Request by Scripps Institution of Oceanography for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during a Low-Energy Marine Geophysical Survey by the R/V *Roger Revelle* in the Northeastern Pacific Ocean, September 2017

submitted by

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to

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SUMMARY

The Scripps Institution of Oceanography (SIO) plans to support a research activity that would involve a low-energy seismic survey in the northeastern Pacific Ocean during September 2017. The research activity would be funded by the U.S National Science Foundation (NSF). The seismic survey 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 in water depths ~130–2600 m within the Exclusive Economic Zone (EEZ) of the U.S. but outside of territorial waters. SIO requests that it be issued an Incidental Harassment Authorization (IHA) allowing non-lethal takes of marine mammals incidental to the planned seismic survey. This request is submitted pursuant to Section 101 (a)(5)(D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371(a)(5).

Numerous species of marine mammals inhabit the proposed survey area in the northeastern Pacific Ocean. Under the U.S. Endangered Species Act (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. SIO is proposing a marine mammal monitoring and mitigation program to minimize the potential impacts of the proposed activity on marine mammals present during conduct of the proposed research, and to document the nature and extent of any effects.

Other marine ESA-listed species that could occur in the project area include the ***endangered*** leatherback and loggerhead turtles; the ***threatened*** green and olive ridley turtles; the ***endangered*** short-tailed albatross; the ***threatened*** marbled murrelet and western snowy plover; 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.

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

I. Operations to be Conducted

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

Overview of the Activity

SIO plans to conduct a low-energy seismic survey off the coasts of Oregon and Washington during ~22–29 September 2017. The survey would take place off the continental margin out to 127.5°W and between ~43 and 46.5°N (see Fig. 1). Water depths in the survey area are ~130–2600 m. The seismic survey would be conducted in the EEZ of the U.S., outside of territorial waters. Seismic surveying could take place anywhere within the project area as shown in Figure 1; however, two potential survey sites have been proposed within this area—the Astoria Fan and the Southern Oregon survey areas. Representative survey tracklines are shown in Figure 1. However, some deviation in actual track lines and timing 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 proposed surveys involve 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. In addition, the survey would provide critical data to understand the sediment and crustal structure within the Cascadia continental margin. The proposed survey 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 (Texas A & M University), Drs. A. Trehu and M. Lyle (Oregon State University), and G. Mountain (Rutgers University) propose to collect low-energy, high-resolution multi-channel seismic (MCS) profiles off the coasts of Oregon and Washington. In addition to the PIs, a number of early career researchers and students would participate in the survey activities.

The procedures to be used for the seismic survey would be similar to those used during previous seismic surveys by SIO and would use conventional seismic methodology. The survey would involve one source vessel, the R/V *Roger Revelle*. The *Revelle* would deploy a pair of 45-in^3 GI airguns as an energy source with a total discharge 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 in Figure 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 survey sites 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.

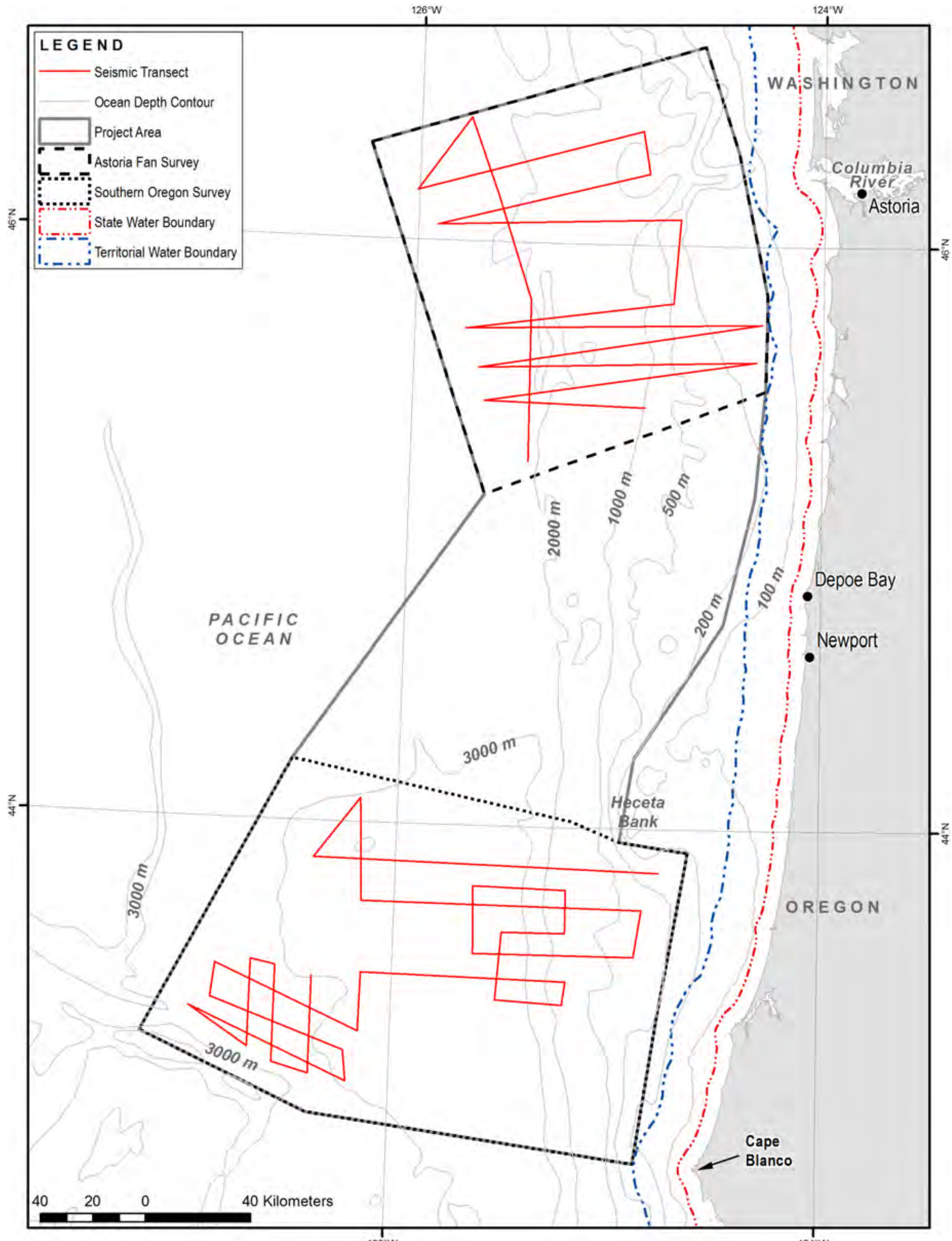


FIGURE 1. Locations of the proposed low-energy seismic survey in the northeastern Pacific Ocean, September 2017.

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 the calculations (see § VII), 25% has been added in the form of operational days, which is equivalent to adding 25% to the proposed line km to be surveyed.

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 project area. All planned geophysical data acquisition activities would be conducted by SIO with on-board assistance by the scientists who have proposed the study. The vessel would be self-contained, and the crew would live aboard the vessel for the entire cruise.

Source 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 an 1180-hp azimuthing jet bow thruster. An operation speed of 9.3 km/h (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 observers (PSOs) 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 § XIII.

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 GI Airguns:	Price Air Compressors, 300 cfm at 1750 psi
Accommodation Capacity:	22 crew plus 37 scientists

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); 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 transfers 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 level of 160 dB re 1 μPa_{rms} in the far field would typically correspond to ~170 dB re 1 μPa_{p}, and to ~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.

Mitigation zones for the proposed marine seismic survey were not derived from the farfield signature but calculated based on modeling by Lamont-Doherty Earth Observatory (L-DEO) of Columbia University for both the exclusion zones (EZ) for Level A takes and safety zones (160 dB re 1μPa_{rms}) for Level B takes. Received sound levels have been predicted by L-DEO's model (Diebold et al. 2010,

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

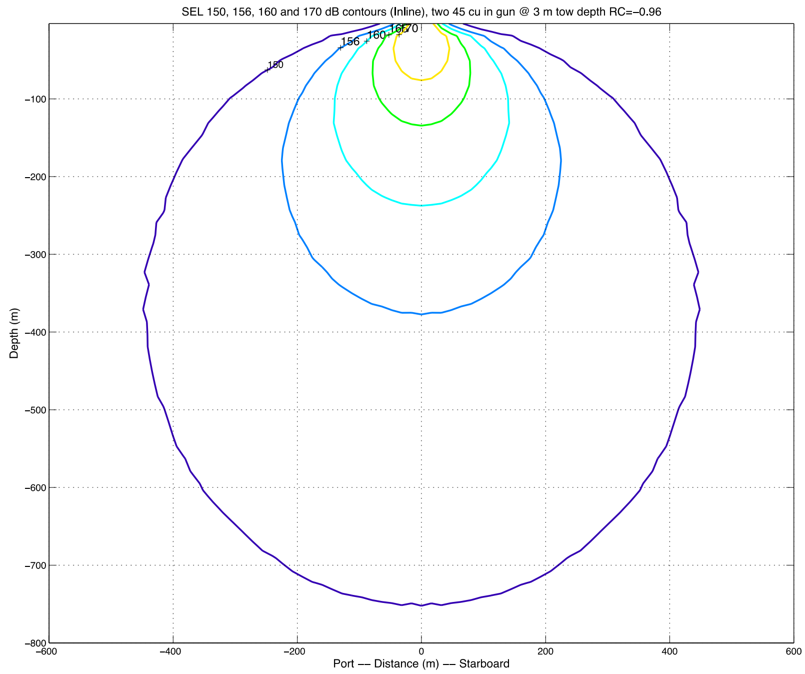
provided as Appendix H in the NSF/USGS PEIS[2]), as a function of distance from the airguns, for the two 45-in^3 GI guns. This modeling approach uses ray tracing for the direct wave traveling from the array to the receiver and its associated source ghost (reflection at the air-water interface in the 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 survey 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 for various Sound Exposure Levels (SEL)[3] obtained from L-DEO model results down to a maximum water depth of 2000 m (Fig. 2).

[2] 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 (June 2011) and Record of Decision (June 2012) is referred to herein as the PEIS.

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



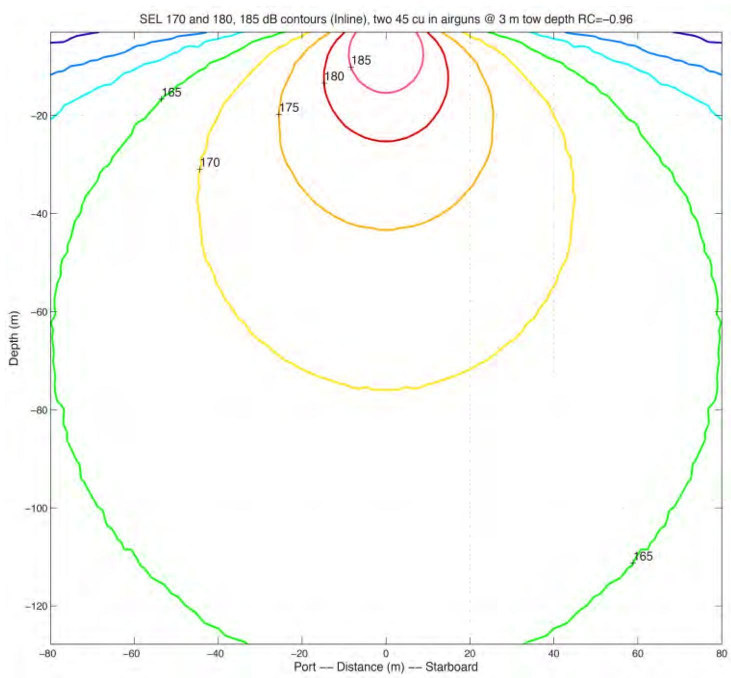


FIGURE 2. Modeled deep-water received sound exposure levels (SELs) from the two 45-in^3 GI guns planned for use during the proposed surveys in the northeastern Pacific Ocean at a 3-m tow depth. Received rms levels (SPLs) are expected to be ~10 dB higher. The radius to the 150-dB SEL isopleth is a proxy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

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$_{rms}$ sound levels are expected to be received for the two 45-in^3 GI guns at a 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 the National Marine Fisheries Service (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[4] 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) 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 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 for impulsive sources was assumed to be 15 dB or 6 dB higher when considering SEL_{cum} and SPL_{flat}, respectively. For impulsive sounds, such airgun pulses, the new guidance incorporates marine mammal auditory weighting functions (Fig. 3) and dual metrics of cumulative sound exposure level (SEL_{cum} over 24 hours) and peak sound pressure levels (SPL_{flat}). Different thresholds are provided for the various hearing groups, including low-frequency (LF) cetaceans (e.g., baleen whales), mid-frequency (MF) cetaceans (e.g., most delphinids), high-frequency (HF) cetaceans (e.g., porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW). As required by NMFS (2016a), the largest distance of the dual criteria (SEL_{cum} or Peak SPL_{flat}) was used to calculate takes and Level A threshold distances. The new guidance did not alter the current threshold, 160 dB re 1µPa$_{rms}$, for Level B harassment (behavior).

The SEL_{cum} and Peak SPL for the *Reveille* array are derived from calculating the modified farfield signature. The farfield signature is often used as a theoretical representation of the source level. To compute the farfield signature, the source level is estimated at a large distance (right) below the array (e.g., 9 km), and this level is back projected mathematically to a notional distance of 1 m from the array's geometrical center. However, it has been recognized that the source level from the theoretical farfield signature is never physically achieved at the source when the source is an array of multiple airguns separated in space (Tolstoy et al. 2009). Near the source (at short ranges, distances <1 km), the pulses of

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

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 survey in the northeastern Pacific Ocean 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.

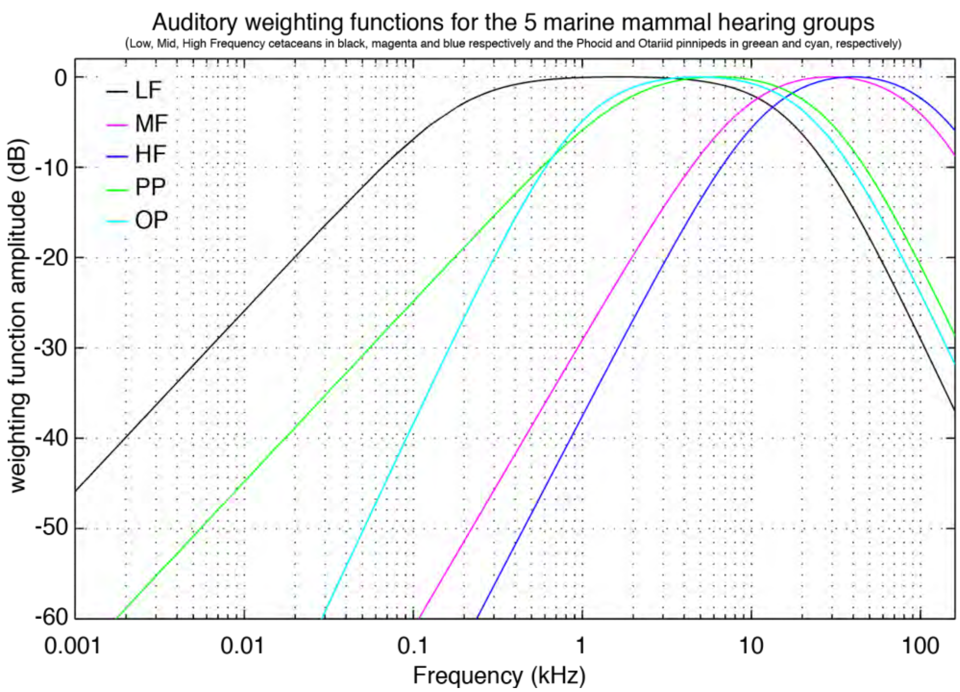


FIGURE 3. Auditory weighting functions from NMFS technical guidance.

sound pressure from each individual airgun in the source array do not stack constructively as they do for the theoretical farfield signature. The pulses from the different airguns spread out in time such that the source levels observed or modeled are the result of the summation of pulses from a few airguns, not the full array (Tolstoy et al. 2009). At larger distances, away from the source array center, sound pressure of all the airguns in the array stack coherently, but not within one time sample, resulting in smaller source levels (a few dB) than the source level derived from the farfield signature. Because the farfield signature does not take into account the large array effect near the source and is calculated as a point source, the modified farfield signature is a more appropriate measure of the sound source level for large arrays. For this smaller array, the modified farfield changes will be correspondingly smaller as well but we use this method for consistency across all array sizes.

To estimate SEL_{cum} and Peak SPL, we used the acoustic modeling developed at L-DEO (same as used for Level B takes) with a small grid step in both the inline and depth directions. The propagation modeling takes into account all airgun interactions at short distances from the source including interactions between subarrays which we do using the NUCLEUS software to estimate the notional signature and the MATLAB software to calculate the pressure signal at each mesh point of a grid.

PTS onset acoustic thresholds estimated in the NMFS User Spreadsheet rely on override of default values and calculating individual adjustment factors (dB) and by using the difference between levels with and without weighting functions for each of the five categories of hearing groups. The new adjustment factors in the spreadsheet allow for the calculation of SEL_{cum} isopleths in the spreadsheet and account for the accumulation (Safe Distance Methodology) using the source characteristics (duty cycle and speed) after Sivle et al. (2014). The Peak SPL calculations are achieved by applying a high pass band filter over the ranges of hearing as defined in the NMFS Technical Guidance. The methodology (input) for calculating the distances to the SEL_{cum} PTS thresholds (Level A) for the airgun array is shown below.

SEL_{cum} Methodology Parameters (Sivle et al. 2014) †

Source Velocity (meters/second)	2.572222
1/Repetition rate^ (seconds)	7.775377

† Methodology assumes propagation of 20 log R. ^ Time between onset of successive pulses. Activity duration (time) independent. The source velocity and 1/Repetition rate were used as inputs to the NMFS User Spreadsheet.

For the LF cetaceans, we estimated a new adjustment value by computing the distance from the geometrical center of the source to where the 183 dB SEL_{cum} isopleth is the largest. We first ran the modeling for a single shot without applying any weighting function; the maximum 183 dB SEL_{cum} isopleth was located at 14.15 m from the source. We then ran the modeling for a single shot with the LF cetacean weighting function applied to the full spectrum; the maximum 183 dB SEL_{cum} isopleth was located at 7.10 m from the source. The difference between 14.15 m and 7.10 m gives an adjustment factor of 5.98 dB assuming a propagation of $20\log_{10}$(Radial distance) (Table 2).

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

For the two GI guns, the results for single shot SEL source level modeling are shown in Table 2. The weighting function calculations, thresholds for SEL_{cum}, and the distances to the PTS thresholds are shown in Table 3. Figure 4 shows the impact of weighting functions by hearing group. Figures 5–6 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure 7 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans.

TABLE 2. Table showing the results for one single SEL source level modeling without and with applying weighting function to the five hearing groups. The modified farfield signature is estimated using the distance from the source array geometrical center to where the SEL_{cum} threshold is the largest. A propagation is of 20 $\log_{10}$ (Radial distance) is used to estimate the modified farfield SEL.

SEL_{cum} Threshold	**183**	**185**	**155**	**185**	**203**
Distance (m) (no weighting function)	14.1522	11.1735	370.845	11.1735	1.55
Modified Farfield SEL	206.0165	205.9638	206.384	205.9638	206.806
Distance (m) (with weighting function)	7.1051	N.A.	N.A.	N.A.	N.A.
Adjustment (dB)	- 5.98	N.A.	N.A.	N.A.	N.A.

N.A. means not applicable or not available.

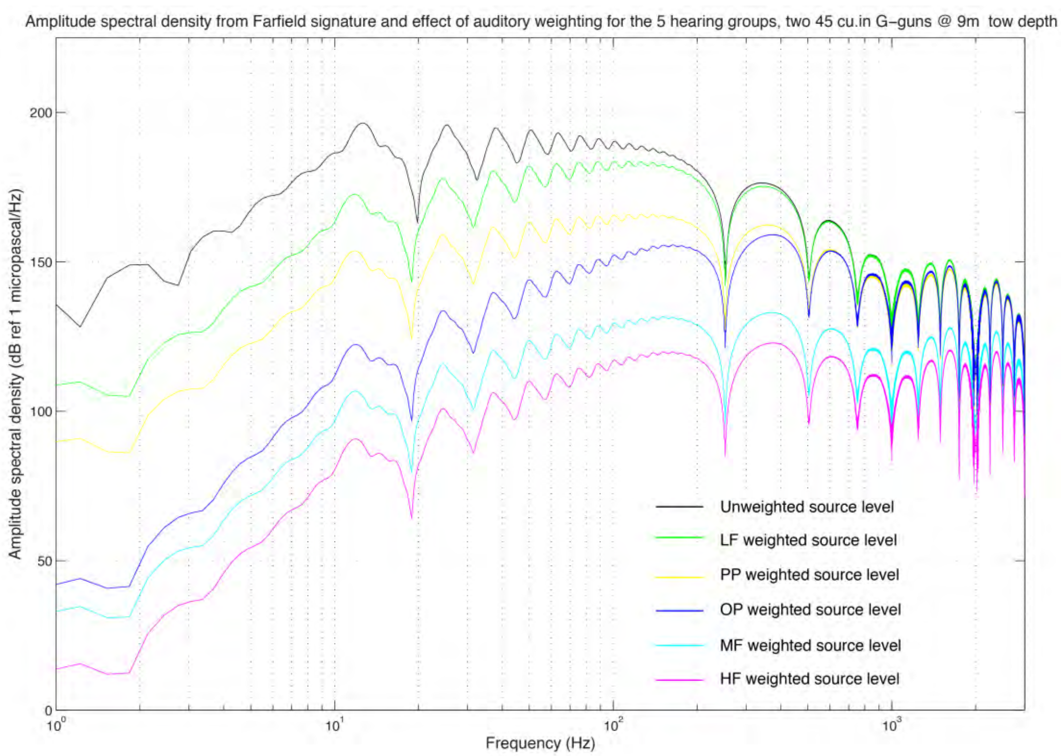


FIGURE 4. Modeled amplitude spectral density of the two GI guns farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral levels are used to calculate the difference between the unweighted and weighted source level at each frequency and to derive the adjustment factors for the hearing groups as inputs into the NMFS User Spreadsheet.

TABLE 3. NMFS User Spreadsheet. Results for single shot SEL source level modeling for the two GI guns with weighting function calculations for the SEL_{cum} criteria, as well as resulting isopleths to thresholds for various hearing groups.

STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	R/V Revelle - SIO
PROJECT/SOURCE INFORMATION Please include any assumptions	two 45 cu.in g-gun @ a 3 m tow depth
PROJECT CONTACT	

STEP 2: WEIGHTING FACTOR ADJUSTMENT

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

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

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

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

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

STEP 3: SOURCE-SPECIFIC INFORMATION

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

NOTE: LDEO modeling relies on Method F2

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

SEL_{cum}

Source Velocity (meters/second)	2.5722
1/Repetition rate^ (seconds)	7.7753

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

^Time between onset of successive pulses.

Modified farfield SEL	206.0165	205.9638	206.384	205.9638	206.806
Source Factor	5.13964E+19	5.07765E+19	5.59349E+19	5.07765E+19	6.16429E+19

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)	7.9	0.0	0.0	0.1	0.0

WEIGHTING FUNCTION CALCULATIONS

Weighting Function Parameters	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	
a	1	1.6	1.8	1	2	
b	2	2	2	2	2	
f_1	0.2	8.8	12	1.9	0.94	
f_2	19	110	140	30	25	
C	0.13	1.2	1.36	0.75	0.64	
Adjustment (dB)†	-5.98	-53.10	-62.15	-23.35	-28.88	OVERIDE Using LDEO Modeling

†For LF cetaceans, the adjustment factor (dB) is derived by estimating the radial distance of the 183-dB isopleth without applying the weighting function and a second time with applying the weighting function. Adjustment was derived using a propagation of $20\log_{10}$ (Radial distance) and the modified farfield signature. For MF and HF cetaceans and pinnipeds, the difference between weighted–unweighted spectral source levels at each frequency was integrated to calculate adjustment factors (see spectrum levels in Figure 4).

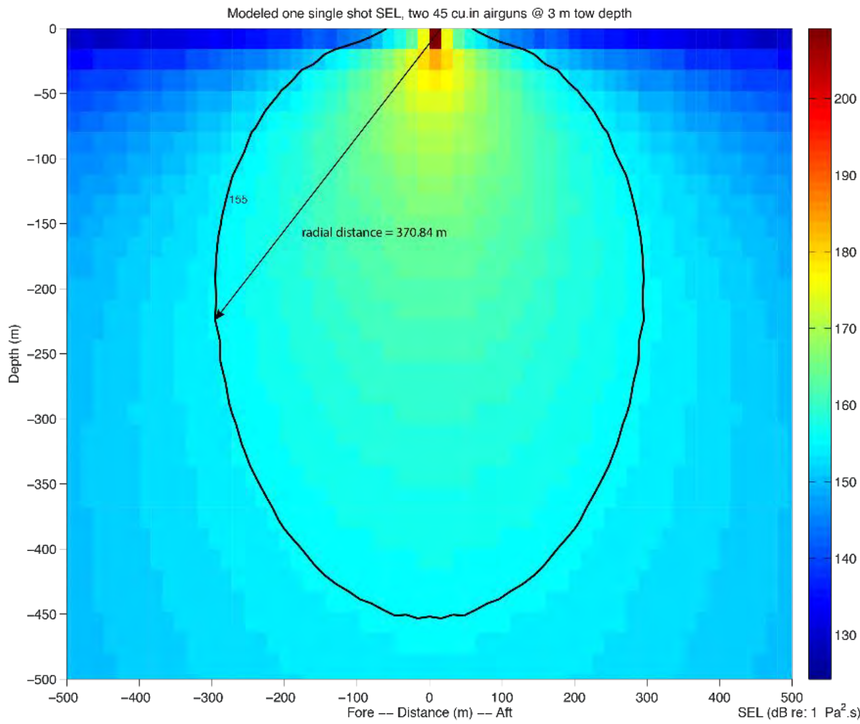


FIGURE 5. Modeled received sound levels (SELs) in deep water from the two 45 in³ GI guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (370.84 m).

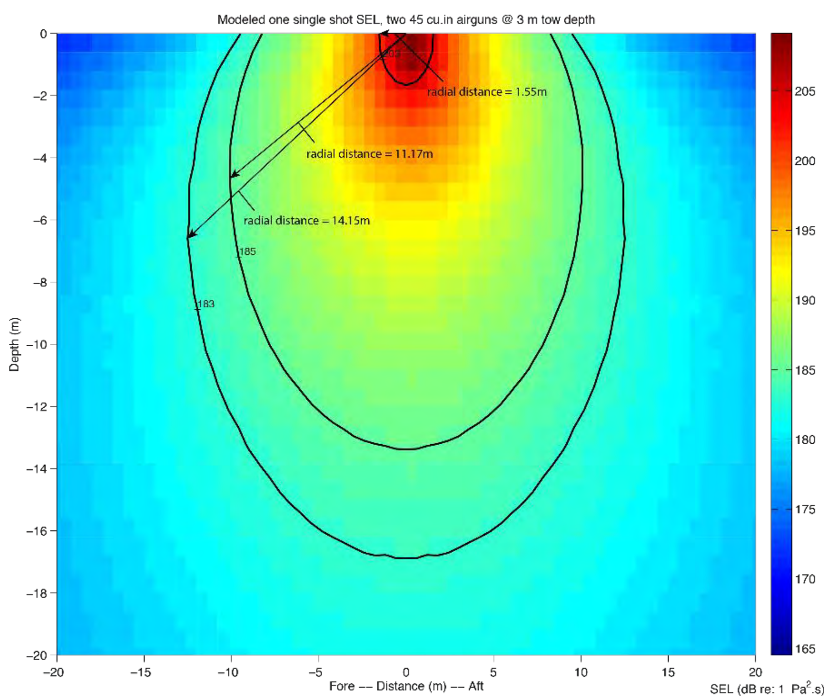


FIGURE 6. Modeled received sound levels (SELs) in deep water from the two 45 in³ GI guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183-, 185-, and 203-dB SEL isopleths.

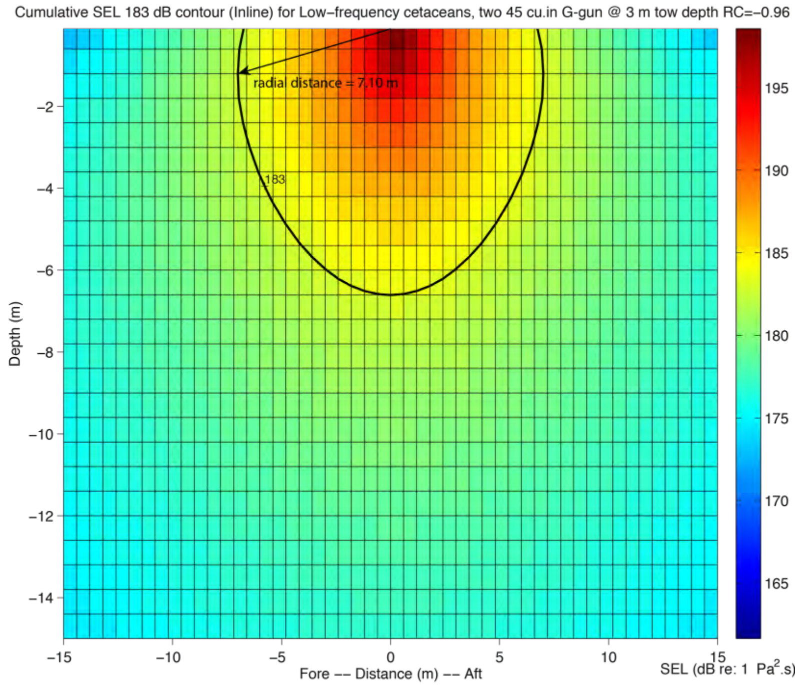


FIGURE 7. Modeled received sound exposure levels (SELs) from the two 45 in³ GI guns at a 3-m tow depth, after applying the auditory weighting function for the LF cetaceans following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SELcum isopleth for one shot. The difference in radial distances between Fig. 6 (254.58 m) and this figure (2.29 m) allows us to estimate the adjustment in dB.

The thresholds for Peak SPL_{flat} for the two GI guns, as well as the distances to the PTS thresholds, are shown in Table 4. Figures 8–10 show the modeled received sound levels to the Peak SPL_{flat} thresholds, for a single shot, with a high pass filter applied for each hearing group. Figures 11–12 show the modeled received sound levels to the Peak SPL_{flat} thresholds, for a single shot, without applying a high pass filter.

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 in³. 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 is used here for the pair of 45-in³ 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-in³ 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-in³ GI guns are used here to determine the 160-dB radius for the pair of 45-in³ GI airguns (see Table 1).

This IHAA has been prepared in accordance with the current NOAA acoustic practices, and 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).

TABLE 4. NMFS Level A acoustic thresholds (Peak SPL_{flat}) for impulsive sources for marine mammals and predicted radial distances to Level A thresholds for various marine mammal hearing groups that could be received from the two GI guns during the proposed seismic surveys in the northeastern Pacific Ocean.

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
PK Threshold	**219**	**230**	**202**	**218**	**232**
Radial distance to threshold (m)	4.901	0.987	34.943	5.222	0.436
Modified Farfield Peak SPL*	232.805	229.89	232.867	232.356	224.7897
Distance (m) (HP filter)	4.68	N.A.	12.49	3.865	N.A.
Adjustment (dB)	-0.40	N.A.	- 8.93	- 2.61	N.A.
PTS PK Isopleth to threshold (m)	**4.7**	**0**	**12.5**	**3.8**	**0**

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

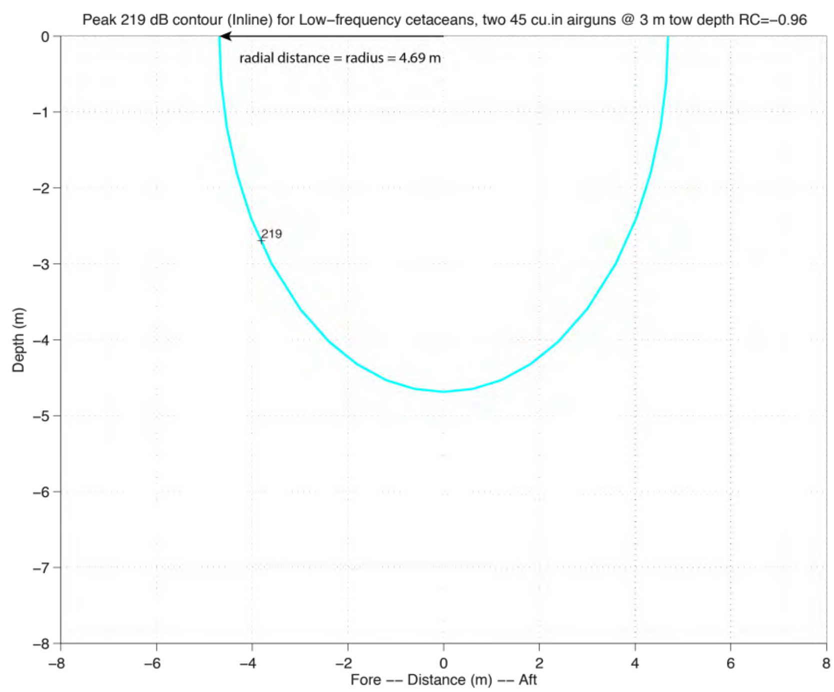


FIGURE 8. Modeled deep-water received Peak SPL from the two 45-in^3 GI guns at 3-m tow depth after applying a high pass filter of 7 Hz for LF cetaceans as described in the NMFS Acoustic Guidance. The plot provides the radius to the 219-dB Peak SPL isopleth for one airgun shot that corresponds to the PTS Peak SPL threshold for LF cetaceans.

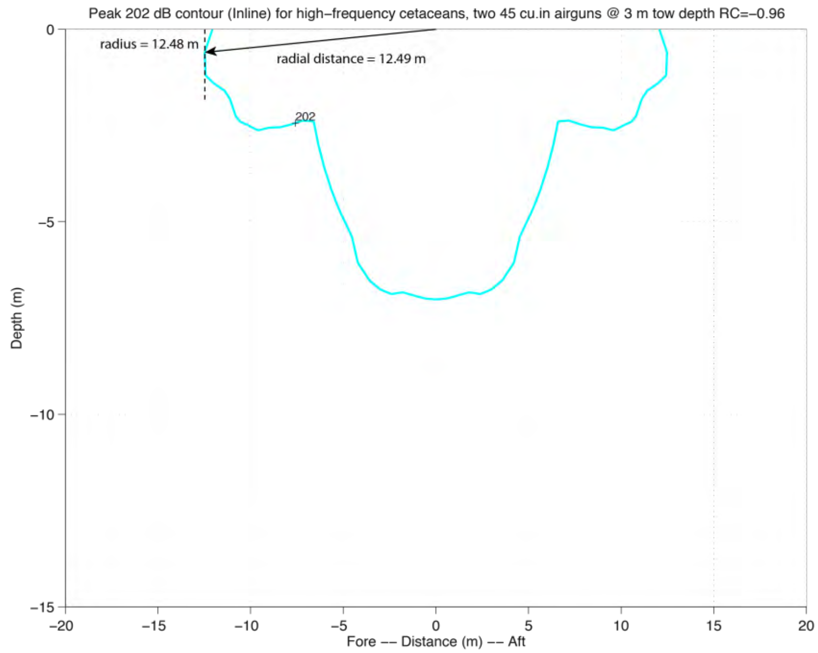


FIGURE 9. Modeled deep-water received Peak SPL from the two 45-in^3 GI guns at 3-m tow depth after applying a high pass filter of 275 Hz for HF cetaceans as described in the NMFS Acoustic Guidance. The plot provides the radius to the 202-dB Peak SPL isopleth for one shot that corresponds to the PTS Peak SPL threshold for HF cetaceans.

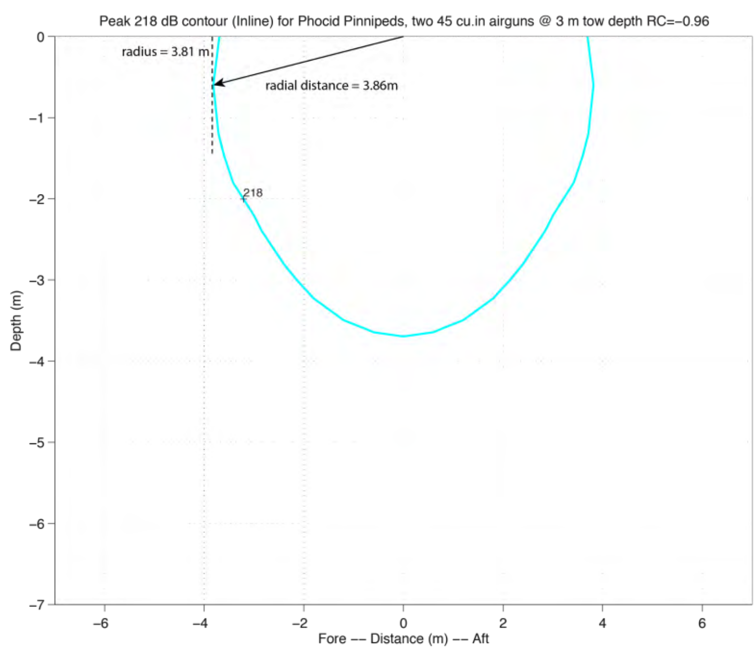


FIGURE 10. Modeled deep-water received Peak SPL from the two-45-in^3 GI guns at 3-m tow depth after applying a high pass filter of 50 Hz for Phocids Underwater as described in the NMFS Acoustic Guidance. The plot provides the radius to the 218-dB Peak SPL isopleth for one shot that corresponds to the PTS Peak SPL threshold for Phocids.

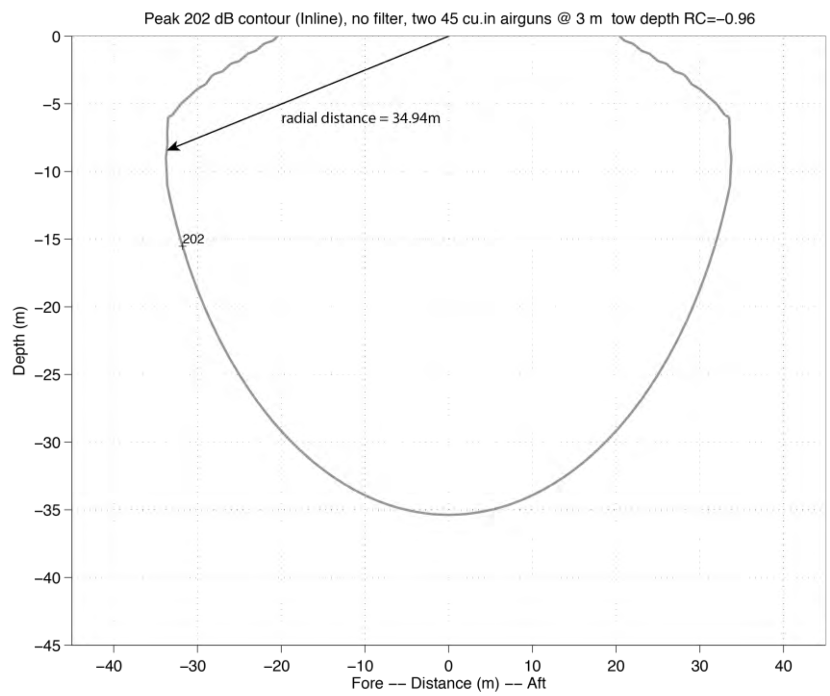


FIGURE 11. Modeled deep-water received Peak SPL from two 45-in³ GI guns at a 3-m tow depth. The plot provides the radial distance from the source geometrical center to the 202-dB peak isopleth (34.94 m).

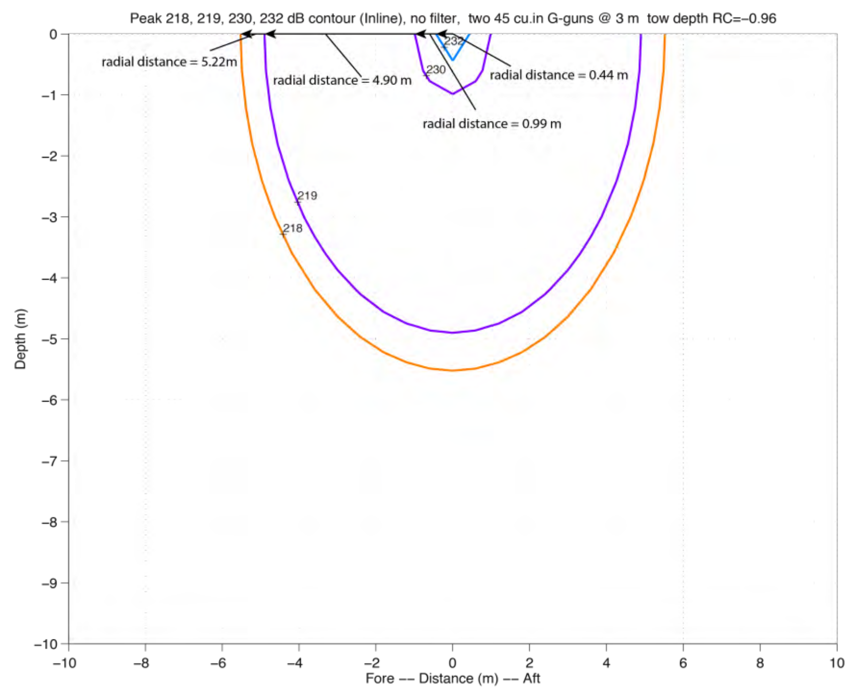


FIGURE 12. Modeled deep-water received Peak SPL from two 45 in³ GI guns at a 3-m tow depth. The plot provides the radial distances from the source geometrical center to the 218-, 219-, 230-, and 232-dB Peak isopleths.

Description of Operations

The proposed survey would involve one source vessel, the *Revelle*. The *Revelle* would tow a pair of 45-in^3 GI airguns and an 800-m streamer containing hydrophones along predetermined lines. As the GI 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 in Figure 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. 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 track distance to be surveyed is estimated to be no greater than ~1057 km with no more than ~23% of line km in intermediate water, and no effort in water <100 m.

Along with the airgun operations, two additional acoustical data acquisition systems would be operated during the entire survey. 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.

II. Dates, Duration, and Region of Activity

The date(s) and duration of such activity and the specific geographical region where it will occur.

The proposed survey would take place during September 2017 off the Oregon continental margin out to 127.5°W and between ~43 and 46.5°N (Fig. 1). Water depths in the survey area are ~130–2600 m. 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 unforeseen events such as weather, logistical issues, or mechanical issues with the research vessel and/or equipment. Seismic operations would take ~4 to 5 days, and the transit to and from Newport would take ~2 days.

III. Species and Numbers of Marine Mammals in Area

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

Thirty-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 5). To avoid redundancy, we have included the required information about the species and (insofar as it is known) numbers of these species in § IV, below.

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

TABLE 5. 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.

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 project area and are not addressed in the summaries below.

IV. Status, Distribution and Seasonal Distribution of Affected Species or Stocks of Marine Mammals

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

Sections III and IV are integrated here to minimize repetition.

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 project area. It is possible although very unlikely that individuals from the ***Endangered*** Western North Pacific gray whale population could occur in the proposed project area.

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 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.

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.

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 Washington, presumably in response to changing oceanographic conditions on both annual and seasonal time scales (Forney and Barlow 1998; Buchanan et al. 2001). The highest densities were predicted along the coasts of Washington, Oregon, and central and southern California (Becker et al. 2012). Off Oregon and Washington, Risso's dolphins are most abundant over continental slope and shelf waters during spring and summer, less so during fall, and rare during winter (Green et al. 1992, 1993). Green et al. (1992, 1993) reported most Risso's dolphin groups off Oregon between ~45 and 47ºN. Several sightings were made 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 *endangered* Southern Resident, Offshore, and West Coast Transient stocks could be encountered in the proposed project area (see Carretta et al. 2016a).

Critical habitat for the Eastern North Pacific Southern Resident stock 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, Washington to Point Reyes, California, 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).

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.

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). 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). Federally designated critical habitat for Steller sea lions includes all rookeries and major haulouts, including aquatic zones that extend 0.9 km seaward and air zones extending 0.9 km above these terrestrial and aquatic zones (NMFS 1993). Although the Eastern DPS was delisted from the ESA in 2013, the designated critical habitat remains valid (NOAA 2017a).

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 2008). 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 2008). Pupping occurs from mid-May to mid-July (Pitcher and Calkins 1981) and peaks in June (Pitcher et al. 2002).

Territorial males fast and remain on land during the breeding season (NMFS 2008). 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 2008). 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 2008). Two rookeries in southern Oregon, Orford Reef (Long Brown Rock and Seal Rock) and Rogue Reef (Pyramid Rock), are designated as critical habitat; the rookey in northern Oregon, Three Arch Rocks, is not. 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. Several haul-out sites are also located in Washington (NMFS 2008). 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.

V. TYPE OF INCIDENTAL TAKE AUTHORIZATION REQUESTED

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

SIO requests an IHA pursuant to Section 101 (a)(5)(D) of the MMPA for incidental take by harassment during its planned seismic survey in the northeastern Pacific Ocean during September 2017.

The operations outlined in § I have the potential to take marine mammals by harassment. Sounds would be generated by the GI airguns used during the survey, by echosounders, and by general vessel operations. "Takes" by harassment would potentially result when marine mammals near the activities are exposed to the pulsed sounds generated by the GI airguns or echosounders. The effects would depend on the species of marine mammal, the behavior of the animal at the time of reception of the stimulus, as well as the distance and received level of the sound (see § VII). Disturbance reactions are likely amongst some of the marine mammals near the tracklines of the source vessel.

At most, effects on marine mammals would be anticipated as falling within the MMPA definition of "Level B Harassment" for those species managed by NMFS. No take by serious injury is expected, given the nature of the planned operations and the mitigation measures that are planned (see § XI, MITIGATION MEASURES), and no lethal takes are expected. However, per NMFS requirement, small numbers of Level A takes are also being requested for the remote possibility of low-level physiological effects. Because of the characteristics of the proposed study and the proposed monitoring and mitigation measures, in addition to the general avoidance by marine mammals of loud sounds, Level A takes are considered highly unlikely.

VI. NUMBERS OF MARINE MAMMALS THAT COULD BE TAKEN

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

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

VII. ANTICIPATED IMPACT ON SPECIES OR STOCKS

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

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

- First we summarize the potential impacts on marine mammals of airgun operations, as called for in § VII, and refer 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 § 3.6.4.3, § 3.7.4.3, and Appendix E of the PEIS.
- Then we summarize the potential impacts of operations by the echosounders. A more comprehensive review of the relevant background information appears in § 3.6.4.3, § 3.7.4.3, and Appendix E of the PEIS.
- Finally, we estimate the numbers of marine mammals that could be affected by the proposed survey in the northeastern Pacific Ocean during September 2017. This section includes a description of the rationale for the estimates of the potential numbers of harassment "takes" during the planned survey, as called for in § VI.

Summary of Potential Effects of Airgun Sounds

As noted in the PEIS (§ 3.6.4.3, § 3.7.4.3, § 3.8.4.3), the effects of sounds from airguns could include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and at least in theory, temporary or permanent hearing impairment, or non-auditory physical or physiological effects (Richardson et al. 1995; Gordon et al. 2004; Nowacek et al. 2007; Southall et al. 2007; Erbe 2012; Peng et al. 2015; Erbe et al. 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.

Disturbance Reactions

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

Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors (Richardson et al. 1995; Wartzok et al. 2004; Southall et al. 2007; Weilgart 2007; Ellison et al. 2012). 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 $CSEL_{10\text{-}min}$ (cumulative SEL over a 10-min period) of ~94 dB re 1 $\mu Pa^2 \cdot s$, decreased at $CSEL_{10\text{-}min}$ >127 dB re 1 $\mu Pa^2 \cdot s$, and whales were nearly silent at $CSEL_{10\text{-}min}$ >160 dB re 1 $\mu Pa^2 \cdot s$. Thus, bowhead whales in the Beaufort Sea apparently decreased their calling rates in response to seismic operations, although movement out of the area could also have contributed to the lower call detection rate (Blackwell et al. 2013, 2015).

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

There was no indication that *western gray whales* exposed to seismic sound were displaced from their overall feeding grounds near Sakhalin Island during seismic programs in 1997 (Würsig et al. 1999) and in 2001 (Johnson et al. 2007; Meier et al. 2007; Yazvenko et al. 2007a). However, there were indications of subtle behavioral effects among whales that remained in the areas exposed to airgun sounds (Würsig et al. 1999; Gailey et al. 2007; Weller et al. 2006a) and localized redistribution of some individuals within the nearshore feeding ground so as to avoid close approaches by the seismic vessel (Weller et al. 2002, 2006b; Yazvenko et al. 2007a). Despite the evidence of subtle changes in some quantitative measures of behavior and local redistribution of some individuals, there was no apparent change in the frequency of feeding, as evident from mud plumes visible at the surface (Yazvenko et al. 2007b). Similarly, no large changes in gray whale movement, respiration, or distribution patterns were observed (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 μPa_{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 behavioral effects (Scholik-Schlomer 2015). As behavioral responses are not consistently associated with received levels, Gomez et al. (2016) recommended that a response/no response dichotomous approach be used when assessing behavioral 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 behavioral responses were observed.

Hearing Impairment and Other Physical Effects

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds. TTS has been demonstrated and studied in certain captive odontocetes and pinnipeds exposed to strong sounds (reviewed by Southall et al. 2007; Finneran 2015). However, there has been no specific documentation of TTS let alone permanent hearing damage, i.e., PTS, in free-ranging marine mammals exposed to sequences of airgun pulses during realistic field conditions.

Additional data are needed to determine the received sound levels at which small odontocetes would start to incur TTS upon exposure to repeated, low-frequency pulses of airgun sound with variable received levels. To determine how close an airgun array would need to approach in order to elicit TTS, one would (as a minimum) need to allow for the sequence of distances at which airgun pulses would occur, and for the dependence of received SEL on distance in the region of the seismic operation (e.g., Breitzke and Bohlen 2010; Laws 2012). At the present state of knowledge, it is also necessary to assume that the effect is directly related to total received energy (SEL); however, this assumption is likely an over-simplification (Finneran 2012). There is recent evidence that auditory effects in a given animal are not a simple function of received acoustic energy (Finneran 2015). Frequency, duration of the exposure, and occurrence of gaps within the exposure can also influence the auditory effect (Finneran and Schlundt 2010, 2011, 2013; Finneran et al. 2010a,b; Popov et al. 2011, 2013; 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 $L_{eq\text{-}fast}$ (rms average over the duration of the pulse) of 45 dB above the hearing threshold for behavioral responses (i.e., negative phonotaxis). In addition, according to Wensveen et al. (2014) and Tougaard et al. (2015), M-weighting, as used by Southall et al. (2007), might not be appropriate for the harbor porpoise. Thus, Wensveen et al. (2014) developed six auditory weighting functions for the harbor porpoise that could be useful in predicting TTS onset. 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 (see § XI and § XIII). 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 2015b). 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 project 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.

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 expected potential effects (or lack thereof) of MBESs and SBPs on marine mammals appears in § 3.6.4.3, § 3.7.4.3, and § 3.8.4.3 and Appendix E of the PEIS.

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

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

Lurton (2016) modeled MBES radiation characteristics (pulse design, source level, and radiation directivity pattern) applied to a low-frequency (12-kHz), 240-dB source-level system like that used on 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 behavioral 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). 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).

This new information presented here is in agreement with the assessment presented in § 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, (1) given the lower acoustic exposures relative to airguns and (2) because the intermittent and/or narrow downward-directed nature of these sounds would result in no more than one or two brief ping exposures of any individual marine mammal given the movement and speed of the vessel.

Other Possible Effects of Seismic Surveys

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

Vessel noise from the *Revelle* could affect marine animals in the proposed survey area. Houghton et al. (2015) proposed that vessel speed is the most important predictor of received noise levels. 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, 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 (e.g., Redfern et al. 2013). Information on vessel strikes is reviewed in § 3.6.4.4 and § 3.8.4.4 of the PEIS. Wiley et al. (2016) concluded that reducing ship speed is one of the most reliable ways to avoid ship strikes. 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 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 any of the vessels in the U.S. academic research fleet in the last two decades.

Numbers of Marine Mammals that could be "Taken by Harassment"

All takes would be anticipated to be Level B "takes by harassment" as described in § I, involving temporary changes in behavior. As required by NMFS, Level A takes have been requested; given the 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 B and Level B sound levels and present estimates of the numbers of marine mammals that could be affected during the proposed seismic survey. The estimates are based on consideration of the number of marine mammals that could be disturbed appreciably by the seismic survey 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.

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

Basis for Estimating "Take by Harassment"

The Level B estimates are based on a consideration of the number of marine mammals that could be within the area around the operating airgun array where received levels of sound ≥160 dB re 1 μPa_{rms} are predicted to occur (see Table 1). The estimated numbers are based on the densities (numbers per unit area) of marine mammals expected to occur in the 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 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. (2016a).

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 survey. 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 survey 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 survey.

The estimated numbers of individuals potentially exposed are based on the 160-dB re 1 μPa_{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 μPa_{rms} during the seismic survey 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

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*	*0*	*6*	*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	15	582	1.04%	597
Dall's porpoise	54.4	2	68	0.27%	258
Otariids					
Northern fur seal	83.4	0	107	0.02%	6626
California sea lion	283.3	0	362	0.12%	2968
Steller sea lion	15.0	0	20	0.03%	744
Phocids					
Harbor seal	292.3	3	371	1.51%	374
Northern elephant seal	83.1	1	106	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 μPa_{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 (3.2, 0, 5.0, 0, and 1.5 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 5).
[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 5), 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).

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 survey 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 ≥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 2013d). 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 2013d).

Potential Number of Marine Mammals Exposed

The number of marine mammals that could be exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} (Level B) on one or more occasions 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 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, 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 zones are extremely small and mitigation measures would further reduce the 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 597 harbor porpoises and 70 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 μPa_{rms} is 489 otariids and 481 phocids. Although the highest percentage of a population expected to be taken is 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.

Conclusions

The proposed seismic project would involve towing a very small source, a pair of 45-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". 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 required 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 2015c, 2016c,d).

Estimates of the numbers of marine mammals that could be exposed to airgun sounds during the proposed program have been presented, together with the requested "take authorization". The estimated numbers of animals potentially exposed to sound levels sufficient to cause Level A and/or B harassment are low percentages of the regional population sizes (Table 7). Although the calculated take estimates are likely overestimates of the actual number of animals that would be exposed to and would react to the seismic sounds, we have increased the requested takes to 1% of the regional population size (except in a few instances where noted otherwise). 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 could be too low. However, the relatively short-term exposures are unlikely to result in any long-term negative consequences for the individuals or their populations. Therefore, no significant impacts on marine mammals would be anticipated from the proposed activities.

In decades of seismic surveys carried out by 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 160-dB zone and potentially taken, representing <0.03% of the 11,367 authorized takes (RPS 2014). Furthermore, as defined, all animals exposed to sound levels >160 dB are Level B 'takes' whether or not a behavioral response occurred. The EZs, which are based on predicted sound levels, are thought to be conservative; thus, not all animals detected within the EZs would be expected to have been exposed to actual sound levels >160 dB.

VIII. Anticipated Impact on Subsistence

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

There is no subsistence hunting near the proposed survey area, so the proposed activities would not have any impact on the availability of the species or stocks for subsistence users.

IX. Anticipated Impact on Habitat

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

The proposed seismic survey would not result in any permanent impact on habitats used by marine mammals or to the food sources they use. The main impact issue associated with the proposed activity would be temporarily elevated noise levels and the associated direct effects on marine mammals, as discussed in § VII, above. Effects of seismic sound on marine invertebrates (crustaceans and cephalopods), marine fish, and their fisheries are discussed in § 3.2.4 and § 3.3.4 and Appendix D of the PEIS. The PEIS concluded that there could be changes in behavior and other non-lethal, short-term, temporary impacts, and injurious or mortal impacts on a small number of individuals within a few meters of a high-energy acoustic source, but that there would be no significant impacts of NSF-funded marine seismic research on populations.

X. Anticipated Impact of Loss or Modification of Habitat on Marine Mammals

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

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

XI. Mitigation Measures

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

Marine mammals and sea turtles are known to occur in the proposed project area. To minimize the likelihood that impacts would occur to the species and stocks, GI airgun operations would be conducted in accordance with regulations by NMFS under the MMPA and the ESA, including obtaining permission for incidental harassment or incidental 'take' of marine mammals and other endangered species. The proposed activities would take place in the EEZ of the U.S.

The following subsections provide more detailed information about the mitigation measures that are an integral part of the planned activity. The procedures described here are based on protocols used during previous NSF-funded seismic research cruises as approved by NMFS, and on best practices recommended in Richardson et al (1995), Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013), Wright (2014), and Wright and Cosentino (2015).

Planning Phase

As discussed in § 2.4.1.1 of the PEIS, mitigation of potential impacts from the proposed activity begins during the planning phase. Several factors were considered during the planning phase of the proposed activity, 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, seabirds, and sea turtles), weather conditions, equipment, and optimal timing for other proposed research cruises. Many 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*.—**Mitigation zones for the proposed survey were calculated based on modeling by L-DEO for both the Level A EZ and Level B safety zone. The proposed survey would acquire data with two 45-in^3 GI airguns at a tow depth of 3 m. 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.

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) to determine the distance from the airguns where the received sound level is 160 dB re $1\mu Pa_{rms}$. 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 $1\mu Pa_{rms}$ sound levels are expected to be received for the two 45-in^3 GI airguns. 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.

NMFS guidance for assessing the effects of anthropogenic sound on marine mammal hearing (NMFS 2016a) established new thresholds for PTS onset or Level A Harassment (injury), for marine mammal species; the distances to the PTS thresholds for the various marine mammal hearing groups are provided in Tables 3 and 4.

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 is 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. 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).

Mitigation During Operations

Mitigation measures that would be adopted include (1) vessel speed or course alteration, provided that doing so would not compromise operational safety requirements, (2) GI-airgun shut down within calculated EZs, and (3) ramp-up procedures. Although power-down procedures are often standard operating practice for seismic surveys, they would not be used here because powering down from two airguns to one airgun would make only a small difference in the EZs—probably not enough to allow continued one-airgun operations if a mammal or turtle came within the safety radius for two airguns.

Speed or Course Alteration

If a marine mammal or sea turtle is detected outside the EZ, based on its position and the relative motion, is likely to enter the EZ, the vessel's speed and/or direct course could be changed. This would be done if operationally practicable while minimizing the effect on the planned science objectives. The activities and movements of the marine mammal or sea turtle (relative to the seismic vessel) would then be closely monitored to determine whether the animal is approaching the applicable EZ. If the animal appears likely to enter the EZ, further mitigative actions would be taken, i.e., either further course alterations or a shut down of the seismic source. Typically, during seismic operations, the source vessel is unable to change speed or course and one or more alternative mitigation measures (see below) would need to be implemented.

Shut-down Procedures

If a marine mammal or turtle is detected outside the EZ but is likely to enter the EZ, and if the vessel's speed and/or course cannot be changed to avoid having the animal enter the EZ, the GI airguns would be shut down before the animal is within the EZ. Likewise, if a mammal or turtle is already within the EZ when first detected, the GI airguns would be shut down immediately. The operating airguns would also be shut down in the event an ESA-listed seabird were observed diving or foraging within the designated EZ.

Following a shut down, seismic activity would not resume until the marine mammal or turtle has cleared the EZ, or until the PSO is confident that the animal has left the vicinity of the vessel. The animal would be considered to have cleared the EZ zone if

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

Ramp-up Procedures

A ramp-up procedure would be followed when the pair of GI airguns begins operating after a specified period without GI airgun operations. It is proposed that, for the present survey, this period would be 15 min. Ramp up would not occur if a marine mammal or sea turtle has not cleared the EZ as described earlier.

Ramp up would begin with one GI airgun 45 in^3, and the second GI airgun would be added after 5 min. During ramp up, the PSOs would monitor the EZ, and if marine mammals or turtles are sighted, a shut down would be implemented as though the full array were operational.

If the EZ has not been visible for at least 30 min prior to the start of operations in either daylight or nighttime, ramp up would not commence. If one GI airgun has operated, ramp up to full power would be permissible at night or in poor visibility, on the assumption that marine mammals and turtles would be alerted to the approaching seismic vessel by the sounds from the single GI airgun and could move away if they choose. A ramp up from a shut down may occur at night, but only where the safety radius is small enough to be visible. Ramp up of the GI airguns would not be initiated if a sea turtle or marine mammal is sighted within or near the applicable EZ during day or night.

XII. Plan of Cooperation

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

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

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

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

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

Not applicable. The proposed activity would take place in the northeastern Pacific Ocean off Oregon and Washington, and no activities would take place in or near a traditional Arctic subsistence hunting area.

XIII. Monitoring and Reporting Plan

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

SIO proposes to sponsor marine mammal monitoring during the present project, in order to implement the proposed mitigation measures that require real-time monitoring, and to satisfy the anticipated monitoring requirements of the IHA.

SIO's proposed Monitoring Plan is described below. SIO understands that this Monitoring Plan would be subject to review by NMFS, and that refinements may be required.

The monitoring work described here has been planned as a self-contained project independent of any other related monitoring projects that may be occurring simultaneously in the same regions. SIO is prepared to discuss coordination of its monitoring program with any related work that might be done by other groups insofar as this is practical and desirable.

Vessel-based Visual Monitoring

PSO observations would take place during daytime GI airgun operations and nighttime start ups of the airguns. GI airgun operations would be suspended when marine mammals, turtles, or diving ESA-listed seabirds are observed within, or about to enter, designated EZs [see § XI above] where there is concern about potential effects on hearing or other physical effects. PSOs would also watch for marine mammals and turtles near the seismic vessel for at least 30 min prior to the planned start of airgun operations. When feasible, PSOs would also make observations during daytime periods when the seismic system is not operating for comparison of animal abundance and behavior. PSOs would also watch for any potential impacts of the acoustic sources on fish.

Three PSOs would be appointed by SIO, with NMFS Office of Protected Resources concurrence. At least one PSO would monitor the EZ during seismic operations. PSOs would normally work in shifts of 4-hour duration or less. The vessel crew would also be instructed to assist in detecting marine mammals and turtles.

The *Revelle* is a suitable platform from which PSOs would watch for marine mammals and turtles. The *Revelle* has been used for that purpose during the routine CalCOFI (California Cooperative Oceanic Fisheries Investigations). Observing stations are located at the 02 level, with the observer eye level at ~10.4 m above the waterline. At a forward-centered position on the 02 deck, the view is ~240º; an aft-centered view includes the 100-m radius area around the GI airguns. The observer eye level on the bridge is ~15 m above sea level. Standard equipment for marine mammal observers would be 7 x 50 reticule binoculars and optical range finders. At night, night-vision equipment would be available. The observers would be in communication with ship's officers on the bridge and scientists in the vessel's operations laboratory, so they can advise promptly of the need for avoidance maneuvers or seismic source shut down.

PSO Data and Documentation

PSOs would record data to estimate the numbers of marine mammals, turtles, and diving ESA-listed seabirds exposed to various received sound levels and to document apparent disturbance reactions or lack thereof. They would also record any observations of fish potentially affected by the sound sources. Data would be used to estimate numbers of marine mammals potentially 'taken' by harassment (as defined in the MMPA). They would also provide information needed to order a power down or shut down of the airguns when a marine mammal, sea turtle, or diving ESA-listed seabird is within or near the EZ.

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

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

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

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

Results from the vessel-based observations would provide

1. The basis for real-time mitigation (GI airgun shut down).
2. Information needed to estimate the number of marine mammals potentially taken by harassment, which must be reported to NMFS.
3. Data on the occurrence, distribution, and activities of marine mammals, turtles, and diving ESA-listed seabirds in the area where the seismic study is conducted.
4. Information to compare the distance and distribution of marine mammals, turtles, and diving ESA-listed seabirds relative to the source vessel at times with and without seismic activity.
5. Data on the behavior and movement patterns of marine mammals and turtles seen at times with and without seismic activity.
6. any observations of fish potentially affected by the sound sources.

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

XIV. Coordinating Research to Reduce and Evaluate Incidental Take

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

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

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