Areas, except for Destruction Island in Quillayute Needles NWR. As many as 500 Steller sea lions haul out and 150,000 pelagic birds nest annually on these islands (USFWS 2007). The OCNMS incorporates the entire area surrounding the islands and rocks of all three Refuges. (USFWS 2007). The northeastern extremity of the Astoria Fan survey area is located ~60 km southwest of the Copalis NWR boundary.

***Olympic Coast National Marine Sanctuary.—***The Olympic Coast National Marine Sanctuary (OCNMS), designated in 1994, includes 8259 km$^2$ of marine waters off the Washington coast, extending 40–72 km seaward and covering much of the continental shelf and several major submarine canyons (NOAA 2011a). The sanctuary protects a productive upwelling zone with high productivity and a diversity of marine life (NOAA 2011a). This area also has numerous shipwrecks. The OCNMS management plant provides a framework for the sanctuary to manage potential threats to the sanctuary's marine resources under the National Marine Sanctuaries Act. Federal law provides national marine sanctuaries the authority to adopt regulations and issue permits for certain activities, including taking any marine mammal, sea turtle, or seabird in or above the sanctuary, except as authorized by the MMPA, the ESA, and the Migratory Bird Treaty Act. The southern boundary of the OCNMS is ~50 km north of the Astoria Fan survey area.

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

***Lewis and Clark National Wildlife Refuge.***—The Lewis and Clark National Wildlife Refuge includes ~20 islands stretching over 43.5 km of the Columbia River, from the mouth upstream to nearly Skamakowa, Washington (USFWS 2012). This refuge was established in 1972 to preserve the fish and wildlife habitat of the Columbia River estuary, and supports large numbers of waterfowl, gulls, terns, wading birds, shorebirds, raptors and songbirds. It is located ~50 km east of the Astoria Fan survey area (see Fig. 1).

***Willapa National Wildlife Refuge.***—The Willapa National Wildlife Refuge is located within Willapa Bay and Columbia River, Washington. It was established in 1973 by President Franklin D. Roosevelt to protect migrating birds and their habitat (USFWS 2013). It consists of multiple segments, with the nearest ~30 km east of the Astoria Fan survey area (see Fig. 1).

***Oregon Islands National Wildlife Refuge.***—The Oregon Islands National Wildlife Refuge (OINWR) spans 515 km of the Oregon coast from the Oregon-California border to Tillamook Head (~45.9°N) and includes all rocks and islands above the line of mean high tide, except for rocks and islands of the Three Arch Rocks NWR. All of the island acreage is designated National Wilderness, with the exception of Tillamook Rock (USFWS 2016c). The OINWR is located ~25 km east of the nearest portions of the proposed survey areas (see Fig. 1).

***Three Arch Rocks National Wildlife Reserve.***—Three Arch Rocks NWR consists of 60 $m^2$ on three large and six small rocky islands located ~1 km from shore. It is one of the smallest designated wilderness areas in the U.S., and is the only northern Oregon pupping site for the Steller sea lion (USFWS 2016b). The Astoria Fan survey area is located ~20 km northwest from the NWR (see Fig. 1).

***Washington State Seashore Conservation Area.***—The Washington State Seashore Conservation Area includes all seashore between the line of ordinary high tide and the line of extreme low tide between Cape Disappointment (~46°18'N) and Griffiths Priday State Park (~47°07'N). The Conservation Area is under the jurisdiction of the Washington state parks and recreation commission (RCW 79A.05.605). The Seashore Conservation Area is ~25 km east of the northeastern portion of the Astoria Fan survey area (see Fig. 1).

***Cape Falcon Marine Reserve.***—The Cape Falcon Marine Reserve combines a marine reserve and two marine protected areas located at ~45.7ºN, 124ºW. The entire marine protected area extends ~7 km along the coast of Oregon (see Fig. 1) and out to ~7 km (OOI 2017a). The reserve and marine protected area portions are 32 $km^2$ and 19.7 $km^2$, respectively. The Cape Falcon Marine Reserve is located ~15 km east of the Astoria Fan survey area (see Fig. 1).

***Cascade Head Marine Reserve.*****—**This site includes a marine reserve surrounded by three marine protected areas, and is located off the central Oregon coast at ~45°N, 124ºW. The entire marine protected area extends 16 km along the coast (see Fig. 1) and out to 5.6 km (OOI 2017a), with total areas of 25.1 $km^2$ and 59.7 $km^2$ for the marine reserve and marine protected areas portions, respectively. Cascade Head Marine Reserve is located ~20 km east of the proposed project area (see Fig. 1).

***Otter Rock Marine Reserve.*****—**The Otter Rock Marine Reserve was established on 15 November 2011. Otter Rock encompasses 3.4 $km^2$ of nearshore water at ~44.72–44.75°N (OAR 141-142-0030). The Otter Rock Marine Reserve is located ~30 km east of the proposed project area (see Fig. 1).

***Cape Perpetua Marine Reserve.*****—**This site combines a marine reserve, two marine protected area, and a seabird protection area. It is located off the central Oregon coast at ~44.2ºN, 124.1ºW. The entire protected area extends ~26.5 km along the coast (see Fig. 1, and out to ~5 km, with total areas of 36.5 $km^2$ and 48.7 $km^2$ for the reserve and marine protected area portions, respectively (OOI 2017a). The Southern Oregon survey area is located ~40 km southwest from the Cape Perpetua Marine Reserve boundary (see Fig. 1).

***Redfish Rock Marine Reserve and Marine Protected Area.*****—**The Redfish Rock Marine Reserve and Marine Protected Area were established on 15 November 2011 at ~42.67–44.70°N (OAR 141-142-0035; OAR 141-142-0035). The marine reserve encompasses 6.7 $km^2$ of nearshore water. The adjacent marine protected area covers an additional ~13 $km^2$. Redfish Rock Marine Reserve is located ~30 km southeast of the Southern Oregon survey area (see Fig. 1).

## Marine Mammals

Thirty-two marine mammal species could occur or have been documented to occur in the marine waters off Oregon and Washington, excluding extralimital sightings or strandings (Fiscus and Niggol 1965; Green et al. 1992, 1993; Barlow 1997, 2003; Mangels and Gerrodette 1994; Von Saunder and Barlow 1999; Barlow and Taylor 2001; Buchanan et al. 2001; Calambokidis et al. 2004a; Calambokidis and Barlow 2004). The species include 7 mysticetes (baleen whales), 19 odontocetes (toothed whales, such as dolphins), 5 pinnipeds (seals), and the sea otter (Table 4). Seven of the species that could occur in the proposed survey area are listed under the ESA as ***Endangered***, including the sperm, humpback (Central America DPSs), sei, fin, blue, North Pacific right, and killer whales (Southern Resident DPS). The ***Threatened*** Mexico DPS of the humpback whale could also occur in the proposed survey area. It is possible although very unlikely that individuals from the ***Endangered*** Western North Pacific gray whale population could occur in the proposed survey area.

The proposed Astoria Fan and southern Oregon survey areas are located at least 23 km from the east coast of the U.S. over water depths ~130–2600 m (see Fig. 1). The sea otter is not expected in the proposed survey areas because its occurrence off Washington and Oregon is limited to very shallow (<30 m depth), coastal (<4 km from shore) waters (Laidre et al. 2009). Vagrant ringed seals, hooded seals, and ribbon seals have been sighted or stranded on the coast of California (see Mead 1981; Reeves et al. 2002) and presumably passed through Oregon waters. A vagrant beluga whale was seen off the coast of Washington (Reeves et al. 2002). In addition, records exist for Perrin's beaked whale (*M. perrini*) and the lesser beaked whale (*M. peruvianus*) and gingko-toothed beaked whale (*M. ginkgodens*) off the coast of California and/or Baja California (MacLeod et al. 2006). These seven species are unlikely to be seen in the proposed survey area and are not addressed in the summaries below.

General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of marine mammals are given in § 3.6.1, § 3.7.1, and § 3.8.1 of the PEIS. One of the

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

| Species | Occurrence in Area | Habitat | Abundance[1] | U.S. ESA[2] | IUCN[3] | CITES[4] |
|---|---|---|---|---|---|---|
| **Mysticetes** | | | | | | |
| North Pacific right whale | Rare | Coastal, shelf, offshore | 31[5] | EN | EN | I |
| Gray whale | Uncommon | Coastal, shelf | 21,210[6] | DL/EN[18] | LC | I |
| Humpback whale | Common | Mainly nearshore and banks | 21,808[7] | EN/T[19] | LC | I |
| Minke whale | Uncommon | Nearshore, offshore | 9000[8] | NL | LC | I |
| Sei whale | Rare | Mostly pelagic | 12,620[9] | EN | EN | I |
| Fin whale | Common | Slope, pelagic | 8499[10] | EN | EN | I |
| Blue whale | Uncommon | Pelagic and coastal | 1146[10] | EN | EN | I |
| **Odontocetes** | | | | | | |
| Sperm whale | Common | Pelagic, steep topography | 24,000[11] | EN | VU | I |
| Pygmy sperm whale | Rare | Deep, off shelf | 4111[10,12] | NL | DD | II |
| Dwarf sperm whale | Rare | Deep, shelf, slope | 4111[10,12] | NL | DD | II |
| Cuvier's beaked whale | Common | Pelagic | 3359[10] | NL | LC | II |
| Baird's beaked whale | Common | Pelagic | 6552[10] | NL | DD | I |
| Blainville's beaked whale | Rare | Pelagic | 1099[10,13] | NL | DD | II |
| Hubb's beaked whale | Rare | Slope, offshore | 1099[10,13] | NL | DD | II |
| Stejneger's beaked whale | Uncommon | Slope, offshore | 1099[10,13] | NL | DD | II |
| Common bottlenose dolphin | Rare | Coastal, shelf, deep | 1924[10] | NL | LC | II |
| Striped dolphin | Rare | Off continental shelf | 29,211[10] | NL | LC | II |
| Short-beaked common dolphin | Uncommon | Shelf, pelagic, mounts | 969,861[10] | NL | LC | II |
| Pacific white-sided dolphin | Common | Offshore, slope | 26,556[10] | NL | LC | II |
| Northern right whale dolphin | Common | Slope, offshore waters | 54,604[10] | NL | LC | II |
| Risso's dolphin | Common | Shelf, slope, mounts | 6336[10] | NL | LC | II |
| False killer whale | Rare | Pelagic | N.A. | NL | DD | II |
| Killer whale | Common | Widely distributed | 452[10] | EN/NL[20] | DD | II |
| Short-finned pilot whale | Rare | Pelagic, high-relief | 836[10] | NL | DD | II |
| Harbor porpoise | Uncommon | Coastal and inland waters | 57,256[14] | NL | LC | II |
| Dall's porpoise | Common | Shelf, slope, offshore | 25,750[10] | NL | LC | II |
| **Pinnipeds** | | | | | | |
| Northern fur seal | Common | Pelagic, offshore | 662,584[15] | NL | VU | N.A. |
| California sea lion | Uncommon | Coastal, shelf | 296,750 | NL | LC | N.A. |
| Steller sea lion | Common | Coastal, shelf | 60,131-74,448[16] | DL[21] | NT[22] | N.A. |
| Harbor seal | Common | Coastal | 24,732 | NL | LC | N.A. |
| Northern elephant seal | Common | Coastal, pelagic in migration | 179,000[17] | NL | LC | N.A. |

N.A. - Data not available or species status was not assessed.

[1] Abundance for the California/Oregon/Washington, Eastern North Pacific, or U.S. stock (Carretta et al. 2016a), unless otherwise stated.

[2] U.S. Endangered Species Act (NMFS 2017): EN = Endangered, T = Threatened, DL = Delisted, NL = Not listed.

[3] Classification from the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2016); EN = Endangered; VU = Vulnerable; LC = Least Concern; DD = Data Deficient.

[4] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2017): Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled.

[5] Bering Sea (Wade et al. 2011).

[6] California migration estimate for eastern North Pacific population (Durban et al. 2015).

[7] Barlow et al. (2011).

[8] North Pacific (Wada 1976).

[9] North Pacific (Tillman 1977).

[10] California/Oregon/Washington; means of the 2008 and 2014 abundance estimates (Barlow 2016).

[11] Eastern Temperate North Pacific (Whitehead 2002).

[12] Combined *Kogia* spp.

[13] All mesoplodont whales.

[14] Northern Oregon/Washington Coast and Northern California/Southern Oregon stocks combined (Forney et al. 2014).

[15] Eastern Pacific stock numbers 648,534 (Muto et al. 2016) plus California stock of 14,050 (Carretta et al. 2016a).

[16] Eastern U.S. stock (Muto et al. 2016).

[17] California breeding stock (Carretta et al. 2016a).

[18] Eastern North Pacific population was delisted in 2013; Western North Pacific population is listed as endangered.

[19] The Central America DPS is endangered; the Mexico DPS is threatened.

[20] The Southern Resident stock is listed as endangered; no other stocks listed.

[21] Eastern DPS delisted; Western Pacific DPS listed as endangered.

[22] Globally listed as near threatened; eastern population is designated as least concern.

qualitative analysis areas (QAAs) defined in the PEIS, the BC Coast, is located to the north of the proposed survey area. The general distribution of mysticetes, odontocetes, and pinnipeds off the BC Coast is discussed in § 3.6.3.2, § 3.7.3.2, and § 3.8.3.2 of the PEIS, respectively. In addition, one of the detailed analysis areas (DAAs), S California, is located to the south of the proposed survey area. The general distribution of mysticetes, odontocetes, and pinnipeds off southern California is discussed in § 3.6.2.3,§ 3.7.2.3, and § 3.8.2.3 of the PEIS, respectively. The rest of this section deals specifically with species distribution in the proposed survey area off Oregon and Washington.

## (1) Mysticetes

### North Pacific Right Whale (*Eubalaena japonica*)

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

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

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

### Gray Whale (*Eschrichtius robustus*)

In the North Pacific, gray whales have distinct Eastern and Western stocks, although 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). Thus, it is possible that whales from both the *endangered* Western and delisted Eastern populations could occur along the U.S. west coast (Calambokidis et al. 2015).

Gray whale populations were severely reduced by whaling and the western population has remained highly depleted, but the eastern North Pacific population is considered to have recovered. Punt and Wade (2012) estimated the eastern North Pacific population to be at 85% of its carrying capacity in 2009. The eastern North Pacific gray whale breeds and winters in Baja, California, and migrates north to summer feeding grounds in the northern Bering Sea, Chukchi Sea, and western Beaufort Sea (Rice and Wolman 1971; Jefferson et al. 2015). Gray whales are found primarily in shallow water; most follow the coast during migration, staying close to the shoreline except when crossing major bays, straits, and inlets (Braham 1984).

A small portion of the population also summers along the Pacific coast from northern Vancouver Island, British Columbia (BC) to central California (Rice and Wolman 1971; Nerini 1984; Calambokidis and Quan 1999) from June to November (Calambokidis et al. 2002, 2010, 2015). There is recent genetic evidence indicating the existence of this Pacific Coast Feeding Group as a distinct local subpopulation (Frasier et al. 2011; Lang et al. 2014). It is estimated that the Pacific Coast Feeding group consists of ~200 individuals (Calambokidis et al. 2002, 2004b, 2010). Biologically Important Areas (BIAs) for feeding gray whales along the coast of Oregon were reported for Depoe Bay, Cape Blanco, and Orford Reef (Calambokidis et al. 2015). At least 28 gray whales were observed near Depoe Bay (~44.8°N), Oregon, for three successive summers (Newell and Cowles 2006). Resident gray whales have been observed foraging off the coast of Oregon from May to October (Newell and Cowles 2006), and off Washington from June through November (Scordino et al. 2014).

BIAs along the coast of Oregon and Washington have also been identified for migrating gray whales; although most whales travel within 10 km from shore, the BIAs were extended out to 47 km from the coastline (Calambokidis et al. 2015). Gray whales from the far north begin to migrate south to breeding grounds on the west coast of Baja California and the southeastern Gulf of California in October and November (Braham 1984; Rugh et al. 2001). Green et al. (1995) reported that the average distance from shore for migrating gray whales recorded during aerial surveys off the Oregon and Washington coasts were 9.2 km and 18.5 km, respectively; the farthest sighting occurred 43 km offshore during the southbound migration in January off Washington. Gray whales migrate closest to the Washington/ Oregon coastline during the spring months (April–June), when most strandings are observed (Norman et al. 2004).

Oleson et al. (2009) observed 116 gray whales off the outer Washington coast (~47ºN) during 42 small boat surveys from August 2004 through September 2008; mean distances from shore during the southern migration (December–January), northern migration (February–April), and summer feeding (May–October) activities were 29, 9, and 12 km, respectively; mean bottom depths during these activities were 126, 26, and 33 m, respectively. Ortega-Ortiz and Mate (2008) tracked the distribution and movement patterns of gray whales off Yaquina Head on the central Oregon coast (~44.7°N) during the southbound and northbound migration in 2008. The average distance from shore to tracked whales ranged from 200 m to 13.6 km; average bottom depth of whale locations was 12–75 m. The migration paths of tracked whales seemed to follow a constant depth rather than the shoreline.

According to predictive density distribution maps, low densities of gray whales could be encountered throughout the Astoria Fan and Southern Oregon survey areas (Menza et al. 2016). During aerial surveys over the shelf and slope off Oregon and Washington, gray whales were seen during the months of January, June–July, and September; one sighting was made within the Astoria Fan survey area in water >200 m during June 2011 (Adams et al. 2014). Two sightings of three whales were seen from the *Northern Light* during a survey off southern Washington during July 2012 (RPS 2012a); sightings were made to the north of the Astoria Fan survey area.

Several human-caused gray whale deaths/entanglements from coastal fishery-related gear occurred during 2009–2010 off Oregon and Washington; there were also several deaths or injuries in the region as a result of vessel strikes during 2009 (Carretta et al. 2016b). Huggins et al. (2015a) observed five stranded gray whales during beach surveys conducted between ~46.7–47.3ºN during 2006–2011.

The proposed surveys would occur during the summer feeding season for gray whales in the Washington/Oregon region. Thus, gray whales could be encountered in the eastern portion of the proposed project area where the water is shallower.

### Humpback Whale (*Megaptera novaeangliae*)

The humpback whale is found throughout all of the oceans of the world (Clapham 2009). The worldwide population of humpbacks is divided into northern and southern ocean populations, but genetic analyses suggest some gene flow (either past or present) between the North and South Pacific (e.g., Baker et al. 1993; Caballero et al. 2001). Geographical overlap of these populations has been documented only off Central America (Acevedo and Smultea 1995; Rasmussen et al. 2004, 2007). Although considered to be mainly a coastal species, humpback whales often traverse deep pelagic areas while migrating (Clapham and Mattila 1990; Norris et al. 1999; Calambokidis et al. 2001).

Humpback whales migrate between summer feeding grounds in high latitudes and winter calving and breeding grounds in tropical waters (Clapham and Mead 1999). North Pacific humpback whales summer in feeding grounds along the Pacific Rim and in the Bering and Okhotsk seas (Pike and MacAskie 1969; Rice 1978; Winn and Reichley 1985; Calambokidis et al. 2000, 2001, 2008). Humpbacks winter in four different breeding areas: (1) along the coast of Mexico; (2) along the coast of Central America; (3) around the main Hawaiian Islands; and (4) in the western Pacific, particularly around the Ogasawara and Ryukyu islands in southern Japan and the northern Philippines (Calambokidis et al. 2008; Bettridge et al. 2015). These breeding areas have been designated as DPSs, but feeding areas have no DPS status (Bettridge et al. 2015; NMFS 2016b). Individuals from two DPSs (Central America and Mexico DPS) could be encountered in the proposed survey area. There is a low level of interchange of whales among the main wintering areas and among feeding areas (e.g., Darling and Cerchio 1993; Salden et al. 1999; Calambokidis et al. 2001, 2008).

The humpback whale is the most common species of large cetacean reported off the coasts of Oregon and Washington from May to November (Green et al. 1992; Calambokidis et al. 2000, 2004a). Shifts in seasonal abundance observed off Oregon and Washington suggest north–south movement (Green et al. 1992). The highest numbers have been reported off Oregon during May and June and during July–September off Washington; no humpbacks were reported for winter (Green et al. 1992; Calambokidis et al. 2000, 2004a). Green et al. (1992) reported the highest encounter rates off Oregon/Washington during June–August followed by September through November; highest densities typically occurred over the slope followed by shelf waters. Off Oregon/Washington, humpbacks occur primarily over the continental shelf and slope during the summer, with few reported in offshore pelagic waters (Green et al. 1992; Calambokidis et al. 2004a, 2015; Becker et al. 2012; Menza et al. 2016). In particular, humpbacks tend to concentrate off Oregon along the southern edge of Heceta Bank (~44°N, 125°W), in the Blanco upwelling zone (~43°N), and other areas associated with upwelling. During extensive systematic aerial surveys conducted up to ~550 km off the Oregon/ Washington coast, only one humpback whale was reported in offshore waters >2000 m deep; that sighting was ~70 km west of Cape Blanco during the spring (Green et al. 1992). Sightings have also been made near the proposed Astoria Fan and Southern Oregon survey areas, including near Astoria Canyon off the Columbia River mouth, between the 200 and 2000 m depth contours, and near Hecate Bank in water >200 m (Green et al. 1992).

BIAs for feeding humpback whales along the coast of Oregon were reported for Stonewall and Heceta Bank for May–November and just south of 42°S at Point St. George for July–November (Calambokidis et al. 2015).

There were multiple sighting locations within or adjacent to the proposed Astoria Fan and Southern Oregon survey sites during 1991–2005 surveys between Washington and California (Barlow and Forney 2007). Oleson et al. (2009) observed 147 humpback whales off the outer Washington coast (~47ºN) during small boat surveys from August 2004 through September 2008, with mean distance from shore and mean depth values of 35 km and 187 m, respectively. At least 12 humpback whale sightings were reported off Oregon/Washington during summer/fall surveys in 2008 (Barlow 2010). During aerial surveys over the shelf and slope off Oregon and Washington (Adams et al. 2014), humpback whales were seen during all survey months (January–February, June–July, September–October), including in winter, as well as near and within the proposed project area. One sighting was made in the Southern Oregon survey area during January 2011 in water >200 m deep, and another sighting was made in the Astoria Fan survey area in June 2011 near the 2000-m depth contour (Adams et al. 2014).

Six sightings of eight individuals were made from the *Langseth* seismic vessel off Washington/ Oregon during June–July 2012 (RPS 2012b), including near or within the Southern Oregon survey area. Thirty-four sightings totaling 83 individuals occurred from the *Langeth* during a survey off southern Washington during July 2012 (RPS 2012a); some sightings were made in the Astoria Fan survey area, but most of the survey effort occurred farther north. In addition, 64 sightings totaling 130 individuals occurred from the *Northern Light* during a survey off southern Washington during July 2012 (RPS 2012a); some sightings were made in the Astoria Fan survey area, but most of the survey effort occurred farther north. Eleven sightings of 23 individuals were made from the *Langseth* seismic vessel off the coast of Oregon during a separate survey July 2012 (RPS 2012c); sightings were made throughout the proposed project area, including one sighting in the Southern Oregon survey area. A 2014 survey indicated an abundance of 2480 humpback whales off the coasts of Oregon and Washington (Barlow 2016).

Humpbacks could be encountered in shelf and slope waters of the proposed project area.

#### Minke Whale (*Balaenoptera acutorostrata*)

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

The International Whaling Commission (IWC) recognizes three stocks of minke whales in the North Pacific: the Sea of Japan/East China Sea, the rest of the western Pacific west of 180ºN, and the remainder of the Pacific (Donovan 1991). Minke whales are relatively common in the Bering and Chukchi seas and in the Gulf of Alaska, but are not considered abundant in any other part of the eastern Pacific (Brueggeman et al. 1990). In the far north, minke whales are thought to be migratory, but they are believed to be year-round residents in coastal waters off the U.S. west coast (Dorsey et al. 1990).

Sightings have been made off Oregon and Washington in shelf and deeper waters (Green et al. 1992; Adams et al. 2014; Carretta et al. 2016a). An estimated abundance of 211 minke whales was reported for the Oregon/Washington region based on sightings data from 1991–2005 (Barlow and Forney

2007), whereas a 2008 survey did not record any minke whales while on survey effort (Barlow 2010). The abundance for Oregon/Washington for 2014 was estimated at 507 mink whales (Barlow 2016). A single minke whale was observed off the outer Washington coast (~47ºN) during small boat surveys from August 2004 through September 2008, 14 km from shore with a bottom depth of 38 m (Oleson et al. 2009). One sighting was made near the Astoria Fan survey area at the 200-m isopleth off the mouth of the Columbia River in July 2012 (Adams et al. 2014). One minke was seen from the *Northern Light* during a survey off southern Washington during July 2012 (RPS 2012a); the sighting was made just to the north of the Astoria Fan survey area. Minke whales strandings have been reported in all seasons in Washington; most strandings (52%) occurred in spring (Norman et al. 2004).

Minke whales could be encountered within the proposed project area during September.

### Sei Whale (*Balaenoptera borealis*)

The distribution of the sei whale is not well known, but it is found in all oceans and appears to prefer mid-latitude temperate waters (Jefferson et al. 2015). The sei whale is pelagic and generally not found in coastal waters (Jefferson et al. 2015). It is found in deeper waters characteristic of the continental shelf edge region (Hain et al. 1985) and in other regions of steep bathymetric relief such as seamounts and canyons (Kenney and Winn 1987; Gregr and Trites 2001). On feeding grounds, sei whales associate with oceanic frontal systems (Horwood 1987) such as the cold eastern currents in the North Pacific (Perry et al. 1999a). Sei whales migrate from temperate zones occupied in winter to higher latitudes in the summer, where most feeding takes place (Gambell 1985a). During summer in the North Pacific, the sei whale can be found from the Bering Sea to the Gulf of Alaska and down to southern California, as well as in the western Pacific from Japan to Korea. Its winter distribution is concentrated at ~20°N (Rice 1998).

Sei whales are rare in the waters off California, Oregon, and Washington (Brueggeman et al. 1990; Green et al. 1992; Barlow 1994, 1997). Only nine confirmed sightings were reported for California, Oregon, and Washington during extensive surveys from 1991–2008, including two within or near the westernmost portion of the Southern Oregon survey area (Green et al. 1992, 1993; Hill and Barlow 1992; Carretta and Forney 1993; Mangels and Gerrodette 1994; Von Saunder and Barlow 1999; Barlow 2003; Forney 2007; Barlow 2010; Carretta et al. 2016a). Based on surveys conducted in 1991–2008, the estimated abundance of sei whales off the coasts of Oregon and Washington was 52 (Barlow 2010); for 2014, the abundance estimate was 468 (Barlow 2016). Two sightings of four individuals were made from the *Langseth* seismic vessel off Washington/Oregon during June–July 2012 (RPS 2012b), including within the proposed project area.

Sei whales could be encountered within the proposed project area during September.

### Fin Whale (*Balaenoptera physalus*)

The fin whale is widely distributed in all the world's oceans (Gambell 1985b), but typically occurs in temperate and polar regions from 20–70° north and south of the Equator (Perry et al. 1999b). Northern and southern fin whale populations are distinct and are sometimes recognized as different subspecies (Aguilar 2009). Fin whales occur in coastal, shelf, and oceanic waters. Sergeant (1977) suggested that fin whales tend to follow steep slope contours, either because they detect them readily or because biological productivity is high along steep contours because of tidal mixing and perhaps current mixing. Stafford et al. (2009) noted that sea-surface temperature is a good predictor variable for fin whale call detections in the North Pacific.

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

Edwards et al. (2015) predicted that average fin whale densities off Washington and Oregon would be zero during December–May, but that densities <0.003 whales/km$^2$ could occur there from June through November. Higher densities were predicted for waters off southern Oregon than for the rest of the proposed project area (Becker et al. 2012; Calambokidis et al. 2015). Based on surveys conducted in 1991–2008, the estimated abundance of fin whales off the coasts of Oregon and Washington was 416 (Barlow 2010); the estimate for 2014 was 3458 (Barlow 2016). At least 20 fin whale sightings were reported during the Oregon/Washington portions of the survey in 2008; several sightings occurred within or near the proposed survey area during 2008 and during surveys between 1991–2005 (Barlow and Forney 2007; Barlow 2010; Calambokidis et al. 2015; Carretta et al. 2016a). One fin whale was sighted north of the proposed project area during surveys between August 2004 and September 2008 (Oleson et al. 2009).

Twelve sightings of 26 individuals were made from the *Langseth* seismic vessel off the southern coast of Washington during July 2012 (RPS 2012a); some sightings were made in the Astoria Fan survey area, but most of the survey effort occurred farther north. In addition, two individuals were seen from the *Northern Light* during a survey off southern Washington during July 2012 (RPS 2012a); several sightings were made in the Astoria Fan survey area, but most of the survey effort occurred farther north. Eight sightings of 19 individuals were made from the *Langseth* seismic vessel off Washington/Oregon during June–July 2012 (RPS 2012b), including in the Astoria Fan and Southern Oregon survey areas. Fin whales were also seen in the Southern Oregon survey area in July 2012 in water >2000 m deep during surveys by Adams et al. (2014).

Fin whales could be encountered throughout the proposed project area during September.

### Blue Whale (*Balaenoptera musculus*)

The blue whale has a cosmopolitan distribution and tends to be pelagic, only coming nearshore to feed and possibly to breed (Jefferson et al. 2015). Although it has been suggested that there are at least five subpopulations of blue whales in the North Pacific (NMFS 1998), analysis of blue whale calls monitored from the U.S. Navy Sound Surveillance System (SOSUS) and other offshore hydrophones (see Stafford et al. 1999, 2001, 2007; Watkins et al. 2000a; Stafford 2003) suggest that there are two separate populations: one in the eastern and one in the western North Pacific (Sears 2009). Broad-scale acoustic monitoring indicates that blue whales occurring in the northeast Pacific during summer and fall may winter in the eastern tropical Pacific (Stafford et al. 1999, 2001).

The distribution of the species, at least during times of the year when feeding is a major activity, occurs in areas that provide large seasonal concentrations of euphausiids (Yochem and Leatherwood 1985). The eastern North Pacific stock feeds in California waters from June to November (Calambokidis et al. 1990; Mate et al. 1999). There are nine BIAs for feeding blue whales off the coast of California (Calambokidis et al. 2015), and core areas have also been identified there (Irvine et al. 2014). Although blue whales have been detected acoustically off Oregon (McDonald et al. 1995; Stafford et al. 1998; Von Saunder and Barlow 1999), few sightings have been reported there (Carretta et al. 2016a). Densities along the U.S. west coast including Oregon were predicted to be highest in shelf waters, with lower densities in deeper offshore areas (Becker et al. 2012; Calambokidis et al. 2015). Based on the absolute dynamic topography of the region, blue whales could occur in relatively high densities off Oregon during July–December (Pardo et al. 2015).

Barlow (2010) estimated 442 blue whales for California/Oregon/Washington, based on line-transect surveys conducted during summer and fall 2008. The estimate of population abundance off California/Oregon/Washington based on mark-recapture data collected in 2004–2006 was 2842 (Calambokidis et al. 2007). However, Buchanan et al. (2001) considered blue whales to be rare off Oregon and Washington. Based on surveys conducted in 1991–2008, the estimated abundance of blue whales off the coasts of Oregon/Washington was 58 (Barlow 2010), while the abundance was estimated at 221 blue whales for 2014 (Barlow 2016). One blue whale was observed off Washington in January 2009, in waters ~1000 m deep (Oleson et al. 2012). Five blue whale sightings were reported in the proposed project area off Oregon/Washington during 1991–2008; one sighting occurred within the nearshore portion of the proposed Astoria Fan survey area, and four sightings occurred nearshore, east of the Southern Oregon survey area (Carretta et al. 2016a). Hazen et al. (2016) examined blue whale tag data from 182 individuals along the western U.S. during 1993–2008; multiple tag data tracks were within the proposed project area, particularly between August and November. During aerial surveys over the shelf and slope off Oregon and Washington in 2011 and 2012, one sighting was made off Oregon during February in water deeper than 200 m, and several sightings were made on the Oregon shelf during September–October (Adams et al. 2014).

Blue whales could be encountered within the proposed project area during September.

## (2) Odontocetes

### Sperm Whale (*Physeter macrocephalus*)

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

Sperm whales generally are distributed over large areas that have high secondary productivity and steep underwater topography, in waters at least 1000 m deep (Jaquet and Whitehead 1996; Whitehead 2009). They are often found far from shore, but can be found closer to oceanic islands that rise steeply from deep ocean waters (Whitehead 2009). Adult males can occur in water depths <100 m and as shallow as 40 m (Whitehead et al. 1992; Scott and Sadove 1997). They can dive as deep as ~2 km and possibly deeper on rare occasions for periods of over 1 h; however, most of their foraging occurs at depths of~300–800 m for 30–45 min (Whitehead 2003).

Sperm whales are distributed widely across the North Pacific (Rice 1989). Off California, they are occur year-round (Dohl et al. 1983; Barlow 1995; Forney et al. 1995), with peak abundance from April to mid-June and from August to mid-November (Rice 1974). Off Oregon, sperm whales are seen in every season except winter (Green et al. 1992). Moderate densities have been predicted to occur in the western portions of the proposed project area off Oregon and Washington (Becker et al. 2012). Based on surveys conducted in 1991–2008, the estimated abundance of sperm whales off the coasts of Oregon and Washington was 329 (Barlow 2010). At least five sightings during these surveys were within or adjacent to the Southern Oregon survey area, and one sighting was within the Astoria Fan survey area (Carretta et al. 2016a). Three sperm whale sightings were reported in water depths >2000 m off Oregon/Washington during 2008 (Barlow 2010). The abundance estimate based on survey data from 2014 was 25 individuals (Barlow 2016).

Sightings have been made in deep water of the Astoria Fan survey area, as well as near the Southern Oregon survey area (Green et al. 1992; Becker et al. 2012; Carretta et al. 2016a). During acoustic monitoring off Washington (north of the proposed Astoria Fan survey area) from August 2004 to September 2008, sperm whale calls were detected year-round at an offshore site with a peak occurrence from April to August; at an inshore site, calls were detected from April to November, with one detection in January (Oleson et al. 2009). Oleson et al. (2009) noted a significant diel pattern in the occurrence of sperm whale clicks at the offshore and inshore monitoring locations, whereby clicks were more commonly heard during the day at the offshore site and were more common at night at the inshore location, suggesting possible diel movements up and down slope in search of prey. Sperm whale acoustic detections were also reported at the inshore site from June through January 2009, with an absence of calls during February to May (Ŝirović et al. 2012). In addition, sperm whales were sighted during surveys off Washington in June 2011 and Oregon in October 2011 (Adams et al. 2014).

Sperm whales are most likely to be encountered in the deep waters of the Astoria Fan and Southern Oregon survey areas, particularly along the slope.

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

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

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

Barlow (2010) used data collected in 1991–2008 to estimate an abundance of 229 *Kogia* sp. off Oregon and Washington, all of which were thought to be pygmy sperm whales as no dwarf sperm whales had been identified on the west coast since the early 1970s. No *Kogia* sp. were sighted during surveys off Oregon and Washington in 2014 (Barlow 2016). No pygmy or dwarf sperm whales were reported within the U.S. EEZ off the coast of Oregon or Washington during 1991–2008; however, one sighting was reported in waters outside of the EEZ to the west of Oregon (Carretta et al. 2016a). Norman et al. (2004)

reported eight confirmed stranding records of pygmy sperm whales for Oregon and Washington, five of which occurred during autumn and winter (Norman et al. 2004).

It is possible that pygmy or dwarf sperm whales could be encountered within the proposed project area, although sightings of dwarf sperm whales would be more likely.

### Cuvier's Beaked Whale (*Ziphius cavirostris*)

Cuvier's beaked whale is probably the most widespread of the beaked whales, although it is not found in polar waters (Heyning 1989). Cuvier's beaked whale appears to prefer steep continental slope waters (Jefferson et al. 2015) and is most common in water depths >1000 m (Heyning 1989). It is mostly known from strandings and strands more commonly than any other beaked whale (Heyning 1989). Its inconspicuous blows, deep-diving behavior, and tendency to avoid vessels all help to explain the infrequent sightings (Barlow and Gisiner 2006). The population in the California Current Large Marine Ecosystem seems to be declining (Moore and Barlow 2012).

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

The abundance for Oregon/Washington for 2014 was estimated at 432 (Barlow 2016). The abundance estimate for Oregon and Washington waters, based on data from 1991–2008, was 137 (Barlow 2010). Four beaked whale sightings were reported in water depths >2000 m off Oregon/Washington during surveys in 2008 (Barlow 2010), none was seen in 1996 or 2001 (Barlow 2003), and several were recorded from 1991 to 1995 (Barlow 1997). One Cuvier's beaked whale sighting was made west of the proposed Southern Oregon survey area during the 1991–2008 surveys (Carretta et al. 2016a). One sighting of three individuals was recorded in June 2006 during surveys off Washington during August 2004 through September 2008, north of the Astoria Fan survey area (Oleson et al. 2009). Acoustic monitoring in Washington offshore waters detected Cuvier's beaked whale pulses between January and November 2011 (Ŝirović et al. 2012b *in* USN 2015).

Cuvier's beaked whales could be encountered in deeper slope and offshore waters of the proposed project area.

### Baird's Beaked Whale (*Berardius bairdii*)

Baird's beaked whale has a fairly extensive range across the North Pacific, with concentrations occurring in the Sea of Okhotsk and Bering Sea (Rice 1998; Kasuya 2009). In the eastern Pacific, Baird's beaked whale is reported to occur as far south as San Clemente Island, California (Rice 1998; Kasuya 2009). Baird's beaked whales that occur off the U.S. west coast are of the gray form unlike some *Berardius* spp. that are found in Alaska and Japan, which are of the black form, which could be a new species (Morin et al. 2016).

Baird's beaked whale is sometimes seen close to shore where deep water approaches the coast, but its primary habitat is over or near the continental slope and oceanic seamounts (Jefferson et al. 2015). Along the U.S. west coast, Baird's beaked whales have been sighted primarily along the continental slope (Green et al. 1992; Becker et al. 2012; Carretta et al. 2016a) from late spring to early fall (Green et al. 1992). The whales move out from those areas in winter (Reyes 1991). In the eastern North Pacific Ocean, Baird's beaked whales apparently spend the winter and spring far offshore, and in June, they move onto the continental slope, where peak numbers occur during September and October. Green et al. (1992) noted that Baird's beaked whales on the U.S. west coast were most abundant in the summer, and were not sighted in the fall or winter. MacLeod et al. (2006) reported numerous sightings and strandings of *Berardius* spp. off the U.S. west coast.

Green et al. (1992) sighted five groups during 75,050 km of aerial survey effort in 1989–1990 off Washington/Oregon spanning coastal to offshore waters: two in slope waters and three in offshore waters, all in Oregon near the Southern Oregon survey area. Barlow (2010) estimated an abundance of 380 Baird's beaked whales for Oregon/Washington waters, based on survey data collected in 1991–2008. Two groups were sighted during summer/fall 2008 surveys off Washington/Oregon, in waters >2000 m deep (Barlow 2010). During 1991–2008 surveys, several sightings were reported to the south and west of the Southern Oregon survey area, to the west of the Astoria Fan survey area, and within the eastern portion of the Astoria Fan survey area (Carretta et al. 2016a). One Baird's beaked whale was seen off southern Oregon in June 2011 near the 200-m isopleth (Adams et al. 2014). The abundance estimate for 2014 was 6314 (Barlow 2016). Predicted density modeling showed higher densities in slope waters off northern Oregon, near the Astoria Fan survey area, compared with southern Oregon (Becker et al. 2012).

Acoustic monitoring offshore Washington detected Baird's beaked whale pulses during January and November 2011, with peaks in February and July (Ŝirović et al. 2012b *in* USN 2015). Keating et al. (2015) analysed cetacean whistles recorded during 2000–2012; two acoustic detections of Baird's beaked whales were recorded west of the Astoria Fan and Southern Oregon survey areas. One whale stranded in Washington in 2003, with the cause of death attributed to a ship strike (Carretta et al. 2016a).

Baird's beaked whales could be encountered in deeper slope and offshore waters of the proposed project area.

### Blainville's Beaked Whale (*Mesoplodon densirostris*)

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

Blainville's beaked whale is unlikely to be encountered in the proposed project area, as its main distribution occurs to the south.

### Stejneger's Beaked Whale (*Mesoplodon stejnegeri*)

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

Washington (Norman et al. 2004). Stejneger's beaked whale calls were detected during acoustic monitoring offshore Washington between January and June 2011, with an absence of calls from mid-July to November 2011 (Ŝirović et al. 2012b *in* USN 2015).

Stejneger's beaked whale could be encountered in the proposed project area.

### Hubb's Beaked Whale (*Mesoplodon carlhubbsi*)

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

Hubb's beaked whale could be encountered in the proposed project area.

### Common Bottlenose Dolphin (*Tursiops truncatus*)

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

Bottlenose dolphins occur frequently off the coast of California, and sightings have been made as far north as 41ºN, but few records exist for Oregon/Washington (Carretta et al. 2016a). Three sightings and one stranding of bottlenose dolphins have been documented in Puget Sound since 2004 (Cascadia Research 2011 *in* USN 2015). It is possible that offshore bottlenose dolphins could be encountered in the proposed survey area during warm-water periods (see Carretta et al. 2016a), although none have been sighted in waters off Oregon (Barlow 2010). Adams et al. (2104) made one sighting in Washington, to the north of the Astoria Fan survey area, during September 2012.

Bottlenose dolphins are unlikely to be encountered during the proposed project.

### Striped Dolphin (*Stenella coeruleoalba*)

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

The abundance of striped dolphins off the U.S. west coast appears to be variable among years and could be affected by oceanographic conditions (Carretta et al. 2016a). Striped dolphins regularly occur off California (Becker et al. 2012), where they are seen 185–556 km from the coast (Carretta et al. 2016a). Very few sightings have been made off Oregon (Barlow 2016), and no sightings have been reported for Washington (Carretta et al. 2016a). However, strandings have occurred along the coasts of Oregon and Washington (Carretta et al. 2016a). During surveys off the U.S. west coast in 2014, striped dolphins were seen as far north as 44ºN; based on those sightings, Barlow (2016) calculated an abundance estimate of 13,171 striped dolphins for the Oregon/Washington region. The abundance estimates for 2001, 2005, and 2008 were zero (Barlow 2016). Becker et al. (2012) predicted densities of zero in the proposed project area.

There are 10 stranding records for Oregon and two for Washington during 1930–2002 (Norman et al. 2004), and one stranding in Oregon in 2006 (Carretta et al. 2016a). From 2003–2013, 14 striped dolphin strandings were reported for Oregon and two for Washington (Barre 2014 *in* USN 2015). In January 2016, one dolphin was found stranded on Cannon Beach, Oregon (east of the Astoria Fan survey area), and one washed up in Ocean Park, Washington, northeast of the Astoria Fan survey area (Blackman and Vespa 2016).

Striped dolphins are unlikely to be encountered during the proposed project.

#### Short-beaked Common Dolphin (*Delphinus delphis*)

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

The distribution of short-beaked common dolphins along the U.S. west coast is variable and likely related to oceanographic changes (Heyning and Perrin 1994; Forney and Barlow 1998). It is the most abundant cetacean off California; however, few sightings have been made off Oregon, and no sightings exist for Washington waters (Carretta et al. 2016a). During surveys in 1991–2008, one sighting was made within the Astoria Fan survey area, and several records exist southwest of the Southern Oregon survey area (Carretta et al. 2016a). During surveys off the west coast in 2014, sightings were made as far north as 44°N (Barlow 2014). Based on the absolute dynamic topography of the region, short-beaked common dolphins could occur in relatively high densities off Oregon during July–December (Pardo et al. 2015). In contrast, habitat modeling predicted moderate densities of common dolphins off the Columbia River mouth during summer, with lower densities off southern Oregon (Becker et al. 2014).

Short-beaked common dolphins could be encountered within the proposed project area.

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

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

Results of recent aerial and shipboard surveys strongly suggest seasonal north–south movements of the species between California and Oregon/Washington; the movements apparently are related to oceanographic influences, particularly water temperature (Green et al. 1993; Forney and Barlow 1998; Buchanan et al. 2001). During winter, this species is most abundant in California slope and offshore areas; as northern waters begin to warm in the spring, it appears to move north to slope and offshore waters off Oregon/Washington (Green et al. 1992, 1993; Forney 1994; Forney et al. 1995; Buchanan et al. 2001; Barlow 2003). The highest encounter rates off Oregon and Washington have been reported during

March–May in slope and offshore waters (Green et al. 1992). Similarly, Becker et al. (2014) predicted relatively high densities off southern Oregon in shelf and slope waters.

Based on year-round aerial surveys off Oregon/Washington, the Pacific white-sided dolphin was the most abundant cetacean species, with nearly all (97%) sightings occurring in May (Green et al. 1992, 1993). Barlow (2003) also found that the Pacific white-sided dolphin was one of the most abundant marine mammal species off Oregon/Washington during 1996 and 2001 ship surveys, and it was the second most abundant species reported during 2008 surveys (Barlow 2010). Sightings have been made throughout the proposed project area, including the Astoria Fan and Southern Oregon survey area, during summer and fall (Forney 2007; Barlow 2010; Becker et al. 2014; Carretta et al. 2016a). Numerous Pacific white-sided dolphin sightings occurred during surveys offshore Washington during August 2004 to September 2008, north of the Astoria Fan survey area (Oleson et al. 2009). Oleson et al. (2009) also detected calls from June through March off Washington, with a notable absence of detections during April and May. Adams et al. (2014) also reported numerous offshore sightings off Oregon during summer, fall, and winter surveys in 2011 and 2012, including in the Southern Oregon survey area during September. Based on surveys conducted during 2014, the abundance was estimated at 20,711 for Oregon/Washington (Barlow 2016).

Fifteen sightings of 231 individuals were made from the *Langseth* seismic vessel off Washington/Oregon during June–July 2012 (RPS 2012b); sightings were made in the Astoria Fan and Southern Oregon survey areas. Nine sightings of 182 individuals were seen from the *Langseth* seismic vessel off the coast of Washington during July 2012 (RPS 2012a); sightings were made just to the north of the Astoria Fan survey area. In addition, 6 sightings totaling 280 individuals occurred from the *Northern Light* during a survey off southern Washington during July 2012 (RPS 2012a); some sightings were made in the Astoria Fan survey area, but most of the survey effort occurred farther north.

Pacific white-sided dolphins are likely to be encountered in the proposed project area during September.

#### Northern Right Whale Dolphin (*Lissodelphis borealis*)

The northern right whale dolphin is found in cool temperate and sub-arctic waters of the North Pacific, from the Gulf of Alaska to near northern Baja California, ranging from 30°N to 50°N (Reeves et al. 2002). In the eastern North Pacific Ocean, including waters off Oregon, the northern right whale dolphin is one of the most common marine mammal species, occurring primarily in shelf and slope waters ~100 to >2000 m deep (Green et al. 1993; Barlow 2003). The northern right whale dolphin comes closer to shore where there is deep water, such as over submarine canyons (Reeves et al. 2002).

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

Becker et al. (2014) predicted relatively high densities off southern Oregon, and moderate densities off northern Oregon and Washington. Based on year-round aerial surveys off Oregon/Washington, the northern right whale dolphin was the third most abundant cetacean species, concentrated in slope waters but also occurring in water out to ~550 km offshore (Green et al. 1992, 1993). Barlow (2003, 2010) also found that the northern right whale dolphin was one of the most abundant marine mammal species off Oregon/Washington during 1996, 2001, 2005, and 2008 ship surveys. Several sightings were within and near the Astoria Fan and Southern Oregon survey areas during the summer and fall during surveys off California, Oregon and Washington (Forney 2007; Barlow 2010; Becker et al. 2012; Carretta et al. 2016a). Three sighting locations (59 individuals) were located north of the Astoria Fan survey area, at a mean distance offshore Washington of 56 km in a mean water depth of 964 m during surveys from August 2004 to September 2008 (Oleson et al. 2009). Offshore sightings were made in the waters of Oregon during summer, fall, and winter surveys in 2011 and 2012, including several in and near the Astoria Fan survey area during September and October (Adams et al. 2014). Barlow (2016) provided an abundance estimate of 54,604 northern right whale dolphins based on 2014 surveys.

During a survey off Washington/Oregon June–July 2012, seven sightings of 231 individuals were made from the *Langseth* seismic vessel (RPS 2012b), including near the Southern Oregon survey area. Five sightings of 217 individuals were made from the *Langseth* seismic vessel off the southern coast of Washington during July 2012 (RPS 2012a); some sightings were made in the Astoria Fan survey area, but most of the survey effort occurred farther north. In addition, three sightings totaling 61 individuals occurred from the *Northern Light* during a survey off southern Washington during July 2012 (RPS 2012a); the sightings were made north of the Astoria Fan survey area.

Northern right whale dolphins are likely to be encountered within the proposed project area during September.

#### Risso's Dolphin (*Grampus griseus*)

Risso's dolphin is distributed worldwide in temperate and tropical oceans (Baird 2009), although it shows a preference for mid-temperate waters of the shelf and slope between 30° and 45° (Jefferson et al. 2014). Although it is known to occur in coastal and oceanic habitats (Jefferson et al. 2014), it appears to prefer steep sections of the continental shelf, 400–1000 m deep (Baird 2009), and is known to frequent seamounts and escarpments (Kruse et al. 1999). Off the U.S. west coast, Risso's dolphin is believed to make seasonal north-south movements related to water temperature, spending colder winter months off California and moving north to waters off Oregon–Washington during the spring and summer as northern waters begin to warm (Green et al. 1992, 1993; Buchanan et al. 2001; Barlow 2003; Becker 2007).

The distribution and abundance of Risso's dolphin is highly variable from California to Wahsington, presumably in response to changing oceanographic conditions on both annual and seasonal time scales (Forney and Barlow 1998; Buchanan et al. 2001). The highest densities were predicted along the coasts of Washington, Oregon, and central and southern California (Becker et al. 2012). Off Oregon and Washington, Risso's dolphins are most abundant over continental slope and shelf waters during spring and summer, less so during fall, and rare during winter (Green et al. 1992, 1993). Green et al. (1992, 1993) reported most Risso's dolphin groups off Oregon between ~45 and 47ºN. Several sightings were made east and south of the Southern Oregon survey area during surveys in 1991–2008, and at least nine sightings occurred within or near the Astoria Fan survey area (Carretta et al. 2016a). One sighting was southeast of the Astoria Fan survey area during the 2005 survey year (Forney 2007). Sightings during ship surveys in summer/fall 2008 were mostly between ~30 and 38ºN; none were reported in Oregon/Washington (Barlow 2010). Based on 2014 survey data, the abundance for Oregon/Washington was estimated at 430 (Barlow 2016)

Two sightings of 38 individuals were recorded north of the Astoria Fan survey area during surveys conducted offshore Washington from August 2004 to September 2008, at a mean distance from shore and water depth of 34 km and 129 m, respectively (Oleson et al. 2009). Risso's dolphins were sighted off Oregon, including near the Astoria Fan and Southern Oregon survey areas, in June and October 2011 (Adams et al. 2014). Two sightings of 21 individuals were made from the *Langseth* seismic vessel off the coast of Washington during July 2012 (RPS 2012a); sightings were made to the east and to the north of the Astoria Fan survey area. In addition, one group of 10 dolphins was seen from the *Northern Light* during a survey off southern Washington during July 2012 (RPS 2012a); sightings were made north of the Astoria Fan survey area.

Risso's dolphin could be encountered within the proposed project area during September.

### False Killer Whale (*Pseudorca crassidens*)

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

False killer whales are unlikely to be encountered during the proposed project.

### Killer Whale (*Orcinus orca*)

The killer whale is cosmopolitan and globally fairly abundant; it has been observed in all oceans of the world (Ford 2009). It is very common in temperate waters and also frequents tropical waters, at least seasonally (Heyning and Dahlheim 1988). Currently, there are eight killer whale stocks recognized in the Pacific U.S.: (1) Alaska Residents, occurring from southeast Alaska to the Aleutians and Bering Sea; (2) Northern Residents, from BC through parts of southeast Alaska; (3) Southern Residents, mainly in inland waters of Washington State and southern BC; (4) Gulf of Alaska, Aleutians, and Bering Sea Transients, from Prince William Sound (PWS) through to the Aleutians and Bering Sea; (5) AT1 Transients, from PWS through the Kenai Fjords; (6) West Coast Transients, from California through southeast Alaska; (7) Offshore, from California through Alaska; and (8) Hawaiian (Carretta et al. 2016a). Individuals from the Southern Resident, Offshore, and West Coast Transient stocks could be encountered in the proposed project area (see Carretta et al. 2016a).

Green et al. (1992) noted that most groups seen during their surveys off Oregon and Washington were likely transients; during those surveys, killer whales were sighted only in shelf waters. Several sightings have been made within or near the Astoria Fan and Southern Oregon survey areas during 1991–2008 surveys off California, Oregon and Washington (Forney 2007; Barlow 2010; Carretta et al. 2016a). Eleven sightings of ~536 individuals were reported off Oregon/Washington during the 2008 survey (Barlow 2010). The abundance estimate for 2014 was estimated at 19 killer whales for Oregon/ Washington (Barlow 2016).

Killer whales were sighted north of the Astoria Fan survey area, offshore Washington, during surveys from August 2004 to September 2008, at a mean of 36 km from shore and 342 m watch depth (Oleson et al. 2009). Keating et al. (2015) analysed cetacean whistles from recordings made during 2000–2012; several killer whale acoustic detections were made within or near the Astoria Fan survey area. Killer whales were sighted near the Astoria Fan survey area in July and September 2012 (Adams et al. 2014). Six of the 17 (35%) stranded killer whales in Washington and Oregon were confirmed as southern residents (Osborne 1999 *in* Norman et al. 2004), and two of the stranded killer whales in Oregon were confirmed as transient (Stevens et al. 1989 *in* Norman et al. 2004).

Killer whales could be encountered within the proposed project area during September.

### Short-finned Pilot Whale (*Globicephala macrorhynchus*)

The short-finned pilot whale is found in tropical, subtropical, and warm temperate waters (Olson 2009); it is seen as far south as ~40ºS and as far north as ~50ºN (Jefferson et al. 2015). Pilot whales are generally nomadic, but may be resident in certain locations, including California and Hawaii (Olson 2009). Short-finned pilot whales were common off southern California (Dohl et al. 1980) until an El Niño event occurred in 1982–1983 (Carretta et al. 2016a). Few sightings were made off California/ Oregon/Washington in 1984–1992 (Green et al. 1992; Carretta and Forney 1993; Barlow 1997), and sightings remain rare (Barlow 1997; Buchanan et al. 2001; Barlow 2010). No short-finned pilot whales were seen during surveys off Oregon and Washington in 1989–1990, 1992, 1996, and 2001 (Barlow 2003). A few sightings were made off California during surveys in 1991–2008 (Barlow 2010). Carretta et al. (2016a) reported two sightings off Oregon during 1991–2008, both near the southern portion of the Astoria Fan survey area. Several stranding events in Oregon/southern Washington have been recorded over the past few decades, including March 1996, June 1998, and August 2002 (Norman et al. 2004).

Short-finned pilot whales are unlikely to be encountered during the proposed project.

### 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. Based on genetic data and density discontinuities, six stocks have been identified in California/Oregon/Washington: (1) Washington Inland Waters, (2) Northern Oregon/Washington Coast, (3) Northern California/Southern Oregon, (4) San Francisco-Russian River, (5) Monterey Bay, and (6) Morro Bay (Carretta et al. 2016a). Harbor porpoises from the Northern Oregon/Washington and the Northern California/Southern Oregon stocks could occur in the proposed project area (Carretta et al. 2016a).

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

Oregon/Washington, with very low densities beyond the 500-m isobath (Menza et al. 2016).

Oleson et al. (2009) reported 114 harbor porpoise sightings northeast of the Astoria Fan survey area, during August 2004 and September 2008, with a mean distance from the coast of 10 km and a mean water depth of 31 m. Sightings during the fall were significantly closer to shore, in shallower water, and farther from the shelf edge than during the summer (Oleson et al. 2009). Nearly 100 sightings were reported within or east of the proposed project area during aerial surveys in 2007–2012 (Forney et al. 2014). Adams et al. (2014) also reported numerous nearshore sightings during summer, fall, and winter surveys in 2011 and 2012. Two sightings of nine individuals were made from the *Langseth* seismic vessel off the southern coast of Washington during July 2012 (RPS 2012b); all sightings occurred nearshore and to the east of the Astoria Fan survey area.

In Oregon, harbor porpoises strand most commonly along the northern and central portions of the state, and strandings are concentrated within Puget Sound in Washington (Norman et al. 2004). During 1930–2002, there were 303 reported harbor porpoise strandings within these two states, with 162 in Oregon and 141 in Washington (Norman et al. 2004). Harbor porpoises stranded at ~20 locations along the Oregon and Washington coasts, east of the proposed project area, during an unusual mortality event in the U.S. Pacific northwest in 2006–2007 (Huggins et al. 2015b). There were ~20 harbor porpoise strandings per year along both the Oregon and Washington coasts during 2007–2011, with the exception of over 40 strandings in Washington in 2011 (Huggins et al. 2015b). Huggins et al. (2015a) observed 12 stranded harbor porpoises during beach surveys conducted between ~46.7º–47.3ºN (northeast of the Astoria Fan survey area) during 2006–2011, with one to five strandings observed per year during this period.

Given their preference for coastal waters, harbor porpoises could be encountered in shallower water in the easternmost portions of the proposed project area.

### Dall's Porpoise (*Phocoenoides dalli*)

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

Off Oregon and Washington, Dall's porpoise is widely distributed over shelf and slope waters, with concentrations near shelf edges, but is also commonly sighted in pelagic offshore waters (Morejohn 1979; Green et al. 1992; Becker et al. 2014; Carretta et al. 2016a). Combined results of various surveys out to ~550 km offshore indicate that the distribution and abundance of Dall's porpoise varies between seasons and years. North–south movements are believed to occur between Oregon/Washington and California in response to changing oceanographic conditions, particularly temperature and distribution and abundance of prey (Green et al. 1992, 1993; Mangels and Gerrodette 1994; Barlow 1995; Forney and Barlow 1998; Buchanan et al. 2001). Becker et al. (2014) predicted high densities off southern Oregon throughout the year, with moderate densities to the north. According to predictive density distribution maps, the highest densities off southern Washington and Oregon occur along the 500-m isobath (Menza et al. 2016). Barlow (2016) provided an abundance estimate of 16,294 for waters off Oregon/Washington in 2014.

Encounter rates reported by Green et al. (1992) during aerial surveys off Oregon/Washington were highest in fall, lowest during winter, and intermediate during spring and summer. Encounter rates during the summer were similarly high in slope and shelf waters, and somewhat lower in offshore waters (Green et al. 1992). Dall's porpoise was the most abundant species sighted off Oregon/Washington during 1996, 2001, 2005, and 2008 ship surveys up to ~550 km from shore (Barlow 2003, 2010), with numerous other sightings within and near the Astoria Fan and Southern Oregon survey areas during the summer and fall (Becker et al. 2014; Carretta et al. 2016a). Oleson et al. (2009) reported 44 sightings of 206 individuals north of the Astoria Fan survey area off Washington during surveys form August 2004 to September 2008, at a mean distance from shore of 46 km in a mean water depth of 501 m. Dall's porpoise were seen in the waters off Oregon during summer, fall, and winter surveys in 2011 and 2012, including near the Southern Oregon survey area during September (Adams et al. 2014). During a survey off Washington/ Oregon June–July 2012, 19 sightings of 144 individuals were made from the *Langseth* seismic vessel (RPS 2012b), including within the Astoria Fan and Southern Oregon survey areas. Nine sightings of 32 individuals were made from the *Langseth* seismic vessel off the southern coast of Washington during July 2012 (RPS 2012b), including a sighting within the Astoria Fan survey area. Dall's porpoise strandings were reported in every month in Washington and Oregon, with the highest numbers in spring (44%) and summer (34%; Norman et al. 2004). During 1930–2002, there were 107 stranding records in the region, with 14 in Oregon and 93 in Washington (Norman et al. 2004).

Dall's porpoises are likely to be encountered within the proposed project area during September.

## (3) Pinnipeds

### Northern Fur Seal (*Callorhinus ursinus*)

The northern fur seal is endemic to the North Pacific Ocean and occurs from southern California to the Bering Sea, Sea of Okhotsk, and Sea of Japan (Jefferson et al. 2015). The worldwide population of northern fur seals has declined from a peak of ~2.1 million in the 1950s to the present population estimate of 648,534 (Muto et al. 2016). They were subjected to large-scale harvests on the Pribilof Islands to supply a lucrative fur trade. Two stocks are recognized in U.S. waters: the Eastern Pacific and the California stocks. The Eastern Pacific stock ranges from southern California during winter to the Pribilof Islands and Bogoslof Island in the Bering Sea during summer (Carretta et al. 2016a; Muto et al. 2016). Abundance of the Eastern Pacific Stock has been decreasing at the Pribilof Islands since the 1940s and increasing on Bogoslof Island. The California stock is much smaller, estimated at 14,050 (Carretta et al. 2016a).

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

The northern fur seals spends ~90% of its time at sea, typically in areas of upwelling along the continental slopes and over seamounts (Gentry 1981). The remainder of its life is spent on or near rookery islands or haulouts. The main breeding season is in July (Gentry 2009). Adult males usually occur on shore from May to August, though some may be present until November; females are usually found ashore from June to November (Carretta et al. 2016a). While at sea, northern fur seals usually occur singly or in pairs, although larger groups can form in waters rich with prey (Antonelis and Fiscus 1980; Gentry 1981). Northern fur seals dive to relatively shallow depths to feed: 100–200 m for females, and <400 m for males (Gentry 2009). Tagged adult female fur seals were shown to remain within 200 km of the shelf break (Pelland et al. 2014).

Bonnell et al. (1992) noted the presence of northern fur seals year-round off Oregon/Washington, with the greatest numbers (87%) occurring in January–May. Northern fur seals were seen as far out from the coast as 185 km, and numbers increased with distance from land; they were 5–6 times more abundant in offshore waters than over the shelf or slope (Bonnell et al. 1992). The highest densities were seen in the Columbia River plume (~46°N) and in deep offshore waters (>2000 m) off central and southern Oregon (Bonnell et al. 1992). The waters off Washington are a known foraging area for adult females, and concentrations of fur seals were also reported to occur near Cape Blanco, Oregon, at ~42.8°N (Pelland et al. 2014). Tagged adult fur seals were tracked from the Pribilof Islands to the waters off Washington/Oregon/California, with recorded movement throughout the proposed project area (Pelland et al. 2014). During a survey off Washington/Oregon June–July 2012, 31 sightings of 63 individuals were made from the *Langseth* seismic vessel (RPS 2012b); including in deep water near the Southern Oregon survey area and north of the Astoria Fan survey area. Five sightings of individual fur seals occurred from the *Northern Light* during a survey off southern Washington during July 2012 (RPS 2012a); sightings were made north of the Astoria Fan survey area.

Northern fur seals could be encountered in the proposed project area in September.

### California Sea Lion (*Zalophus californianus*)

The primary range of the California sea lion includes the coastal areas and offshore islands of the eastern North Pacific Ocean from BC, Canada, to central Mexico, including the Gulf of California (Jefferson et al. 2015). However, its distribution is expanding (Jefferson et al. 2015), and its secondary range extends into the Gulf of Alaska where it is occasionally recorded (Maniscalco et al. 2004) and southern Mexico (Gallo-Reynoso and Solórzano-Velasco 1991). California sea lion rookeries are on islands located in southern California, western Baja California, and the Gulf of California (Carretta et al. 2016a). Five genetically distinct geographic populations have been identified: (1) Pacific Temperate (includes rookeries in U.S. waters and the Coronados Islands to the south), (2) Pacific Subtropical, (3) Southern Gulf of California, (4) Central Gulf of California, and (5) Northern Gulf of California (Schramm et al. 2009). Animals from the Pacific Temperate population occur in the proposed project area.

In California and Baja California, births occur on land from mid-May to late June. Females are ready to breed and actively solicit mates ~3 weeks after giving birth (Odell 1984; Trillmich 1986). During August and September, after the mating season, the adult males migrate northward to feeding areas in Oregon, Washington, and BC (Lowry et al. 1992). They remain there until spring (March–May), and then migrate back to the breeding colonies (Lowry et al. 1992; Weise et al. 2006). The distribution of juvenile California sea lions is less well known, but some make northward migrations that are shorter in length than the migrations of adult males (Huber 1991). Most females and pups remain near the rookeries for most of the year (Lowry et al. 1992).

California sea lions are coastal animals that often haul out on shore throughout the year. Off Oregon and Washington, peak numbers occur during the fall. During aerial surveys off the coasts of Oregon and Washington during 1989–1990, California sea lions were sighted at sea during the fall and winter, but no sightings were made during June–August (Bonnell et al. 1992). Numbers off Oregon decrease during winter, as animals travel further north (Mate 1975 *in* Bonnell et al. 1992). King (1983) noted that sea lions are rarely found more than 16 km offshore. During fall and winter surveys off Oregon and Washington, mean distance from shore was ~13 km and most were observed in water <200 m deep; however, sightings were made in water as deep as 356 m (Bonnell et al. 1992). Weise et al. (2006) reported that males normally forage almost exclusively over the continental shelf, but during anomalous climatic conditions they can forage farther out to sea (up to 450 km offshore). Adams et al. (2014) reported sightings more than 60 km off the coast of Oregon.

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

California sea lions could be encountered in the proposed project area in September.

#### Steller Sea Lion (*Eumetopias jubatus*)

The Steller sea lion ranges along the North Pacific Rim from northern Japan to California (Loughlin et al. 1984). There are two DPSs of Steller sea lions – the Western and the Eastern DPS (NMFS 2017). The Eastern DPS was listed as *threatened* under the ESA but was delisted in 2013 (NMFS 2013b). Rookeries of Steller sea lions from the Eastern DPS are located in southeast Alaska, BC, Oregon, and California; there are no rookeries in Washington (NMFS 2013c; Muto et al. 2016). Breeding adults occupy rookeries from late May to early July (NMFS 2008a). Males arrive at rookeries in May to establish their territory and are soon followed by females. Non-breeding adults use haulouts or occupy sites at the periphery of rookeries during the breeding season (NMFS 2008a). Pupping occurs from mid-May to mid-July (Pitcher and Calkins 1981) and peaks in June (Pitcher et al. 2002).

Territorial males fast and remain on land during the breeding season (NMFS 2008a). Andrews et al. (2001) estimated that females foraged for generally brief trips (7.1–25.6 h) around rookeries, spending 49–76% of their time at the rookeries. Females with pups feed principally at night during the breeding season and generally stay within 30 km of the rookeries in shallow (30–120 m) water (NMFS 2008a). Steller sea lion pups enter the water 2–4 weeks after birth (Sandegren 1970 *in* Raum-Suryan et al. 2002), but do not tend to move from their natal rookeries to haulouts with their mothers until they are 2–3 months old (Merrick et al. 1988 *in* Raum-Suryan et al. 2002). Tagged juvenile sea lions showed localized movements near shore (Briggs et al. 2005). During the non-breeding season, sea lions may disperse great distances from the rookeries (e.g., Mathews 1996; Raum-Suryan 2001).

Steller sea lions typically inhabit waters from the coast to the outer continental shelf and slope throughout their range; they are not considered migratory, although foraging animals can travel long distances (Loughlin et al. 2003; Raum-Suryan et al. 2002). Loughlin et al. (2003) reported that most (88%) of 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).

Three rookeries and seven haul-out sites are located in Oregon (NMFS 2008a). Two rookeries in southern Oregon, Orford Reef and Rogue Reef, are designated as critical habitat; the rookey in northern Oregon, Three Arch Rocks, is not. Several haul-out sites are also located in Washington (NMFS 2008a). Jeffries et al. (2000) identified four haul-out sites in the Split Rock area (47.4°N) in Washington; animals at these haulout locations are assumed to be immatures and non-breeding adults associated with rookeries in Oregon and BC (Pitcher et al. 2007). The mean count of non-pups at Washington haul-out sites during 2011 was 1749 (Muto et al. 2016). A total of 4761 non-pups and 1418 pups were counted in Oregon during 2013 and 2009, respectively (Muto et al. 2016).

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

Steller sea lions could be encountered in the proposed project areas, especially in the waters closer to shore.

### Harbor Seal (*Phoca vitulina*)

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. richardsi* in the eastern Pacific Ocean. *P.v. richardsi* occurs in nearshore, coastal, and estuarine areas ranging from Baja California, Mexico, north to the Pribilof Islands in Alaska (Carretta et al. 2016a). Five stocks of harbor seals are recognized along the U.S. west coast: (1) Southern Puget Sound, (2) Washington Northern Inland Waters Stock, (3) Hood Canal, (4) Oregon/Washington Coast, and (5) California (Carretta et al. 2016a). The Oregon/Washington stock occurs in the proposed survey area. The most recent estimate for the Oregon/Washington coastal stock is 24,732 (based on counts in 1999), but no best population estimates are currently available (Carretta et al. 2016a).

Harbor seals inhabit estuarine and coastal waters, hauling out on rocks, reefs, beaches, and glacial ice flows. They are generally non-migratory, but move locally with the tides, weather, season, food availability, and reproduction (Scheffer and Slipp 1944; Fisher 1952; Bigg 1969, 1981). Female harbor seals give birth to a single pup while hauled out on shore or on glacial ice flows; pups are born from May to mid-July. When molting, which occurs primarily in late August, seals spend the majority of the time hauled out on shore, glacial ice, or other substrates. Juvenile harbor seals can travel significant distances (525 km) to forage or disperse, whereas adults were generally found within 190 km of their tagging location in Prince William Sound, Alaska (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 Gulf of Alaska 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 Prince William Sound traveled a mean maximum distance of 43.2 km from their tagging location, whereas those tagged in the Gulf of Alaska moved a mean maximum distance of 86.6 km (Small et al. 2005). Most (40–80%) harbor seal dives in the Gulf of Alaska were to depths <20 m and less than 4 min in duration. Dives of 50–150 m were also recorded, as well as dives as deep as ~500 m (Hastings et al. 2004).

Harbor seals haul out on rocks, reefs, and beaches along the U.S. west coast (Carretta et al. 2016a). Jeffries et al. (2000) documented several harbor seal rookeries and haulouts along the Washington coastline; it is the only pinniped species that breeds in Washington. Pupping in Oregon and Washington occurs from April to July (Brown 1988). Bonnell et al. (1992) noted that most harbor seals sighted off Oregon and Washington were ≤20 km from shore, with the farthest sighting 92 km from the coast. Menza et al. (2015) also showed the highest predicted densities nearshore. During surveys off the Oregon and Washington coasts, 88% of at-sea harbor seals occurred over shelf waters <200 m deep, with a few sightings near the 2000-m contour, and only one sighting over deeper water (Bonnell et al. 1992). Most (68%) at-sea sightings were recorded in September and November (Bonnell et al. 1992). Harbor seals were only seen in nearshore areas during surveys on the shelf and slope in 2011 and 2012 (Adams et al. 2014). Twelve sightings occurred from the *Northern Light* during a survey off southern Washington during July 2012 (RPS 2012a); sightings were made in shallower water to the east of the Astoria Fan survey area. Harbor seals were also taken as bycatch east of the Southern Oregon survey area in the west coast groundfish fishery during 2002–2009 (Jannot et al. 2011).

Given their preference for coastal waters, harbor seals could be encountered in the easternmost parts of the proposed project 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). Pupping has also been observed at Shell Island (~43.3°N) off southern Oregon, suggesting a range expansion (Bonnell et al. 1992; Hodder et al. 1998). The California breeding population was estimated at 179,000 in 2010 (Lowry et al. 2014).

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 seasons. Breeding occurs from December to March (Stewart and Huber 1993). Females arrive in late December and January and give birth within ~1 week of their arrival. Pups are weaned after just 27 days and are abandoned by their mothers. Juvenile elephant seals typically leave the rookeries in April or May and head north, traveling an average of 900–1000 km. Hindell (2009) noted that traveling likely takes place at depths >200 m. Most elephant seals return to their natal rookeries when they start breeding (Huber et al. 1991).

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

Off Washington, most elephant seal sightings at sea were during June, July, and September; off Oregon, sightings were recorded from November through May (Bonnell et al. 1992). Several seals were seen off Oregon during summer, fall, and winter surveys in 2011 and 2012, including one near the Southern Oregon survey area during October 2011 (Adams et al. 2014). Five sightings occurred from the *Northern Light* during a survey off southern Washington during July 2012 (RPS 2012a); some sightings were made in the Astoria Fan survey area, but most of the survey effort occurred farther north. Northern elephant seals were also taken as bycatch within the Astoria Fan and Southern Oregon survey areas in the west coast groundfish fishery during 2002–2009 (Jannot et al. 2011).

Northern elephant seals could be encountered in the proposed project area in September.

## Sea Turtles

Since 1985, four species of sea turtles have been documented off the coasts of Oregon and/or Washington: the leatherback (*Dermochelys coriacea*), loggerhead (*Caretta caretta*), green (*Chelonia mydas*), and olive ridley (*Lepidochelys olivacea*) turtles (Green et al. 1992; Bowlby et al. 1994; Buchanan et al. 2001). Under the ESA, the leatherback turtle and the North Pacific Ocean DPS of the loggerhead turtle are listed as ***Endangered***, the olive ridley population on the Pacific coast of Mexico is listed as ***Endangered*** whereas other populations are listed as ***Threatened***, and the East Pacific DPS of the green turtle is listed as ***Threatened***.

The leatherback turtle is the only sea turtle likely to occur in the waters of the proposed project area. The other three species have been documented off the coasts of Oregon or Washington as strandings and are considered extralimital occurrences of those generally warm-water species (Bowlby et al. 1994; Buchanan et al. 2001). Strandings have increased in recent years, particularly for olive ridley sea turtles, possibly due to warmer ocean conditions or El Niño (Boyer 2017). However, green, loggerhead and olive ridley sea turtles are still considered accidental in Oregon (OFWC 2013). Those three species are not addressed further here.

### (1) Leatherback Turtle

The leatherback is the largest and most widely distributed sea turtle, ranging far from its tropical and subtropical breeding grounds to feed (Plotkin 2003). The leatherback turtle is listed as ***Endangered*** under the ESA and is listed in CITES Appendix I (UNEP-WCMC 2017). Globally, the leatherback turtle is designated as ***Vulnerable*** on the IUCN Red List of Threatened Species, but the East Pacific Ocean subpopulation and the West Pacific Ocean subpopulation are considered ***Critically Endangered*** (IUCN 2016). There have been significant declines and some extirpations of nesting populations in the Pacific (Spotila et al. 2000; Dutton et al. 2007). A recent estimate of the North Atlantic population is 34,000–94,000 adults (TEWG 2007), and nesting beaches in the western Pacific have 2700–4500 breeding females (NMFS and USFWS 2013).

The largest remaining nesting sites for leatherbacks in the Pacific Ocean occur on the beaches of Birdshead Peninsula in Papua, Indonesia (Dutton et al. 2007; Hitipeuw et al. 2007; Benson et al. 2008). In the western Pacific, leatherbacks also nest in New Guinea, the Solomon Islands, and Vanuatu, with fewer nesting in Fiji, Malaysia, and Australia (NMFS and USFWS 2013). Nesting leatherbacks have also been discovered in Japan (Kamezaki et al. 2002). In the eastern Pacific, leatherbacks nest along the west coast of Mexico and Central America (Marquez 1990).

Leatherbacks are highly migratory and feed in areas of high productivity, such as convergence zones, and upwelling areas in the open ocean, along continental margins, and in archipelagic waters (Morreale et al. 1994; Eckert 1995). Adult leatherbacks appear to migrate along bathymetric contours from 200 to 3500 m (Morreale et al. 1994). Adults spend the majority of their time in water >1000 m deep and possibly swim more than 10,000 km each year (Eckert 1995). They appear to use the Kuroshio Extension during migrations from Indonesia to the high seas and eastern Pacific (Benson et al. 2008). Frair et al. (1972) and Greer et al. (1973) reported that leatherback turtles have evolved physiological and anatomical adaptations to cold water, allowing them to venture into higher latitudes than other species of turtle. After nesting, female leatherbacks typically migrate from tropical waters to temperate areas, where higher densities of jellyfish occur in the summer (NOAA 2016).

Hatchling leatherbacks are pelagic, but nothing is known about their distribution for the first four years (Musick and Limpus 1997). Leatherback turtles undertake long migrations from the western, central, or South Pacific toward the California Current Large Marine Ecosystem (Block et al. 2011; Bailey et al. 2012). After analyzing some 363 records of sea turtles sighted along the Pacific coast of North America, Stinson (1984) concluded that the leatherback was the most common sea turtle in U.S. waters north of Mexico. Roe et al. (2014) also predicted high densities off the northwest coast of the U.S. from July–December. Sightings and incidental capture data indicate that leatherbacks are found as far north as 60°N, and documented encounters extend southward through the waters of BC, Washington, Oregon, and California (NMFS and USFWS 1998; Green et al. 1992; Bowlby et al. 1994). Leatherbacks occur north of central California during the summer and fall, when sea surface temperatures are highest (Dohl et al. 1983; Brueggeman 1991). Some aerial surveys of California, Oregon, and Washington waters suggest that most leatherbacks occur in continental slope waters and fewer occur over the continental shelf. Satellite tracking has shown that leatherbacks from the western Pacific population travel to Washington and Oregon waters (including the proposed survey area) to feed in continental shelf and slope waters, particularly near the Columbia River Plume; individuals occurred in the area from July through December (Benson et al. 2011). Other sightings have also been made in water 200–2000 m deep in the Astoria Fan survey area and just south of there (Green et al. 1992; Bowlby et al. 1994).

In the Pacific Ocean, Critical Habitat has recently been designated that includes ~108,600 km$^2$ of marine habitat off the U.S. west coast, including an area stretching along the California coast, and an area stretching from Cape Flattery, Washington, to Cape Blanco, Oregon, east of a line approximating the 2000-m depth contour. Both the Astoria Fan and southern Oregon survey sites occur in designated critical habitat.

## Seabirds

Three bird species that are listed under the Endangered Species Act (ESA) could occur in or near the proposed survey areas. Only two of the three species nest in the area. The marbled murrelet (*Brachyramphus marmoratus*) is fairly common or regular along the Pacific Coast, but are unlikely to occur far offshore (beyond 5 km). The marbled murrelet is listed as ***Threatened***. The ***Endangered*** short-tailed albatross (*Phoebastria albatrus*) could occur as a seasonal visitor to the project area. The

***Threatened*** western snowy plover (*Charadrius alexandrinus nivosus*) is a coastal species and would not be encountered offshore.

In addition, the brown pelican is listed as *endangered* by both Washington and Oregon states but was delisted from the ESA in 2009 because of its recovery (USFWS 2009). In Washington, Cassin's auklet and the common murre are candidates for designation by the Washington Department of Fish and Wildlife, and the tufted puffin is considered *endangered* (WDFW 2008). In Oregon, the tufted puffin, rhinoceros auklet, and Cassin's auklet are considered vulnerable sensitive species that, although not currently imperiled with extirpation could become so if threats to populations and habitats were to continue (OBIC 2016).

### (1) Short-tailed Albatross

The short-tailed albatross, which breeds on islands off the coast of Japan and is listed as ***Endangered*** under the ESA, occasionally visits Pacific Coast waters during the non-breeding season. It is listed as ***Vulnerable*** on the IUCN Red List of Threatened Species (IUCN 2016). Historically, millions of short-tailed albatrosses bred in the western North Pacific Ocean on islands off the coast of Japan. This species was the most abundant albatross in the North Pacific. However, the entire population was nearly extirpated during the last century by feather hunters at Japanese breeding colonies. In addition, the breeding grounds of the remaining birds were threatened by volcanic eruptions in the 1930s; this species was believed to be extinct in 1949 until it was rediscovered in 1951 (USFWS 2008). The population is now increasing, and the most recent population estimate is 2406 (USFWS 2008). Current threats to the species include volcanic activity on Torishima, commercial fisheries, and pollutants (USFWS 2008).

Currently, nearly all short-tailed albatrosses breed on two islands off the coast of Japan: Torishima and Minami-kojima (USFWS 2008). Single nests have been found in recent years on other islands, including Kita-Kojima, Senkaku; Yomejima Island; and Midway Island, Hawaii (USFWS 2008). During the breeding season (December to May), the highest densities are found around Japan (BirdLife International 2017); parents forage primarily off the east coast of Honshu Island, where the warm Kuroshio and the cold Oyashio currents meet (USFWS 2008).

During the non-breeding season, short-tailed albatrosses roam much of the North Pacific Ocean; females spend more time offshore from Japan and Russia, whereas males and juveniles spend more time around the Aleutian Islands and Bering Sea (Suryan et al. 2007). Post-breeding dispersal occurs from April through August (USFWS 2008). After leaving the breeding areas, short-tailed albatrosses seem to spend the majority of time within the EEZs of Japan, Russia, and the U.S., primarily in the Aleutian Islands and Bering Sea (Suryan et al. 2007). Most of the short-tailed albatrosses sighted off the Pacific Coast of North America (south to California) are juveniles and sub-adults (USFWS 2008; O'Connor 2013). Satellite-tracked first and second year birds were found in Oregon waters most often during winter and spring, possibly in response to ice conditions in the Bering Sea (O'Connor 2013). They are considered a continental shelf-edge specialist (Piatt et al. 2006). One short-tailed albatross was taken as bycatch in the Astoria Fan survey area during the west coast groundfish fishery in 2002–2009 (Jannot et al. 2011). The short-tailed albatross could be encountered in very small numbers in the proposed project area.

### (2) Western Snowy Plover

The western snowy plover is listed as a ***Threatened*** species under the ESA (USFWS 1993). It is listed as ***Least Concern*** on the IUCN Red List of Threatened Species because of its very large worldwide range (IUCN 2016). However, the Eurasian subspecies of snowy plover has recently been split from the North American population on the basis of calls, morphology, and genetic differences (Chesser et al. 2011). The North American breeding population is thought to be ~18,000 individuals (Page et al. 2009).

In North America, snowy plovers are distributed across the Great Plains, locally along the Gulf Coast, and down the west coasts of Washington, Oregon, and California. The Pacific coastal population of the western snowy plover is threatened by increasing development and disturbance in their breeding and wintering habitat along Pacific coast beaches (Page et al. 2009). This species is strictly coastal, and is not found offshore. The breeding population in Oregon was 337 in 2014 (Lauten et al. 2014); in Washington, it was 33 in 2012 (Pearson et al. 2013).

Breeding habitat includes sandy beaches and dune systems immediately inland from the active beach face as well as salt flats, mud flats, and gravel bars. These areas are above high tides and below heavily vegetated areas, and they have minimal disturbance from humans. Shoreline areas with little or no vegetation that are subject to intermittent inundation are important feeding areas (USFWS 2011). The western snowy plover would be unlikely to occur in the offshore waters of the proposed project area, although they could be sighted in the areas closer to shore.

### (3) Marbled Murrelet

The marbled murrelet was listed as a ***Threatened*** species under the ESA in the southern part of its range (Washington, Oregon, and California) by the USFWS in 1992 (USFWS 1992). It is listed as ***Endangered*** on the IUCN Red List of Threatened Species (IUCN 2016). In January 2010, USFWS published a 12-month finding that a petition to remove the California, Oregon, and Washington population of the marbled murrelet from the Federal List of Endangered and Threatened Wildlife was not warranted (USFWS 2010). The population marbled murrelets in California, Oregon, and Washington has declined by nearly 30% from 23,700 individuals in 2000 to 16,700 individuals in 2010 (Miller et al. 2012). The primary reason for declining populations is the fragmentation and destruction of old-growth forest nesting habitat. Marbled murrelets are also threatened by gillnet fishing, nest predation, and oil spills. They are widespread along the Pacific Coast and generally found in nearshore waters, usually within 5 km of shore (Nelson 1997).

Critical marbled murrelet nesting habitat consists of forest stands containing large trees (greater than 81 cm diameter) with potential nest platforms (including large branches, deformities, mistletoe infestations) at 10 meters in height. High canopy cover is important for nesting murrelets. Feeding habitat for marbled murrelets is mostly within 2 km of shore (outside of the survey area) in waters up to 30 m deep (USFWS 2006). Although they have been observed more than 40 km from shore in water deeper than 200 m (Adams et al. 2014), the mean offshore distance over a three year tracking study was 1.4 km (Hebert and Golightly 2008). Marbled murrelet nesting activities in Washington and Oregon occur between late March and August and they remain in Washington and Oregon waters during the non-breeding season. The single egg is incubated by both adults who alternate incubation duties every 24 h. Upon arrival of the non-incubating individual at dawn, incubating individuals leave the nest to feed at sea and return to the nest the following morning. Marbled murrelets occur in open-ocean habitats after breeding. They feed on small schooling fish and invertebrates in bays and fiords and in the open ocean (Nelson 1997).

During surveys of the Oregon and Washington shelf in October 2011 and September 2012, no marbled murrelets were sighted (Adams et al. 2014). Similarly, predictive density distribution maps for southern Washington indicate that murrelets are unlikely to occur in deeper waters off the coast (Menza et al. 2016). On the California shelf, the highest densities were seen during fall (Adams et al. 2014). During 1989-1990 offshore and coastal counts of marbled murrelets off Oregon and Washington, 71 murrelets were seen during September 1990 but none were seen during September 1989; the September 1990 count was the highest during the surveys which were conducted during all seasons (Briggs et al. 1992). Marbled murrelets would be unlikely to occur in the offshore waters of the proposed project area, although they could be sighted in the areas closer to shore.

## Fish

### (1) ESA-listed Species

The term "species" under the ESA includes species, subspecies, and, for vertebrates only, DPSs or "evolutionarily significant units (ESUs)"; for Pacific salmon, ESUs are essentially equivalent to DPSs for the purpose of the ESA. ESA-listed species that could occur in the proposed project area off Washington and Oregon are the ESUs of chinook, chum, coho, and sockeye salmon and the DPSs of Pacific eulachon, steelhead, and green sturgeon listed in Table 5 (NMFS 2017). Listed critical habitat for salmon and steelhead is in freshwater, whereas listed critical habitat for green sturgeon includes freshwater and coastal bays, estuaries, and marine waters <100 m deep off California, Oregon, Washington, and Alaska (NMFS 2009). Listed critical habitat for the Pacific eulachon includes freshwater and estuarine waters for spawning. Nearshore and offshore foraging habitat are not considered critical habitat (NMFS 2011a).

### (2) Essential Fish Habitat

Essential Fish Habitat (EFH) is identified for only those species managed under a federal Fishery Management Plan (FMP). In Washington and Oregon, there are four FMPs covering groundfish, coastal pelagic species, highly migratory species, and Pacific salmon. The entire western seaboard from the coast to the limits of the EEZ is EFH for one or more species for which EFH has been designated. The proposed project areas encompasses several EFHs.

The Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C.§1801-1882) established Regional Fishery Management Councils and mandated that FMPs be developed to manage exploited fish and invertebrate species responsibly in federal waters of the U.S. When Congress reauthorized the act in 1996 as the Sustainable Fisheries Act, several reforms and changes were made. One change was to charge NMFS with designating and conserving EFH for species managed under existing FMPs.

***Groundfish EFH.***—The Pacific Coast Groundfish FMP manages more than 90 species (160 species/life stage combinations). The FMP provides a description of groundfish EFH for each of the species and their life stages (PFMC 2016a). When the EFH are taken together, the EFH for Pacific Coast groundfish includes all waters and substrate from the mean higher high water level or the upriver extent of saltwater intrusion along the coasts of Washington, Oregon, and California to within water depths <3500 m and seamounts in depths >3500 m (PMFC 2016a). In addition to the EFH parameters mentioned above, there are several distinct EFH Conservation Areas within the proposed project area, including Astoria Canyon and Nehalem Bank/Shale Pile within the Astoria Fan survey area; Bandon High Spot and Deepwater off Coos Bay within the Southern Oregon survey area; and Daisy Bank/Nelson Island and Siletz Deepwater are located between the two survey sites; Heceta Bank is located just to the east of the proposed project area, and Newport Rockpile/Stonewall Bank is located outside of the project area to the east (USGS 2016; NOAA WCR 2017; OOI 2017b). The Astoria Canyon and Deepwater off Coos Bay EFH Conservation Areas overlap the proposed seismic track lines in the Astoria Fan and

TABLE 5. Fish "species" listed under the ESA that could occur in the proposed project area off Washington and Oregon.

| Species | ESU or DPS | Status[1] | Critical Habitat |
|---|---|---|---|
| Pacific eulachon/smelt | Southern DPS | T | Freshwater/estuarine |
| Green sturgeon | Southern DPS | T | Marine/freshwater |
| Chinook salmon | Lower Columbia River | T | Freshwater |
| | Upper Columbia River spring-run | EN | Freshwater |
| | Snake River fall-run | T | — |
| | Snake River spring/summer-run | T | — |
| | Upper Willamette River | T | Freshwater |
| Chum salmon | Columbia River | T | Freshwater |
| Coho salmon | Lower Columbia River | T | Freshwater |
| | Oregon coast | T | Freshwater |
| | S. Oregon and N. California coasts | T | — |
| Sockeye salmon | Ozette Lake | T | Freshwater |
| | Snake River | EN | — |
| Steelhead trout | Lower Columbia River | T | Freshwater |
| | Middle Columbia River | T | Freshwater |
| | Upper Columbia River | EN | Freshwater |
| | Snake River Basin | T | Freshwater |
| | Upper Willamette River | T | Freshwater |

[1] Status under the ESA: EN = Endangered; T = Threatened.

Southern Oregon survey areas, respectively (Fig. 4). These seven EFHs are closed to bottom trawl fishing gear (OOI 2017b).

***Coastal pelagic species EFH.***—The FMP for Pacific coast Coastal Pelagic Species (CPS) includes four finfish (Pacific sardine, Pacific [chub] mackerel, northern anchovy and jack mackerel), market squid and all euphausiids (krill) species that occur in the West Coast EEZ (PFMC 2016b). EFH for these species is defined both through geographic boundaries and by sea-surface temperature ranges. Because of similarities in their life histories and similarities in their habitat requirements, the four CPS finfish are treated as a single species complex for the purposes of EFH. Market squid are also treated in this same complex because they are similarly fished above spawning aggregations. The geographic boundary of EFH for CPS finfish and market squid is defined to be all marine and estuarine waters from the shoreline along the coasts of California, Oregon, and Washington offshore to the limits of the EEZ and above the thermocline where sea surface temperatures range between 10°C and 26°C. The southern extent of the EFH is the U.S.-Mexico boundary. The northern boundary of the range of CPS finfish is the position of the 10°C isotherm which varies both seasonally and annually (PFMC 2016b). EFH for krill (*Thysanoessa spinifera*) extends from the shoreline outwards to a depth of 1000 m, while EFH for *Euphausia pacifica* and other krill species in the area extends from the shoreline to ~2000-m depth in Washington, Oregon, and California (NOAA 2017b). The *E. pacifica*/other sp. and *T. spinifera* krill EFHs overlap with the central and eastern portions of the proposed Astoria Fan survey area, and with the eastern portion of the Southern Oregon survey area (Fig. 5).

***Pacific coast salmon EFH.***—The FMP for Pacific coast salmon includes the coast-wide aggregate of natural and hatchery salmon species that is contacted by salmon fisheries in the EEZ off the coasts of Washington, Oregon, and California (PFMC 2016c). The PFMC manages the fisheries for coho, chinook,

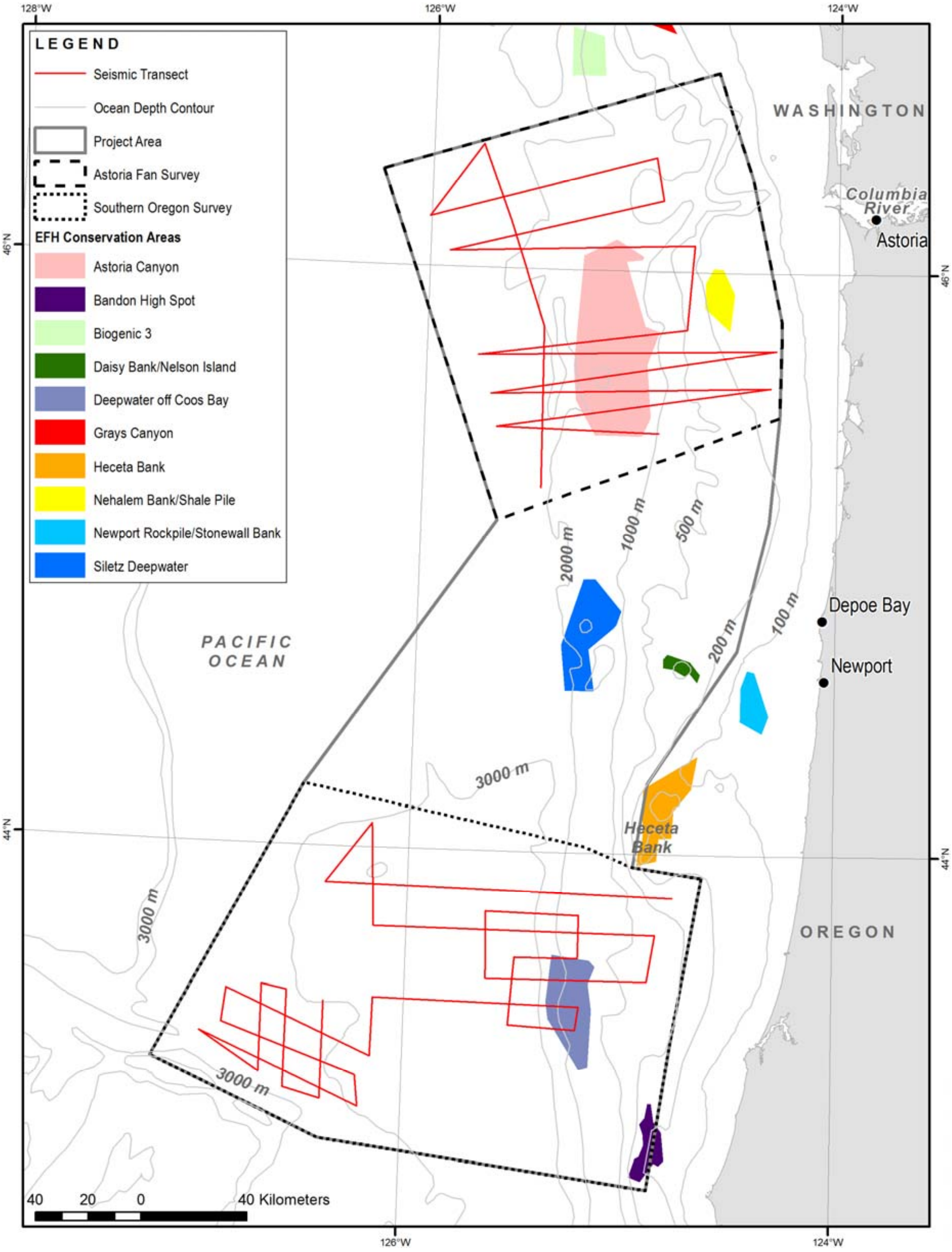


FIGURE 4. EFH for groundfish species in Washington and Oregon. Sources: USGS 2016; NOAA 2017b; NOAA WCR 2017; OOI 2017b.

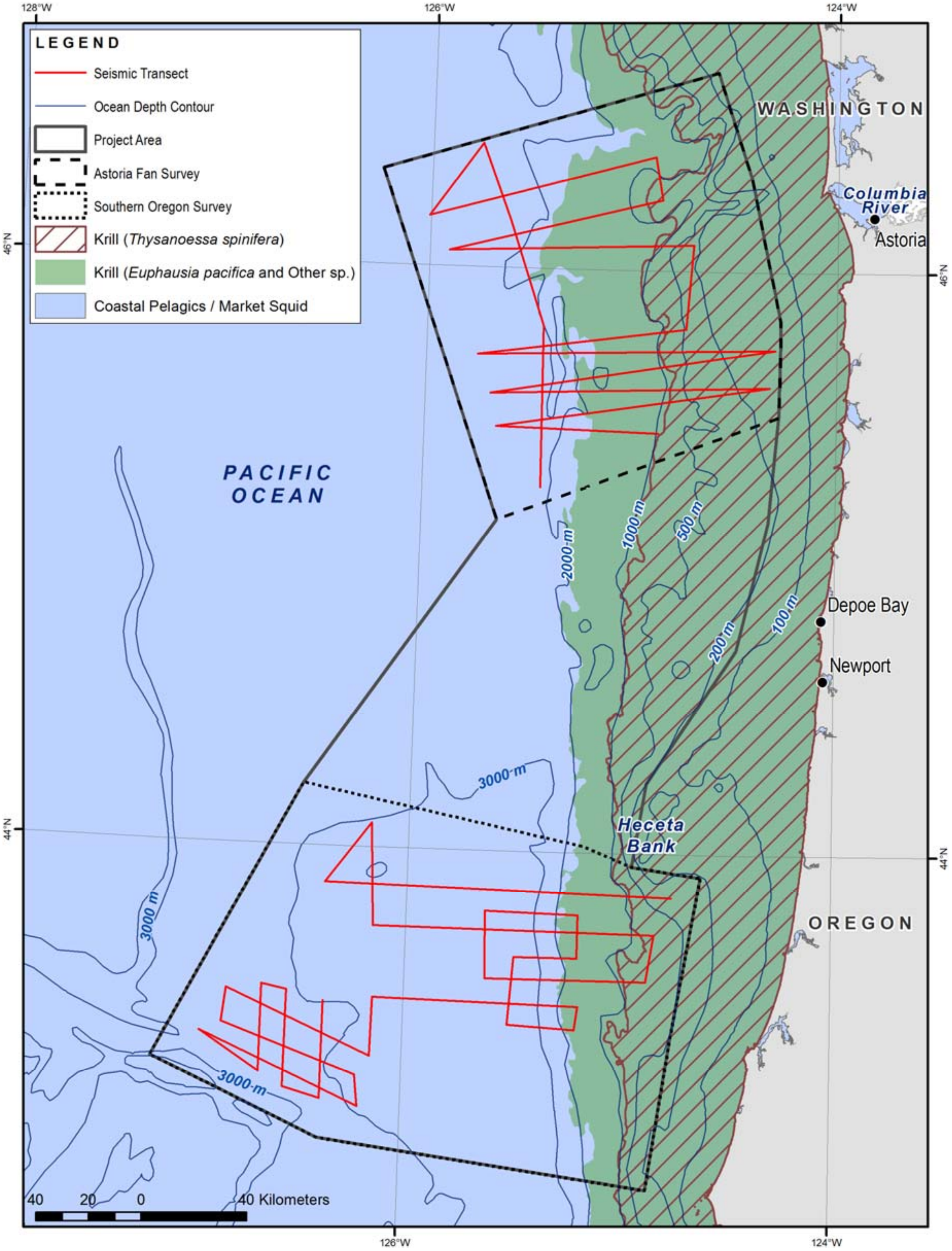


FIGURE 5. EFH for Coastal Pelagic species in Washington and Oregon. Sources: USGS 2016; NOAA 2017b; NOAA WCR 2017; OOI 2017b.

and pink (odd-numbered years) salmon and has defined EFH for these three species. Pacific coast salmon EFH includes marine areas within the EEZ, from the extreme high tide line in nearshore and tidal submerged environments within state territorial waters out to the full extent of the EEZ, along with estuarine and all currently or historically occupied freshwater habitat within the internal waters of Washington, Oregon, Idaho, and California north of Point Conception (PFMC 2016c).

***Highly migratory species EFH.***—The FMP for the U.S. west coast fisheries for highly migratory species includes dorado/dolphinfish and important species of tunas (North Pacific albacore, yellowfin, bigeye, skipjack, and northern bluefin), billfish/swordfish (striped marlin and swordfish), and sharks (common thresher, shortfin mako/bonito and blue) which are harvested by West Coast fisheries (PFMC 2016d). EFH for each life stage of these species is described in the FMP (PFMC 2016d); collectively the highly migratory species EFH extends outwards from near shore (~10 m water depth) to the limit of the EEZ off of Washington, Oregon, and California (NOAA 2017b).

## (3) Habitat Areas of Particular Concern

Habitat Areas of Particular Concern (HAPCs) are a subset of EFH that provide highly important ecological functions or are especially vulnerable to degradation. Rocky reefs are designated as HAPCS in the proposed Astoria Fan and Southern Oregon survey areas, and one area of interest HAPC is within the proposed project area between these two survey sites (Fig. 6; PFMC 2016a):

***Rocky Reefs HAPC.***—The rocky reefs HAPC includes waters, substrates, and other biogenic features associated with hard substrate (bedrock, boulders, cobble, gravel, etc.) to mean higher high water level. The HAPC occurs primarily in Oregon waters 200–2000 m deep. The rocky reefs HAPC in Washington are mostly scattered in <200 m depth, including in the northern portion of the Olympic Coast National Marine Sanctuary and northeastern portion of the Astoria Fan survey area. The majority of the Astoria Fan survey area and the eastern portion of the Southern Oregon survey area are located in the Rocky Reefs HAPC off Oregon (PFMC 2016a).

***Daisy Bank/Nelson Island HAPC.***—Daisy Bank area of interest HAPC is a highly unique geological feature that occurs in Federal waters due west of Newport, Oregon (44°38'N), and appears to play a unique and potentially rare ecological role for groundfish and large invertebrate sponge species. The bank supports more than 600,000 juvenile rockfish per km$^2$. Daisy Bank also appears to support more and larger lingcod and large sponges than other nearby banks (M. Hixon, pers. comm. 2004 *in* PFMC 2016a). The Daisy Bank/Nelson Island HAPC occurs within the proposed project area between the Astoria Fan and Southern Oregon survey sites.

***Washington State waters HAPC.***—The Washington State waters HAPC encompasses all waters and sea bottom in state waters shoreward from the 5.6 km boundary of the territorial sea shoreward to mean higher high water level. The HAPC encompasses a variety of habitats important to groundfish, including other HAPCs such as rocky reef habitat supporting juvenile rockfish (primarily north of 47.2°N). Sandy substrates within state waters (primarily south of 47.2°N) are important habitat for juvenile flatfish. A large proportion of this area is also contained within the Olympic Coast National Marine Sanctuary (PFMC 2016a). The Washington State waters HAPC is located ~20 km east of the proposed Astoria Fan survey area.

***Thomson and President Jackson Seamounts HAPC.***—Seamounts have relatively high biodiversity and up to a third of species occurring on these features may be endemic (de Forges et al. 2000 *in* PFMC 2016a). Currents generated by seamounts retain rockfish larvae and zooplankton, a principal food source for rockfish (Genin et al. 1988, Mullineaux and Mills 1997, Haury et al. 2000, and

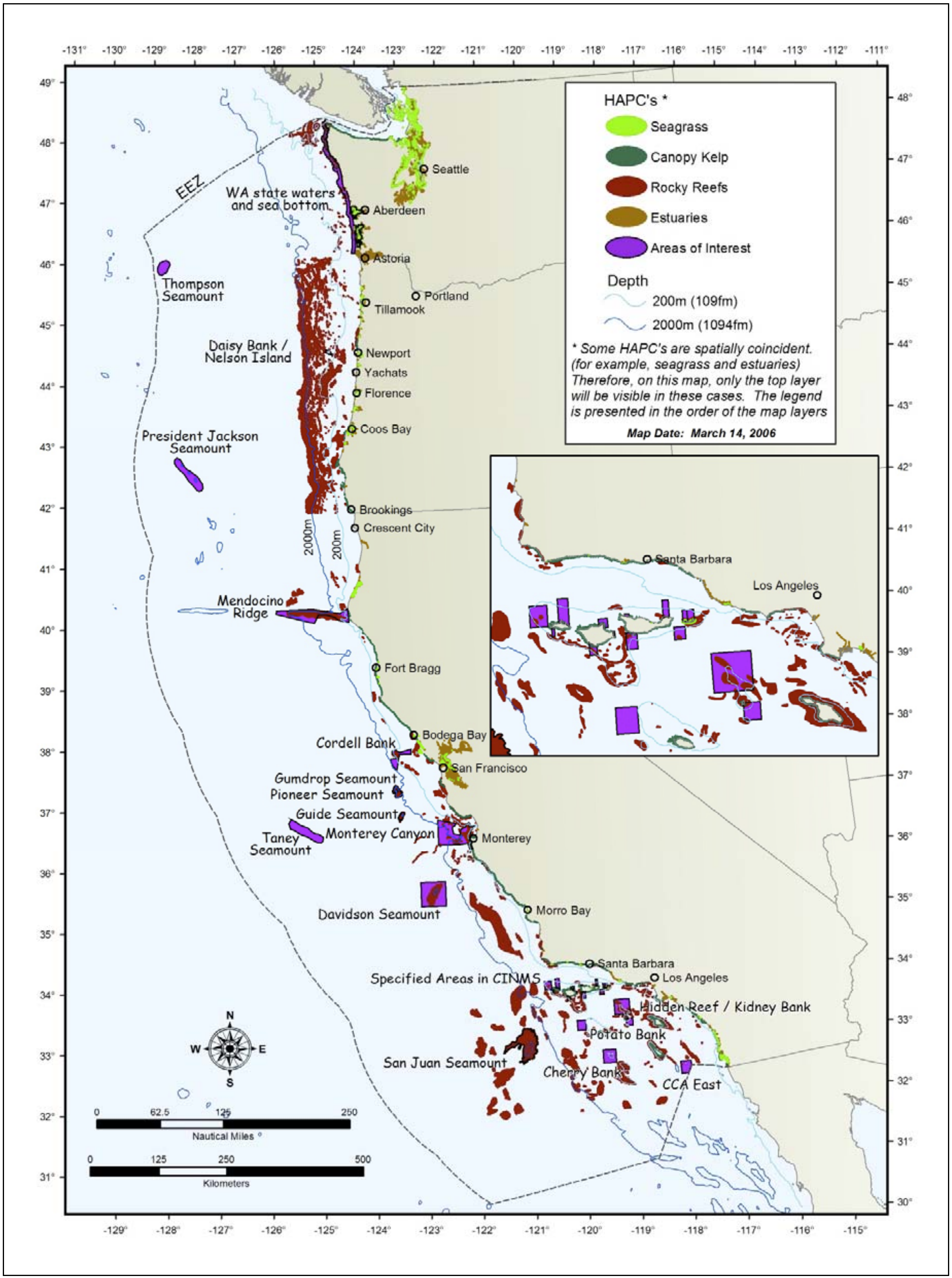


FIGURE 6. Groundfish HAPC in Washington, Oregon, and California. Source: PFMC (2016a).

Dower and Perry 2001 *in* PFMC 2016a). Deep-sea corals also occur on seamounts (Monterey Bay National Marine Sanctuary 2005 *in* PFMC 2016a). The northwestern extent of the proposed Astoria Fan survey area occurs ~180 km east of the Thomson Seamount area of interest HAPC. President Jackson Seamount area of interest HAPC is located ~90 km southwest of the proposed Southern Oregon survey area.

There are no HAPCs designated at this time for highly migratory species (PFMC 2016d).

### (4) Critical Habitat

Critical habitat for the ESA-listed fish species that occurs near the proposed project area is listed in Table 5. Most of these are freshwater habitats which are located outside of the proposed project area. Critical habitat for the Southern DPS of North American green sturgeon occurs in marine waters near the proposed project area, but the survey was planned so it would not overlap with this habitat (see Fig. 1).

Critical habitat for green sturgeon includes freshwater and coastal bays, estuaries, and marine waters out to the ~109-m (60 fathom) contour off California, Oregon, Washington, and Alaska (NMFS 2009). The coastal portion of this critical habitat includes marine waters from Monterey Bay, California, north to Cape Flattery, Washington, to its U.S. boundary (NMFS 2009).

### (5) Fisheries

The commercial Oregon and Washington fisheries include at least 134 species of fish, 24 species of crustaceans, 15 species of mollusks, and several other invertebrates (PFIN 2015; ODFW 2017a). The highest landings (in metric tons) are in July and August, followed by June and September in both states (NMFS 2015b). The most common gear type used in both states in 2015 was trawls (87% of the total catch in Washington; 52% of the total catch in Oregon). The next most common gear types in Washington were nets (15%), troll lines (12%) and pots and traps (11%), and in Oregon, troll lines (5%) and nets (4%) (NMFS 2015b). The total catch weight and value for commercial fisheries in Oregon in 2016 were 102,976 mt and $148.9 million, respectively (ODFW 2017a), and in Washington for 2015, 76,880 mt and $300.2 million, respectively (PFIN 2015).

Four commercial species accounted for 77% of the total landings value for Oregon during 2016, Pacific whiting (hake; 50%), pink shrimp (16%), Dungeness crab (7%) and northern anchovy (5%) (ODFW 2017a). The total landings values for each of these species in 2016 were $8.7 million, $25.1 million, $55.6 million and $1.2 million, respectively (ODFW 2017a). For Washington, pink shrimp (25%), pacific whiting (19%), albacore tuna (10%), and Dungeness crab (9%) accounted for a combined 63% of the total landings value for Washington during 2015. The total landings values for each of these species in 2015 were $29.9 million, $2.6 million, $20 million, and $72.6 million, respectively (PFIN 2015).

Marine recreational fisheries on the U.S. west coast occur in both non-federal (shore to 5.6 km off the coast) and federal (5.6 km to the extent of the EEZ) waters, and include resident and non-resident anglers fishing from shore, private boats, and commercial passenger fishing vessels (NMFS 2016c). Species typically taken during recreational fisheries on the west coast include highly migratory species (albacore and other tunas, striped marlin, common thresher and shortfin mako sharks), salmon (Chinook, coho), steelhead, groundfish (rockfish, lingcod scorpionfish, greenling, flatfish and sharks), coastal pelagic species (Pacific sardine, northern anchovy, market squid, Pacific mackerel), various state-managed species (barracuda, bass, bonito, sturgeon, surfperches), and invertebrates (abalone, lobster, crab, clams, oysters) (NMFS 2013d). During 2013, 1.7 million anglers took 7.5 million saltwater fishing trips, supporting over \$2.5 billion in sales (trip and durable goods-related) on the U.S. west coast (NMFS 2016c).

Recreational fisheries off Washington include marine salmon (Chinook, coho, chum, pink, sockeye and jacks), marine fish (bottomfish [e.g., rockfish, lingcod, sole, flounder], forage fish [e.g., herring, smelt], tunas and mackerels, and Pacific halibut), and shellfish (e.g., clams, oysters, shrimp, crab) (Kraig and Scalici 2017). The recreational fishing season varies by species and location, but overall run from May to October with peaks typically during mid-summer to early-fall (Kraig and Scalici 2017).

Recreational oceanic salmon fisheries off Oregon are open from March to October (location- and species-dependent); during 2016, there were 34,546 angler trips for this fishery (ODFW 2017b). Recreational groundfish taken off Oregon for which catch quotas are set include black rockfish, cabezon, canary rockfish, kelp, and rock greenlings, "minor nearshore rockfishes" (blue, China, copper grass and quillback), and yelloweye rockfish; these species are principally fished from late-spring to the fall, with peak catches typically during late-summer (ODFW 2016). Pacific halibut are also caught during both nearshore and offshore recreational fisheries off Oregon, with the season running from May to October, with peak catches during mid- to late-spring and late-summer/early-fall (ODFW 2017c).

# IV. ENVIRONMENTAL CONSEQUENCES

## Proposed Action

### (1) Direct Effects on Marine Mammals and Sea Turtles and Their Significance

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

This section also includes estimates of the numbers of marine mammals that could be affected by the proposed seismic surveys scheduled to occur during September 2017, along with a description of the rationale for NSF's estimates of the numbers of individuals exposed to received sound levels ≥160 dB re 1 $\mu Pa_{rms}$. Acoustic modeling for the proposed action was conducted by L-DEO, consistent with past EAs and determined to be acceptable by NMFS for use in the calculation of estimated Level B takes under the MMPA.

#### (a) Summary of Potential Effects of Airgun Sounds

As noted in the PEIS (§ 3.4.4.3, § 3.6.4.3, § 3.7.4.3, § 3.8.4.3), the effects of sounds from airguns could include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and at least in theory, temporary or permanent hearing impairment, or non-auditory physical or physiological effects (Richardson et al. 1995; Gordon et al. 2004; Nowacek et al. 2007; Southall et al. 2007; Erbe 2012; Peng et al. 2015; Erbe et al. 2015, 2016). 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 temporary threshold shift (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 2016). These findings have raised some doubts as to whether TTS should continue to be considered a non-injurious effect (Weilgart 2014; Tougaard et al. 2015, 2016). Although the possibility cannot be entirely excluded, it is unlikely that the proposed surveys would result in any cases of temporary or permanent hearing impairment, or any significant non-auditory physical or physiological effects. If marine mammals encounter a survey while it is underway, some behavioral disturbance could result, but this would be localized and short-term.

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

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

Some baleen and toothed whales are known to continue calling in the presence of seismic pulses, and their calls usually can be heard between the pulses (e.g., Nieukirk et al. 2012; Thode et al. 2012; Bröker et al. 2013; Sciacca et al. 2016). Cerchio et al. (2014) suggested that the breeding display of humpback whales off Angola could be disrupted by seismic sounds, as singing activity declined with increasing received levels. In addition, some cetaceans are known to change their calling rates, shift their peak frequencies, or otherwise modify their vocal behavior in response to airgun sounds (e.g., Di Iorio and Clark 2010; Castellote et al. 2012; Blackwell et al. 2013, 2015). The hearing systems of baleen whales are undoubtedly more sensitive to low-frequency sounds than are the ears of the small odontocetes that have been studied directly (e.g., MacGillivray et al. 2014). The sounds important to small odontocetes are predominantly at much higher frequencies than are the dominant components of airgun sounds, thus limiting the potential for masking. In general, masking effects of seismic pulses are expected to be minor, given the normally intermittent nature of seismic pulses. We are not aware of any information concerning masking of hearing in sea turtles.

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

Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors (Richardson et al. 1995; Wartzok et al. 2004; Southall et al. 2007; Weilgart 2007; Ellison et al. 2012). If a marine mammal does react briefly to an underwater sound by changing its behavior or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or population (e.g., New et al. 2013a). However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on individuals and populations could be significant (Lusseau and Bejder 2007; Weilgart 2007; New et al. 2013b; Nowacek et al. 2015). Some studies have attempted modeling to assess consequences of effects from underwater noise at the population level (e.g., New et al. 2013b; King et al. 2015; Costa et al. 2016a,b; Ellison et al. 2016; Harwood et al. 2016; Nowacek et al. 2016).

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

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

### *Baleen Whales*

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

Responses of *humpback whales* to seismic surveys have been studied during migration, on summer feeding grounds, and on Angolan winter breeding grounds; there has also been discussion of effects on the Brazilian wintering grounds. Off Western Australia, avoidance reactions began at 5–8 km from the array, and those reactions kept most pods ~3–4 km from the operating seismic boat; there was localized displacement during migration of 4–5 km by traveling pods and 7–12 km by more sensitive resting pods of cow-calf pairs (McCauley et al. 1998, 2000). However, some individual humpback whales, especially males, approached within distances of 100–400 m. More recent studies examining the behavioral responses of humpback whales to airguns have also been conducted off eastern Australia (Cato et al. 2011, 2012, 2013, 2016), although results are not yet available for all studies. Dunlop et al. (2015) reported that humpback whales 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 $in^3$ (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). Responses to ramp up and use of a 3130 $in^3$ array elicited greater behavioral changes in humpbacks when compared with small arrays (Dunlop et al. 2016c).

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

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

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

Bowhead whale calls detected in the presence and absence of airgun sounds have been studied extensively in the Beaufort Sea. Bowheads continue to produce calls of the usual types when exposed to airgun sounds on their summering grounds, although numbers of calls detected are significantly lower in the presence than in the absence of airgun pulses (Blackwell et al. 2013, 2015). Blackwell et al. (2013) reported that calling rates in 2007 declined significantly where received SPLs from airgun sounds were 116–129 dB re 1 μPa; at SPLs <108 dB re 1 μPa, calling rates were not affected. When data for 2007–2010 were analyzed, Blackwell et al. (2015) reported an initial increase in calling rates when airgun pulses became detectable; however, calling rates leveled off at a received $\mathrm{CSEL}_{10\text{-min}}$ (cumulative SEL over a 10-min period) of ~94 dB re 1 $\mu\mathrm{Pa}^2 \cdot \mathrm{s}$, decreased at $\mathrm{CSEL}_{10\text{-min}}$ >127 dB re 1 $\mu\mathrm{Pa}^2 \cdot \mathrm{s}$, and whales were nearly silent at $\mathrm{CSEL}_{10\text{-min}}$ >160 dB re 1 $\mu\mathrm{Pa}^2 \cdot \mathrm{s}$. Thus, bowhead whales in the Beaufort Sea apparently decreased their calling rates in response to seismic operations, although movement out of the area could also have contributed to the lower call detection rate (Blackwell et al. 2013, 2015).

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

There was no indication that *western gray whales* exposed to seismic sound were displaced from their overall feeding grounds near Sakhalin Island during seismic programs in 1997 (Würsig et al. 1999) and in 2001 (Johnson et al. 2007; Meier et al. 2007; Yazvenko et al. 2007a). However, there were indications of subtle behavioral effects among whales that remained in the areas exposed to airgun sounds (Würsig et al. 1999; Gailey et al. 2007; Weller et al. 2006a) and localized redistribution of some individuals within the nearshore feeding ground so as to avoid close approaches by the seismic vessel (Weller et al. 2002, 2006b; Yazvenko et al. 2007a). Despite the evidence of subtle changes in some quantitative measures of behavior and local redistribution of some individuals, there was no apparent change in the frequency of feeding, as evident from mud plumes visible at the surface (Yazvenko et al. 2007b). Similarly, no large changes in gray whale movement, respiration, or distribution patterns were observed (Bröker et al. 2015; Gailey et al. 2016). Although sighting distances of gray whales from shore increased slightly during a 2-week seismic survey, this result was not significant (Muir et al. 2015). However, there may have been a possible localized avoidance response to high sound levels in the area (Muir et al. 2016). The 2001 seismic program, as well as a subsequent survey in 2010, involved a comprehensive combination of real-time monitoring and mitigation measures designed to avoid exposing western gray whales to received SPLs of sound above about 163 dB re 1 $\mu\mathrm{Pa}_{\mathrm{rms}}$ (Johnson et al. 2007; Nowacek et al. 2012, 2013b). The lack of strong avoidance or other strong responses was presumably in part a result of the mitigation measures; effects probably would have been more significant without such intensive mitigation efforts. Gray whales in British Columbia exposed to seismic survey sound levels up to ~170 dB re 1 µPa did not appear to be strongly disturbed (Bain and Williams 2006). The few whales that were observed moved away from the airguns but toward deeper water where sound levels were said to be higher due to propagation effects (Bain and Williams 2006).

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

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

Data on short-term reactions by cetaceans to impulsive noises are not necessarily indicative of long-term or biologically significant effects. It is not known whether impulsive sounds affect reproductive rate or distribution and habitat use in subsequent days or years. However, gray whales have continued to migrate annually along the west coast of North America with substantial increases in the population over recent years, despite intermittent seismic exploration (and much ship traffic) in that area for decades. The western Pacific gray whale population did not seem affected by a seismic survey in its feeding ground during a previous year. In addition, bowhead whales have continued to travel to the eastern Beaufort Sea each summer, and their numbers have increased notably, despite seismic exploration in their summer and autumn range for many years.

### *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), but foraging behavior can be altered upon exposure to airgun sound (e.g., Miller et al. 2009). 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). Preliminary data from the Gulf of Mexico show a correlation between reduced sperm whale acoustic activity during periods with airgun operations (Sidorovskaia et al. 2014).

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

The limited available data suggest that *harbor porpoises* show stronger avoidance of seismic operations than do Dall's porpoises. 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. (2013) reported decreased densities and reduced acoustic detections of harbor porpoise in response to a seismic survey in Moray Firth, Scotland, at ranges of 5–10 km (SPLs of 165–172 dB re 1 µPa, SELs of 145–151 dB $\mu Pa^2 \cdot s$). For the same survey, Pirotta et al. (2014) reported that the probability of recording a porpoise buzz decreased by 15% in the ensonified area, and that the probability was positively related to the distance from the seismic ship; the decreased buzzing occurrence may indicate reduced foraging efficiency. Nonetheless, animals returned to the area within a few hours (Thompson et al. 2013). Kastelein et al. (2013a) reported that a harbor porpoise showed no response to an impulse sound with an SEL below 65 dB, but a 50% brief response rate was noted at an SEL of 92 dB and an SPL of 122 dB re 1 $\mu Pa_{0\text{-peak}}$. However, Kastelein et al. (2012c) reported a 50% detection threshold at a SEL of 60 dB to a similar impulse sound; this difference is likely attributable to the different transducers used during the two studies (Kastelein et al. 2013a). 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).

Odontocete reactions to large arrays of airguns are variable and, at least for delphinids, seem to be confined to a smaller radius than has been observed for the more responsive of the mysticetes and some other odontocetes. A ≥170 dB disturbance criterion (rather than ≥160 dB) is considered appropriate for delphinids, which tend to be less responsive than the more responsive cetaceans. NMFS is currently developing new guidance for predicting behavioural effects (Scholik-Schlomer 2015). As behavioural responses are not consistently associated with received levels, Gomez et al. (2016) recommended that a response/no response dichotomous approach be used when assessing behavioural reactions.

#### *Pinnipeds*

Pinnipeds are not likely to show a strong avoidance reaction to an airgun array. Visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds and only slight (if any) changes in behavior. However, telemetry work has suggested that avoidance and other behavioral reactions may be stronger than evident to date from visual studies (Thompson et al. 1998). Observations from seismic vessels operating large arrays off the U.K. from 1994 to 2010 showed that the detection rate for grey seals was significantly higher when airguns were not operating; for surveys using small arrays, the detection rates were similar during seismic vs. non-seismic operations (Stone 2015). No significant differences in detection rates were apparent for harbor seals during seismic and non-seismic periods (Stone 2015). There were no significant differences in CPA distances of grey or harbor seals during seismic vs. non-seismic periods (Stone 2015). Lalas and McConnell (2015) made observations of New Zealand fur seals from a seismic vessel operating a 3090 $in^3$ airgun array in New Zealand during 2009. However, the results from the study were inconclusive in showing whether New Zealand fur seals respond to seismic sounds. Reichmuth et al. (2016) exposed captive spotted and ringed seals to single airgun pulses; only mild behavioural responses were observed.

#### *Sea Turtles*

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

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

Based on available data, it is likely that sea turtles will exhibit behavioral changes and/or avoidance within an area of unknown size near a seismic vessel. To the extent that there are any impacts on sea turtles, seismic operations in or near areas where turtles concentrate would likely have the greatest impact; concentration areas are not known to occur within the proposed survey area. There are no specific data that demonstrate the consequences to sea turtles if seismic operations with large or small arrays of airguns occur in important areas at biologically important times of the year.

***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; Finneran 2012, 2015; Kastelein et al. 2012a,b; 2013b,c, 2014, 2015a, 2016; Ketten 2012; Supin et al. 2016).

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

Recent studies have also shown that the SEL necessary to elicit TTS can depend substantially on frequency, with susceptibility to TTS increasing with increasing frequency above 3 kHz (Finneran and Schlundt 2010, 2011; Finneran 2012). When beluga whales were exposed to fatiguing noise with sound levels of 165 dB re 1 μPa for durations of 1–30 min at frequencies of 11.2–90 kHz, the highest TTS with the longest recovery time was produced by the lower frequencies (11.2 and 22.5 kHz); TTS effects also gradually increased with prolonged exposure time (Popov et al. 2013). Additionally, Popov et al. (2015) demonstrated that the impacts of TTS include deterioration of signal discrimination. Kastelein et al. (2015b) 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.

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)

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, 2013b,c, 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.

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.

Based on the best available information at the time, Southall et al. (2007) recommended a TTS threshold for exposure to single or multiple pulses of 183 dB re 1 $\mu Pa^2 \cdot s$ for all cetaceans and 173 dB re 1 $\mu Pa^2 \cdot s$ for pinnipeds in water. For the harbor porpoise, Tougaard et al. (2015) have suggested an exposure limit for TTS as an SEL of 100–110 dB above the pure tone hearing threshold at a specific frequency; they also suggested an exposure limit of $L_{\text{eq-fast}}$ (rms average over the duration of the pulse) of 45 dB above the hearing threshold for behavioral responses (i.e., negative phonotaxis). In addition, according to Wensveen et al. (2014) and Tougaard et al. (2015), M-weighting, as used by Southall et al. (2007), might not be appropriate for the harbor porpoise. Thus, Wensveen et al. (2014) developed six auditory weighting functions for the harbor porpoise that could be useful in predicting TTS onset. 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. In addition, Mulsow et al. (2015) suggested that basing weighting functions on equal latency/loudness contours may be more appropriate than M-weighting for marine mammals. Houser et al. (2017) provide a review of the development and application of auditory weighting functions, as well as recommendations for future work.

Hermannsen et al. (2015) reported that there is little risk of hearing damage to harbor seals or harbor porpoises when using single airguns in shallow water. Similarly, it is unlikely that a marine mammal would remain close enough to a large airgun array for sufficiently long to incur TTS, let alone PTS. There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal, even with large arrays of airguns. However, given the possibility that some mammals close to an airgun array might incur at least mild TTS, there has been further speculation about the possibility that some individuals occurring very close to airguns might incur PTS (e.g., Richardson et al. 1995, p. 372*ff*; Gedamke et al. 2011). In terrestrial animals, exposure to sounds sufficiently strong to elicit a large TTS induces physiological and structural changes in the inner ear, and at some high level of sound exposure, these phenomena become non-recoverable (Le Prell 2012). At this level of sound exposure, TTS grades into PTS. Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage, but repeated or (in some cases) single exposures to a level well above that causing TTS onset might elicit PTS (e.g., Kastak and Reichmuth 2007; Kastak et al. 2008).

The new noise exposure criteria for marine mammals that were recently released by NMFS (2016a) account for the newly-available scientific data on TTS, the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors. For impulsive sounds, such airgun pulses, the thresholds use dual metrics of cumulative SEL ($SEL_{cum}$ over 24 hours) and Peak $SPL_{flat}$. Onset of PTS is assumed to be 15 dB higher when considering $SEL_{cum}$ and 6 dB higher when considering $SPL_{flat}$. Different thresholds are provided for the various hearing groups, including LF cetaceans (e.g., baleen whales), MF cetaceans (e.g., most delphinids), HF cetaceans (e.g., porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW).

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

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

Since 1991, there have been 62 Marine Mammal Unusual Mortality Events (UME) in the U.S. (NMFS 2015c). In a hearing to examine the Bureau of Ocean Energy Management's 2017-2022 OCS Oil and Gas Leasing Program (http://www.energy.senate.gov/public/index.cfm/hearings-and-business-meetings?ID=110E5E8F-3A65-4BEC-9D25-5D843A0284D3), it was Dr. Knapp's (a geologist from the University of South Carolina) interpretation that there was no evidence to suggest a correlation between UMEs and seismic surveys given the similar percentages of UMEs in the Pacific, Atlantic, and Gulf of Mexico, and the greater activity of oil and gas exploration in the Gulf of Mexico.

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

#### *Sea Turtles*

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

Although it is possible that exposure to airgun sounds could cause mortality or mortal injuries in sea turtles close to the source, this has not been demonstrated and seems highly unlikely (Popper et al. 2014), especially because sea turtles appear to be highly resistant to explosives (Ketten et al. 2005 *in* Popper et al. 2014). Nonetheless, Popper et al. (2014) proposed sea turtle mortality/mortal injury criteria of 210 dB SEL or >207 $dB_{peak}$ for sounds from seismic airguns.

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

### (b) 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, but not during transits. Information about this equipment was provided in § 2.2.3.1 of the PEIS. A review of the anticipated potential effects (or lack thereof) of MBESs and SBPs on marine mammals and sea turtles appears in § 3.4.4.3, § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS.

There has been some recent attention given to the effects of MBES on marine mammals, as a result of a report issued in September 2013 by an IWC independent scientific review panel linking the operation of an MBES to a mass stranding of melon-headed whales (*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 the *Revelle*. 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 behavioural response were 9 m and 70 m. For pinnipeds, "all ranges are multiplied by a factor of 4" (Lurton 2016:209).

There is no available information on marine mammal behavioral response to MBES sounds (Southall et al. 2013) or sea turtle responses to MBES systems. Much of the literature on marine mammal response to sonars relates to the types of sonars used in naval operations, including low-frequency active sonars (e.g., Miller et al. 2012; Sivle et al. 2012; Samarra and Miller 2016), mid-frequency active sonars (e.g., Tyack et al. 2011; Melcón et al. 2012; Miller et al. 2012, 2014; Sivle et al. 2012, 2015; DeRuiter et al. 2013a,b; Goldbogen et al. 2013; Antunes et al. 2014; Baird et al. 2014; Kastelein et al. 2012d, 2015a; Wensveen et al. 2015; Friedlaender et al. 2016; Isojunno et al. 2016; Samarra and Miller 2016), and high-frequency active sonars (Kastelein et al. 2015c,d). However, the MBES sounds are quite different from naval sonars. Ping duration of the MBES is very short relative to naval sonars. Also, at any given location, an individual marine mammal would be in the beam of the MBES for much less time given the generally downward orientation of the beam and its narrow fore-aft beamwidth; naval sonars often use near-horizontally-directed sound. In addition, naval sonars have higher duty cycles. These factors would all reduce the sound energy received from the MBES relative to that from naval sonars.

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

Deng et al. (2014) measured the spectral properties of pulses transmitted by three 200-kHz echosounders and found that they generated weaker sounds at frequencies below the center frequency (90–130 kHz). These sounds are within the hearing range of some marine mammals, and the authors suggested that they could be strong enough to elicit behavioral responses within close proximity to the sources, although they would be well below potentially harmful levels. Hastie et al. (2014) reported behavioral responses by grey seals to echosounders with frequencies of 200 and 375 kHz. Short-finned pilot whales increased their heading variance in response to an EK60 echosounder with a resonant frequency of 38 kHz (Quick et al. 2016).

Despite the aforementioned information that has recently become available, this Draft EA is in agreement with the assessment presented in § 3.4.7, 3.6.7, 3.7.7, and 3.8.7 of the PEIS that operation of MBESs and SBPs is not likely to impact marine mammals and is not expected to affect sea turtles, (1) given the lower acoustic exposures relative to airguns and (2) because the intermittent and/or narrow downward-directed nature of these sounds would result in no more than one or two brief ping exposures of any individual marine mammal or sea turtle given the movement and speed of the vessel. Also, for sea turtles, the associated frequency ranges are above their known hearing range.

### (c) Other Possible Effects of Seismic Surveys

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

Vessel noise from the *Revelle* 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. 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 harbour porpoise (Dyndo et al. 2015). Increased levels of ship noise have been shown to affect foraging by porpoise (Teilmann et al. 2015).

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. 2015). In addition to the frequency and duration of the masking sound, the strength, temporal pattern, and location of the introduced sound also play a role in the extent of the masking (Branstetter et al. 2013, 2016; Finneran and Branstetter 2013; Sills et al. 2017). Branstetter et al. (2013) reported that time-domain metrics are also important in describing and predicting masking. In order to compensate for increased ambient noise, some cetaceans are known to increase the source levels of their calls in the presence of elevated noise levels from shipping, shift their peak frequencies, or otherwise change their vocal behavior (e.g., Parks et al. 2011, 2012, 2016a,b; Castellote et al. 2012; Melcón et al. 2012; Azzara et al. 2013; Tyack and Janik 2013; Luís et al. 2014; Sairanen 2014; Papale et al. 2015; Bittencourt et al. 2016; Dahlheim and Castellote 2016; Gospić and Picciulin 2016; Gridley et al. 2016; Heiler et al. 2016; Martins et al. 2016; O'Brien et al. 2016; Tenessen and Parks 2016). Harp seals did not increase their call frequencies in environments with increased low-frequency sounds (Terhune and Bosker 2016). Holt et al. (2015) reported that changes in vocal modifications can have increased energetic costs for individual marine mammals. A negative correlation between the presence of some cetacean species and the number of vessels in an area has been demonstrated by several studies (e.g., Campana et al. 2015; Culloch et al. 2016).

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

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

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

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

Another concern with vessel traffic is the potential for striking marine mammals or sea turtles (e.g., Redfern et al. 2013). Information on vessel strikes is reviewed in § 3.4.4.4, § 3.6.4.4, and § 3.8.4.4 of the PEIS. Wiley et al. (2016) concluded that reducing ship speed is one of the most reliable ways to avoid ship strikes. However, McKenna et al. (2015) noted the potential absence of lateral avoidance demonstrated by blue whales and perhaps other large whale species to vessels (McKenna et al. 2015). The PEIS concluded that the risk of collision of seismic vessels or towed/deployed equipment with marine mammals 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 the R/V *Langseth*, or its predecessor, R/V *Maurice Ewing* over the last two decades.

Entanglement of sea turtles in seismic gear is also a concern (Nelms et al. 2016). There have been reports of turtles being trapped and killed between the gaps in tail-buoys offshore from West Africa (Weir 2007), and in April 2011, a dead olive ridley turtle was found in a deflector foil of the seismic gear on the R/V *Langseth* during equipment recovery at the conclusion of a survey off Costa Rica, where sea turtles were numerous. Such incidents are not possible with the pair of GI guns that would be towed by the *Revelle*. Also, towing the hydrophone streamer or other equipment during the proposed survey is not expected to significantly interfere with sea turtle movements, including migration, because sea turtles are not expected to be abundant in the survey areas.

## (2) Mitigation Measures

Several mitigation measures are built into the proposed seismic surveys as an integral part of the planned activities. These measures include the following: ramp ups; typically two, however a minimum of one dedicated observer maintaining a visual watch during all daytime airgun operations; two observers for 30 min before and during ramp ups during the day; and shut downs when mammals or turtles are detected in or about to enter designated EZ. These mitigation measures are described in § 2.4.4.1 of the PEIS and summarized earlier in this document, in § II(3). In addition, the acoustic source would be powered or shut down in the event an ESA-listed seabird were observed diving or foraging within the designated exclusion zones. The fact that the GI airguns, as a result of their design, direct the majority of the energy downward, and less energy laterally, is also an inherent mitigation measure.

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

## (3) Potential Numbers of Marine Mammals Exposed to Various Received Sound Levels

All takes would be anticipated to be Level B "takes by harassment" as described in § I, involving temporary changes in behavior. As required by NMFS, Level A takes have been requested; given the very small exclusion zones and the proposed mitigation measures to be applied, injurious takes would not be expected. (However, as noted earlier and in the PEIS, there is no specific information demonstrating that injurious Level A "takes" would occur even in the absence of the planned mitigation measures.) In the sections below, we describe methods to estimate the number of potential exposures to Level A and Level B sound levels and present estimates of the numbers of marine mammals that could be affected during the proposed seismic surveys. The estimates are based on consideration of the number of marine mammals that could be disturbed appreciably by the seismic surveys in the northeastern Pacific Ocean off the coasts of Oregon and Washington. The main sources of distributional and numerical data used in deriving the estimates are described in the next subsection.

### (a) Basis for Estimating Exposure

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

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

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

Oceanographic conditions, including occasional El Niño and La Niña events, influence the distribution and numbers of marine mammals present in the North Pacific Ocean, including waters off Oregon and Washington, resulting in considerable year-to-year variation in the distribution and abundance of many marine mammal species (Forney and Barlow 1998; Buchanan et al. 2001; Ferrero et al. 2002; Philbrick et al. 2003; Escorza-Treviño 2009). Thus, cetacean densities used here were derived from the pooled results of the 1991–2014 surveys off Oregon and Washington and taken directly from the report (Barlow 2016) with the exception of the gray whale and harbor porpoise. (Abundance and density were not estimated for gray whales or harbor porpoises in the NMFS/SWFSC surveys because their inshore habitats were inadequately covered in those studies.) Gray whale density is based on the USN (2010) method and used the abundance of gray whales that remain between Oregon and BC in summer (updated to abundance calculated by Calambokidis et al. 2014) and the area out to 43 km from shore. Harbor porpoise densities based on aerial line-transect surveys during 2007–2012 for the Northern Oregon/Washington Coast stock were used (Forney et al. 2014).

Table 6 gives the densities for each species of cetacean reported off Oregon and Washington. The densities from NMFS/SWFSC vessel-based surveys have been corrected by the authors for both trackline detection probability and availability bias. Trackline detection probability bias is associated with diminishing sightability with increasing lateral distance from the trackline [$f(0)$]. Availability bias refers to the fact that there is less-than-100% probability of sighting an animal that is present along the survey trackline, and it is measured by $g(0)$.

Table 6 also includes mean density information for the five pinniped species that occur off Oregon and Washington. Four of the five species' densities were calculated using the methods in USN (2010) with updated population sizes based on Carretta et al. (2016a) and Muto et al. (2016), when appropriate. For the harbor seal, densities were calculated using the population estimate for the Oregon/Washington Coastal stock and the range for that stock given in Carretta et al. (2016).

There is some uncertainty about the representativeness of the estimated density data and the assumptions used in their calculations. Oceanographic conditions, including occasional El Niño and La Niña events, influence the distribution and numbers of marine mammals present in the North Pacific Ocean, resulting in considerable year-to-year variation in the distribution and abundance of many marine mammal species. Thus, for some species, the densities derived from past surveys may not be representative of the densities that would be encountered during the proposed seismic surveys. However, the approach used here is based on the best available data. The calculated exposures that are based on these densities are best estimates for the proposed surveys for any time of the year and are based on data collected during the same time of the year (late summer to early fall) as the proposed surveys.

The estimated numbers of individuals potentially exposed are based on the 160-dB re 1 $\mu Pa_{rms}$ criterion for all cetaceans and pinnipeds. It is assumed that marine mammals exposed to airgun sounds that strong could change their behavior sufficiently to be considered "taken by harassment". Table 7 shows the density estimates calculated as described above and the estimates of the number of marine mammals that potentially could be exposed to ≥160 dB re 1 $\mu Pa_{rms}$ during the seismic surveys in the northeastern Pacific Ocean off the coasts of Oregon and Washington if no animals moved away from the survey vessel. The *Requested Take Authorization* is given in the far right column of Table 7. Except for two species (right whale and short-beaked common dolphin), we have included a *Requested Take Authorization* for at least 1% of the population or for the mean group size, whichever is largest, as previous surveys in the area (see Cumulative Effects, below) have encountered higher numbers of individuals compared to expected densities for some species. Mean group sizes are from Barlow (2016) for waters off Oregon and Washington, except for the mean group size of false killer whale, which is from Hawaiian waters (Mobley et al. 2000). No takes of right whales are anticipated or requested.

It should be noted that the following estimates of exposures assume that the proposed surveys would be completed; in fact, the calculated takes ***have been increased by 25%*** (see below). Thus, the following estimates of the numbers of marine mammals potentially exposed to Level B sounds

TABLE 6. Densities of marine mammals off Oregon and Washington. Cetacean densities are from Barlow (2016) and are based on ship transect surveys conducted up to 556 km offshore in 1991, 1993, 1996, 2001, 2005, 2007, and 2014. Pinniped densities are from shore counts and calculations in USN (2010). Cetacean densities from Barlow (2016) are corrected for *f*(0) and *g*(0). Species listed as "Endangered" under the ESA are in italics.

| Species | Density (#/1000 km$^2$) | Mean group size | Source |
|---|---|---|---|
| Mysticetes | | | |
| *North Pacific right whale* | *0* | – | – |
| Gray whale | 2.6 | – | USN (2010)[1] |
| *Humpback whale* | *2.1* | *2* | *Barlow (2016)* |
| Minke whale | 1.3 | 1 | Barlow (2016) |
| *Sei whale* | *0.4* | *2* | *Barlow (2016)* |
| *Fin whale* | *4.2* | *2* | *Barlow (2016)* |
| *Blue whale* | *0.3* | *1* | *Barlow (2016)* |
| Odontocetes | | | |
| *Sperm whale* | *0.9* | *6* | *Barlow (2016)* |
| Pygmy/dwarf sperm whale | 1.6 | 1 | Barlow (2016) |
| Cuvier's beaked whale | 2.8 | 2 | Barlow (2016) |
| Baird's beaked whale | 10.7 | 8 | Barlow (2016) |
| Mesoplodont (unidentified)[2] | 1.2 | 2 | Barlow (2016) |
| Bottlenose dolphin | 0 | 13 | Barlow (2016) |
| Striped dolphin | 7.7 | 109 | Barlow (2016) |
| Short-beaked common dolphin | 69.2 | 286 | Barlow (2016) |
| Pacific white-sided dolphin | 40.7 | 62 | Barlow (2016) |
| Northern right-whale dolphin | 46.4 | 63 | Barlow (2016) |
| Risso's dolphin | 11.8 | 28 | Barlow (2016) |
| False killer whale | 0 | 5[3] | – |
| *Killer whale* | *0.9* | *8* | *Barlow (2016)* |
| Short-finned pilot whale | 0.2 | 18 | Barlow (2016) |
| Harbor porpoise | 467.0 | 2 | Forney et al. (2014) |
| Dall's porpoise | 54.4 | 4 | Barlow (2016) |
| Pinnipeds | | | |
| Northern fur seal | 83.4 | – | USN (2010)[4] |
| California sea lion | 283.3 | – | USN (2010)[5] |
| Steller sea lion | 15.0 | – | USN (2010)[6] |
| Harbor seal | 292.3 | – | See text |
| Northern elephant seal | 83.1 | – | USN (2010)[7] |

*Note:* – mean group size not provided in source and species not included in Barlow (2016).

[1] Population size in USN (2010) was updated based on Calambokidis et al. (2014).

[2] Includes Blainville's, Stejneger's, and Hubb's beaked whales.

[3] Mean group size from Mobley et al. (2000).

[4] Population size in USN (2010) was updated based on Carretta et al. (2016a) and Muto et al. (2016).

[5] Population size in USN (2010) was updated based on Carretta et al. (2016a).

[6] Population size in USN (2010) was updated based on Muto et al. (2016).

[7] Population size in USN (2010) was updated based on Carretta et al. (2016a) with the number of adult males proportionally adjusted.

TABLE 7. Densities and estimates of the possible numbers of individual marine mammals that could be exposed to Level B and Level A thresholds for various hearing groups during the proposed seismic surveys in the northeastern Pacific in September 2017. The proposed sound source consists of a pair of 45-in$^3$ GI airguns with a total discharge volume of ~90 in$^3$. Species in italics are listed under the ESA as *endangered*.

| Species | Estimated Density[1] (#/1000 km$^2$) | Calculated Take, NMFS Daily Method[2] | | Level A + Level B as % of Pop.[5] | Requested Take Authorization[6] |
|---|---|---|---|---|---|
| | | Level A[3] | Level B[4] | | |
| **LF Cetaceans** | | | | | |
| *North Pacific right whale* | *0* | *0* | *0* | *0%* | *0* |
| Gray whale | 2.6 | 0 | 4 | 0.02% | 212 |
| *Humpback whale* | *2.1* | *0* | *3* | *0.01%* | *218* |
| Minke whale | 1.3 | 0 | 2 | 0.02% | 90 |
| *Sei whale* | *0.4* | *0* | *1* | *0.01%* | *126* |
| *Fin whale* | *4.2* | *1* | *5* | *0.07%* | *85* |
| *Blue whale* | *0.3* | *0* | *1* | *0.09%* | *11* |
| **MF Cetaceans** | | | | | |
| *Sperm whale* | *0.9* | *0* | *2* | *0.01%* | *240* |
| Cuvier's beaked whale | 2.8 | 0 | 4 | 0.12% | 34 |
| Baird's beaked whale | 10.7 | 0 | 14 | 0.21% | 66 |
| Mesoplodont (unidentified)[7] | 1.2 | 0 | 2 | 0.18% | 11 |
| Bottlenose dolphin | 0 | 0 | 0 | 0% | 19 |
| Striped dolphin | 7.7 | 0 | 10 | 0.03% | 292 |
| Short-beaked common dolphin | 69.2 | 0 | 89 | 0.01% | **286**[8] |
| Pacific white-sided dolphin | 40.7 | 0 | 52 | 0.20% | 266 |
| Northern right-whale dolphin | 46.4 | 0 | 60 | 0.11% | 546 |
| Risso's dolphin | 11.8 | 0 | 16 | 0.25% | 63 |
| False killer whale | 0 | 0 | 0 | N.A. | **5** |
| *Killer whale*[9] | *0.9* | *0* | *2* | *0.44%* | ***8***[10] |
| Short-finned pilot whale | 0.2 | 0 | 1 | 0.12% | **18**[11] |
| **HF Cetaceans** | | | | | |
| Pygmy/dwarf sperm whale | 1.6 | 0 | 2 | 0.07% | 41 |
| Harbor porpoise | 467.0 | 42 | 555 | 1.04% | 597 |
| Dall's porpoise | 54.4 | 5 | 65 | 0.27% | 258 |
| **Otariids** | | | | | |
| Northern fur seal | 83.4 | 0 | 107 | 0.02% | 6626 |
| California sea lion | 283.3 | 1 | 361 | 0.12% | 2968 |
| Steller sea lion | 15.0 | 0 | 20 | 0.03% | 744 |
| **Phocids** | | | | | |
| Harbor seal | 292.3 | 7 | 367 | 1.51% | 374 |
| Northern elephant seal | 83.1 | 2 | 105 | 0.06% | 1790 |

[1] No correction factors were applied to these calculations; see text for density sources.

[2] Take using NMFS daily method for calculating ensonified area: estimated density multiplied by the daily ensonified area to levels ≥160 dB re 1 $\mu Pa_{rms}$ on one selected day (see text) multiplied by the number of survey days (5), times 1.25; daily ensonified area = 160-dB area (204.2 km$^2$) minus ensonified area for the appropriate PTS threshold (21.6, 0.6, 14.2, 0.4, and 3.6 km$^2$ for LF cetaceans, MF cetaceans, HF cetaceans, Otariids underwater, and Phocids underwater, respectively).

[3] Level A takes if there were no mitigation measures, based on PTS thresholds.

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

[5] Level A and B takes (used by NMFS as proxy for number of individuals exposed), expressed as % of population; N.A. = population size not available (see Table 4).

[6] Requested takes (Level A+Level B) increased to 1% of population or mean group size (in bold) from Barlow (2016), unless otherwise stated.

[7] Includes Blainville's, Stejneger's, and/or Hubb's beaked whales (Barlow 2016). Given their expected occurrence in the study area (Table 4), all calculated Level B takes of *Mesoplodon* sp. are likely to be Stejneger's beaked whale. Nonetheless, take authorization is requested for 2 Blainville's, 2 Hubb's, and 7 Stejneger's beaked whales.

[8] Mean group size (0.03% of population instead of 1%), as common dolphins are unlikely to be encountered during the surveys.

[9] Includes resident, transient, and offshore stocks.

[10] Mean group size (1.8% of population).

[11] Mean group size (2.2% of population).

≥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 both the PEIS and §4.1.1.1 of this document. The 160-dB (rms) criterion currently applied by NMFS, on which the Level B estimates are based, was developed primarily using data from gray and bowhead whales. The estimates of "takes by harassment" of delphinids are thus considered precautionary. Available data suggest that the current use of a 160-dB criterion could be improved upon, as behavioral response might not occur for some percentage of marine mammals exposed to received levels >160 dB, whereas other individuals or groups might respond in a manner considered as "taken" to sound levels <160 dB (NMFS 2013e). 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 2013e).

#### (b) Potential Number of Marine Mammals Exposed *to ≥160 dB*

The number of marine mammals that could be exposed to airgun sounds with received levels ≥160 dB re 1 µPa$_{rms}$ (Level B) for marine mammals on one or more occasions have been estimated using a method required by NMFS for calculating the marine area that would be within the Level B threshold around the operating seismic source, along with the expected density of animals in the area. This method was developed to account in some way for the number of exposures as well as the number of individuals exposed. It involves selecting a seismic trackline(s) that could be surveyed on one day; the 200-km line(s) selected had a proportion of depth intervals (100–1000 m and >1000 m) with associated radii that was roughly similar to that of the entire survey. The area expected to be ensonified on that day was determined by entering the planned survey lines into a MapInfo GIS, using the GIS to identify the relevant areas by "drawing" the applicable 160-dB and PTS threshold buffers (see Tables 1 and 2) around each seismic line. The ensonified areas were then multiplied by the number of survey days (5 days) increased by 25%; this is equivalent to adding an additional 25% to the proposed line km for a total of ~1250 km. 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 the *Revelle* approaches.

Per NMFS requirement, estimates of the numbers of cetaceans and pinnipeds that could be exposed to seismic sounds with received levels equal to Level A thresholds for various hearing groups (see Table 2), if there were no mitigation measures (shut downs when PSOs observed animals approaching or inside the EZs), are also given in Table 7. Those numbers likely overestimate actual Level A takes because the predicted Level A exclusion zone is extremely small and mitigation measures would further chances of, if not eliminate, any such takes. Level A takes are considered highly unlikely.

The estimate of the number of cetaceans that could be exposed to seismic sounds with received levels ≥160 dB re 1 µPa$_{rms}$ in the survey area is 939 (Table 7). That total includes 15 cetaceans listed under the ESA: 6 fin whales, 3 humpbacks, 2 sperm whales, 2 killer whales, 1 sei whale, and 1 blue whale, representing 0.07%, 0.01, 0.01%, 0.44%, 0.01%, and 0.09% of their regional populations, respectively. In addition, 20 beaked whales could be exposed. Most (71%) of the cetaceans potentially exposed would be HF cetaceans, with estimates of 582 harbor porpoises and 68 Dall's porpoises exposed to ≥160 dB re 1 µPa$_{rms}$ (0.27–1.04% of the regional populations); however, the number of harbor porpoises is an overestimate, as most are expected to occur in nearshore waters, away from the majority of the proposed activities. For delphinids, all estimated takes are <0.5% of their regional populations.

The estimate of the number of pinnipeds that could be exposed to seismic sounds with received levels ≥160 dB re 1 µ$\text{Pa}_{\text{rms}}$ is 489 otariids and 481 phocids. Although most estimated takes are for harbor seals (1.5% of the population), this number is an overestimate as this species is unlikely to occur in deeper waters of the proposed project area, where most seismic activities are planned.

## (4) Conclusions for Marine Mammals and Sea Turtles

The proposed seismic project would involve towing a very small source, a pair of 45-$\text{in}^3$ GI airguns that introduce pulsed sounds into the ocean. Routine vessel operations, other than the proposed seismic operations, are conventionally assumed not to affect marine mammals sufficiently to constitute "taking".

### (a) Cetaceans

In § 3.6.7, 3.7.7, and 3.8.7, the PEIS concluded that airgun operations with implementation of the proposed monitoring and mitigation measures could result in a small number of Level B behavioral effects in some cetaceans and pinnipeds in the BC QAA and S California DAA, that Level A effects were highly unlikely, and that operations were unlikely to adversely affect ESA-listed species. NMFS requires the calculation and request of potential Level A takes for the Proposed Action (following a different methodology than used in the PEIS and most previous analyses for NSF-funded seismic surveys). For three past NSF-funded seismic surveys, NMFS issued small numbers of Level A take for some marine mammal species for the remote possibility of low-level physiological effects; however, NMFS expected neither mortality nor serious injury of marine mammals to result from the surveys (NMFS 2015d, 2016d,e).

In this Draft EA, 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 appreciable disturbance are very low percentages of the regional population sizes (Table 7). Based on experience working in the area and variability of the environmental conditions of the project area, we believe the calculated takes for many of the species may be too low. As a result, we have increased the requested takes to 1% of the regional population sizes, except in a few instances where noted otherwise.

The estimates are likely overestimates of the actual number of animals that would be exposed to and would react to the seismic sounds. The reasons for that conclusion are outlined above. 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 SIO and other vessels in the U.S. academic research fleet, PSOs and other crew members have not observed any 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 the *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 the *Langseth* along the U.S. east coast in August–September 2014, only 3 unidentified dolphins were observed within the predicted 160-dB zone and potentially taken, representing <0.03% of the 11,367 authorized takes (RPS 2014b). Furthermore, as defined, all animals exposed to sound levels >160 dB are Level B 'takes' whether or not a behavioral response occurred. The 160-dB zone, which is based on predicted sound levels, is thought to be conservative; thus, not all animals detected within this zone would be expected to have been exposed to actual sound levels >160 dB.

### (b) Sea Turtles

In § 3.4.7, the PEIS concluded that with implementation of the proposed monitoring and mitigation measures, no significant impacts of airgun operations are likely to sea turtle populations in any of the analysis areas, and that any effects are likely to be limited to short-term behavioral disturbance and short-term localized avoidance of an area of unknown size near the active airguns. Only one species of sea turtle—the leatherback—is expected to be encountered in the proposed project area. Only foraging or migrating individuals would occur. Given the proposed activities, no significant impacts on sea turtles would be anticipated. In decades of seismic surveys carried out by SIO and other vessels in the U.S. academic research fleet, PSOs and other crew members have not observed any seismic sound-related turtle injuries or mortality.

## (5) Direct Effects on Invertebrates, Fish, Fisheries, and EFH and Their Significance

Effects of seismic sound on marine invertebrates (crustaceans and cephalopods), marine fish, and their fisheries are discussed in § 3.2.4 and § 3.3.4 and Appendix D of the PEIS. Relevant new studies on the effects of sound on marine invertebrates, fish, and fisheries that have been published since the release of the PEIS are summarized below. Although research on the effects of exposure to airgun sound on marine invertebrates and fishes is increasing, many data gaps remain (Hawkins et al. 2015; Carroll et al. 2016).

### (a) Effects of Sound on Marine Invertebrates

Noise effects on marine invertebrates are varied, ranging from no overt reactions to behavioral/physiological responses, injuries, or mortalities (Aguilar de Soto 2016; Carroll et al. 2016). Fewtrell and McCauley (2012) exposed captive squid (*Sepioteuthis australis*) to pulses from a single airgun; the received sound levels ranged from 120 to 184 dB re 1 dB re 1 $\mu Pa^2 \cdot s$ SEL. Increases in alarm responses were seen at SELs >147–151 dB re 1 $\mu Pa^2 \cdot s$; the squid were seen to discharge ink or change their swimming pattern or vertical position in the water column. Solé et al. (2013) exposed four caged cephalopod species to low-frequency (50–400 Hz) sinusoidal wave sweeps (with a 1-s sweep period for 2 h) with received levels of 157 ± 5 dB re 1 µPa, and peak levels up to 175 dB re 1 µPa. Besides exhibiting startle responses, all four species examined received damage to the statocyst, which is the organ responsible for equilibrium and movement. The animals showed stressed behavior, decreased activity, and loss of muscle tone.

When New Zealand scallop (*Pecten novaezelandiae*) larvae were exposed to recorded seismic pulses, significant developmental delays were reported, and 46% of the larvae exhibited body abnormalities; it was suggested that the malformations could be attributable to cumulative exposure (Aguilar de Soto et al. 2013). Their experiment used larvae enclosed in 60-mL flasks suspended in a 2-m diameter by 1.3-m water depth tank and exposed to a playback of seismic sound at a distance of 5–10 cm. Day et al. (2016) exposed egg-bearing female spiny lobsters (*Jasus edwardsi*) to three different air gun configurations in the field: 45 $in^3$, 150 $in^3$ (low pressure), and 150 $in^3$ (high pressure), each with corresponding maximum peak-to-peak source levels of 209, 210, and 212 dB re 1 µPa; and maximum cumulative SEL source levels of 192, 193, and 199 dB re 1 $\mu Pa^2 \cdot s$. Embryonic development of spiny lobster was assessed through the number, morphology, energy content, and competency of hatched larvae. It was determined that none of these variables were significantly different for the exposed larvae when compared to the control larvae. Other studies conducted in the field have shown no effects on Dungeness crab larvae or snow crab embryos to seismic sounds (Pearson et al. 1994; DFO 2004).

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

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

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

### (b) Effects of Sound on Fish

Potential impacts of exposure to airgun sound on marine fishes have been reviewed by Popper (2009), Popper and Hastings (2009a,b), and Fay and Popper (2012); they include pathological, physiological, and behavioral effects. Radford et al. (2014) suggested that masking of key environmental sounds or social signals could also be a potential negative effect from sound. Popper et al. (2014) presented guidelines for seismic sound level thresholds related to potential effects on fish. The effect types discussed include mortality, mortal injury, recoverable injury, temporary threshold shift, masking, and behavioral effects. Seismic sound level thresholds were discussed in relation to fish without swim bladders, fish with swim bladders, and fish eggs and larvae.

Bui et al. (2013) examined the behavioral responses of Atlantic salmon (*Salmo salar* L.) to light, sound, and surface disturbance events. They reported that the fish showed short-term avoidance responses to the three stimuli. Salmon that were exposed to 12 Hz sounds and/or surface disturbances increased their swimming speeds.

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

Miller and Cripps (2013) used underwater visual census to examine the effect of a seismic survey on a shallow-water coral reef fish community in Australia. The census took place at six sites on the reef before and after the survey. When the census data collected during the seismic program were combined with historical data, the analyses showed that the seismic survey had no significant effect on the overall abundance or species richness of reef fish. This was in part attributed to the design of the seismic survey (e.g., ≥400 m buffer zone around reef), which reduced the impacts of seismic sounds on the fish communities by exposing them to relatively low SELs (<187 dB re 1 μPa$^2$ · s). Fewtrell and McCauley (2012) exposed pink snapper (*Pagrus auratus*) and trevally (*Pseudocaranx dentex*) to pulses from a single airgun; the received sound levels ranged from 120 to 184 dB re 1 dB re 1 μPa$^2$ · s SEL. Increases in alarm responses were seen in the fish at SELs >147–151 dB re 1 μPa$^2$ · s; the fish swam faster and formed more cohesive groups in response to the airgun sounds.

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

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

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

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

### (c) Effects of Sound on Fisheries

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

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

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

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

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

### (d) Conclusions for Invertebrates, Fish, and Fisheries

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

Interactions between the proposed survey and fishing operations in the proposed survey areas are expected to be limited. Two possible conflicts in general are the *Revelle*'s streamer entangling with fishing gear and the temporary displacement of fishers from the proposed survey areas. Fishing activities could occur within the proposed survey areas; however, a safe distance would need to be kept from the *Revelle* and the towed seismic equipment. In this istance, the towed seismic equipment is relatively short, so this distance would be relatively small. Conflicts would be avoided through communication with the fishing community during the survey.

Given the proposed activity, no significant impacts on marine invertebrates, marine fish, and their fisheries would be expected. In decades of seismic surveys carried out by SIO and other vessels in the U.S. academic research fleet, PSOs and other crew members have not observed any seismic sound-related fish or invertebrate injuries or mortality.

### (6) Direct Effects on Seabirds and Their Significance

The underwater hearing of seabirds (including loons, scaups, gannets, and ducks) has recently been investigated, and the peak hearing sensitivity was found to be between 1500 and 3000 Hz (Crowell 2016). Great cormorants were also found to respond to underwater sounds and may have special adaptations for hearing underwater (Hansen et al. 2016; Johansen et al. 2016). Effects of seismic sound and other aspects of seismic operations (collisions, entanglement, and ingestion) on seabirds are discussed in § 3.5.4 of the PEIS. The PEIS concluded that there could be transitory disturbance, but that there would be no significant impacts of NSF-funded marine seismic research on seabirds or their populations. Given the proposed activities and the mitigation measures, no significant impacts on seabirds would be anticipated. In decades of seismic surveys carried out by SIO and other vessels in the U.S. academic research fleet, PSOs and other crew members have not observed any seismic sound-related seabird injuries or mortality.

### (7) Indirect Effects on Marine Mammals, Sea Turtles, Seabirds, Fish, and Their Significance

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

During the proposed seismic surveys, only a small fraction of the available habitat would be ensonified at any given time. Disturbance to fish species and invertebrates, if any, would be short-term, and fish would return to their pre-disturbance behavior once the seismic activity ceased. Thus, the proposed surveys would have little impact on the abilities of marine mammals or sea turtles to feed in the area where seismic work is planned.

### (8) Cumulative Effects

The results of the cumulative impacts analysis in the PEIS indicated that there would not be any significant cumulative effects to marine resources from the proposed NSF-funded marine seismic research. However, the PEIS also stated that, "A more detailed, cruise-specific cumulative effects analysis would be conducted at the time of the preparation of the cruise-specific EAs, allowing for the identification of other potential activities in the area of the proposed seismic surveys that may result in cumulative impacts to environmental resources." Here we focus on activities that could impact animals specifically in the proposed survey area (academic and industry research activities, vessel traffic, tourism, and fisheries).

### (a) Past and future research activities in the area

During September 2007 and July 2009, SIO conducted low-energy seismic surveys for ~6–7 days off the coast of Oregon. During July 2008, University of Texas Institute for Geophysics conducted a low-energy seismic survey for ~6 days off the coast of Oregon. In June–August 2004 and August–October 2005, the riserless drilling vessel *JOIDES Resolution* conducted coring off Oregon. Seismic surveys using a 36-airgun array were conducted off the coast of Oregon and Washington by the *Langseth* during June–July 2012. Other research activities may have been conducted in the past or may be conducted in the study area in the future; however, we are not aware of any research activities that are planned to occur in the proposed project area during September 2017.

### (b) Navy operations in the area

In the summer of 2012, the U.S. Navy conducted a test sponsored by the Naval Sea Systems Command, who is responsible for the research, development, and construction of Navy systems. They tested a towed array with an active acoustic source and a passive receiver. The primary test took place during both a north and south ship transit between San Diego, CA, and Puget Sound in the Pacific Northwest, when the ship was >12 n.mi. (~22 km) from the coast of the U.S. Other navy activities may have been or may be conducted in this region in the future as this area is part of the U.S. Navy's Northwest Training and Testing Area; however, we are not aware of any specific activities that are planned to occur in the proposed survey area during September 2017.

### (c) Vessel traffic

Several major ports are located on the northwestern coast of the U.S., including Portland, and major shipping lanes originate there. Vessel traffic in the proposed survey area will consist mainly of commercial fishing and cargo vessels. Based on the data available through the Automate Mutual-Assistance Vessel Rescue (AMVER) system managed by the U.S. Coast Guard (USCG), 15–49 cargo vessels travelled through the proposed survey areas during the month of September 2012 (USCG 2016). Live vessel traffic information is available from MarineTraffic (2017), including vessel names, types, flags, positions, and destinations. Various types of vessels were in the general vicinity of the proposed survey areas when MarineTraffic (2017) was accessed on 28 February 2017, including cargo vessels (9), tankers (1), tugs (3), and fishing vessels (1). The total transit time by the *Revelle* (8 days) would be minimal relative to the number of other vessels operating in the proposed survey area during September 2017. Thus, the combination of SIO's operations with the existing shipping operations is expected to produce only a negligible increase in overall ship disturbance effects on marine mammals.

### (d) Tourism

Various companies offer whale and dolphin watching off the coast of Oregon and Washington. Whale watching can occur in this area year-round (Oregon Coast Visitors Association 2017). The main focus of the whale watch industry is the southward gray whale migration from mid-December through January and their northbound migration from March to June (Oregon Coast Visitors Association 2017). However, some whales are resident off Oregon in the summer and can be seen there from June through November (Oregon Coast Visitors Association 2017). There are at least 11 whale watching boat charters along the coast of Oregon, including at Newport and Depoe Bay; whale watching flights are also carried out by at least six companies (Oregon Coast Visitors Association 2017). Whale watching also takes place in Washington State, but most of the excursions occur near the San Juan Islands and inshore of the proposed project area.

SIO's operations would not be located in areas used for whale-watching activities and would be short in duration (~8 days), whereas whale watching is ongoing. The combination of the proposed surveys with the existing tourism operations would be expected to produce only a negligible increase in overall disturbance effects on marine mammals.

#### (e) Fisheries

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

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

Before 2000, high bycatch of harbor porpoises, southern sea otters, and pinnipeds (California sea lion, harbor seals, and elephant seals) occurred in the set gillnet fishery for California halibut. The bycatch likely led to the decline of the harbor porpoise. Restrictions applied between 2000 and 2002 effectively closed most of the fishery (Moore et al. 2009).

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

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

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

***Conclusions.***—There may be some localized avoidance or attraction by marine mammals of fishing vessels near the proposed project area. SIO's operations in the proposed project would be limited (cruise duration of ~8 days), and the combination of SIO's operations with the existing fishing operations would be expected to produce only a negligible increase in overall disturbance effects on marine mammals, sea turtles, seabirds, and fish. Proposed survey operations should not impede fishing operations, and the *Revelle* would avoid fishing vessels when towing seismic equipment. Operation of the *Revelle*, therefore, would not be expected to significantly impact recreational or commercial fishing operations in the area.

#### (e) Summary of Cumulative Impacts to Marine Mammals, Sea Turtles, Seabirds, and Fish

Impacts of SIO's proposed seismic survey are expected to be no more than a very minor (and short-term) increment when viewed in light of other human activities within the proposed survey area. Unlike some other ongoing and routine activities in the area (e.g., commercial fishing), SIO's activities are not expected to result in injuries or deaths of marine mammals and sea turtles. Although the airgun sounds from the seismic survey will have higher source levels than do the sounds from most other human activities in the area except perhaps naval sonar, airgun operations during the surveys would last only ~5 days, in contrast to those from many other sources that have lower peak pressures but occur continuously over extended periods. Thus, the combination of SIO's operations with the existing shipping and fishing activities would be expected to produce only a negligible increase in overall disturbance effects on marine mammals and turtles.

### (9) Unavoidable Impacts

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

### (10) Coordination with Other Agencies and Processes

This Draft EA was prepared by LGL on behalf of SIO, NSF, TAMU, OSU, and Rutgers. Potential impacts to endangered species and critical habitat have also been assessed in the document; it will be used to support the ESA Section 7 consultation process with NMFS and USFWS. This document will also be used as supporting documentation for an IHA application submitted to NMFS, under the U.S. MMPA, for "taking by harassment" (disturbance) of small numbers of marine mammals, for this proposed seismic project. In order to protect EFH, federal agencies are required to consult with NMFS on activities that may adversely affect EFH. If NSF determines that the proposed action would adversely affect EFH, the NSF will consult with the Habitat Protection Division of NMFS. SIO and NSF will comply with any additional applicable federal regulations and will continue to coordinate with federal regulatory agencies and their requirements.

## Alternative Action: Another Time

An alternative to issuing the IHA for the period requested, and to conducting the Project then, is to issue the IHA for another time, and to conduct the project at that alternative time. The proposed dates for the cruise (~1 week in September) are the dates when the personnel and equipment essential to meet the overall project objectives are available.

Marine mammals and sea turtles are expected to be found throughout the proposed survey area and throughout the time period during which the project would occur. Except for some baleen whales, most marine mammal species are probably year-round residents in the survey area, so altering the timing of the proposed project likely would result in no net benefits for any species (see § III, above).

## No Action Alternative

An alternative to conducting the proposed activities is the "No Action" alternative, i.e., do not issue an IHA and do not conduct the operations. If the research were not conducted, the "No Action" alternative would result in no disturbance to marine mammals or sea turtles attributable to the proposed activities; however, valuable data about the marine environment would be lost. Chief scientist training for seismic surveys would not occur and information to address questions about earthquake hazards and paleoclimate records in basins off the Oregon continental margin would not be gained. The No Action Alternative would not meet the purpose and need for the proposed activities.

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# VI. LITERATURE CITED

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