Monitoring for Protected Species During a Low-Energy Marine Geophysical Survey by the R/V *Roger Revelle* in the Northeastern Pacific Ocean
September-October 2017

Prepared by

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TABLE OF CONTENTS

INTRODUCTION

Scripps Institution of Oceanography (SIO) conducted a low-energy seismic survey off the coasts of Oregon and Washington during September 26, 2017 to October 02, 2017. The survey as proposed was to be conducted 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 was conducted in the EEZ of the U.S., outside of territorial waters. The research project was conducted on board R/V *Roger Revelle*, which is operated by SIO under a charter agreement with the U.S Office of Naval Research (ONR). The title of the vessel is held by the U.S Navy.

The primary objective of this project was to support an Early Career Seismic Chief Scientist Training Cruise which aimed to train scientists on how to effectively plan seismic surveys, acquire data, and manage activities at sea. In addition, the survey provided critical data to understand the sediment and crustal structure within the Cascadia continental margin. The surveys were conducted 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) collected 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 participated in the survey activities.

Two potential survey sites off the Oregon continental margin were proposed and are depicted in Fig 1. One survey option (Astoria Fan) was located off northern Oregon off the mouth of the Columbia River and near the Astoria Canyon; the other (southern Oregon) was located off the southern Oregon margin. Each of the proposed survey sites had 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 were 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 modified survey plan designed by the participants and conducted is shown in Fig. 2.

The procedures used for the seismic survey are similar to those used during previous seismic surveys by SIO using conventional seismic methodology. The survey was conducted on one source vessel, the R/V *Roger Revelle*. The *Revelle* deployed a pair of 45-in^3 GI air guns as an energy source with a total discharge volume of ~90 in^3. The receiving system consisted of one 800-m hydrophone streamer. As the airguns are towed along the survey lines, the hydrophone streamer received the returning acoustic signals and transferred the data to the on-board processing system.

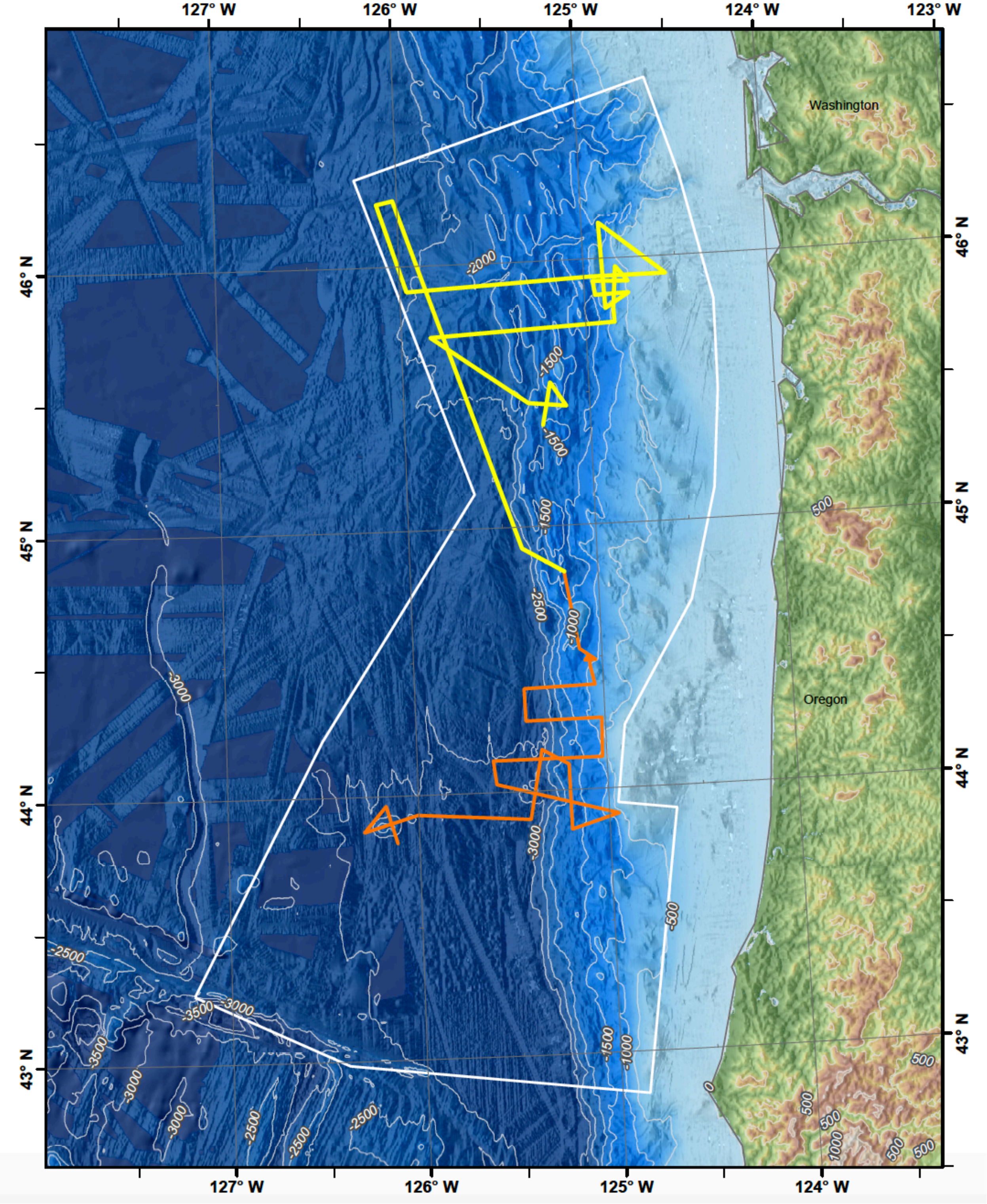

Figure 1. RR1718 IHA Permitted Area and proposed survey transects.

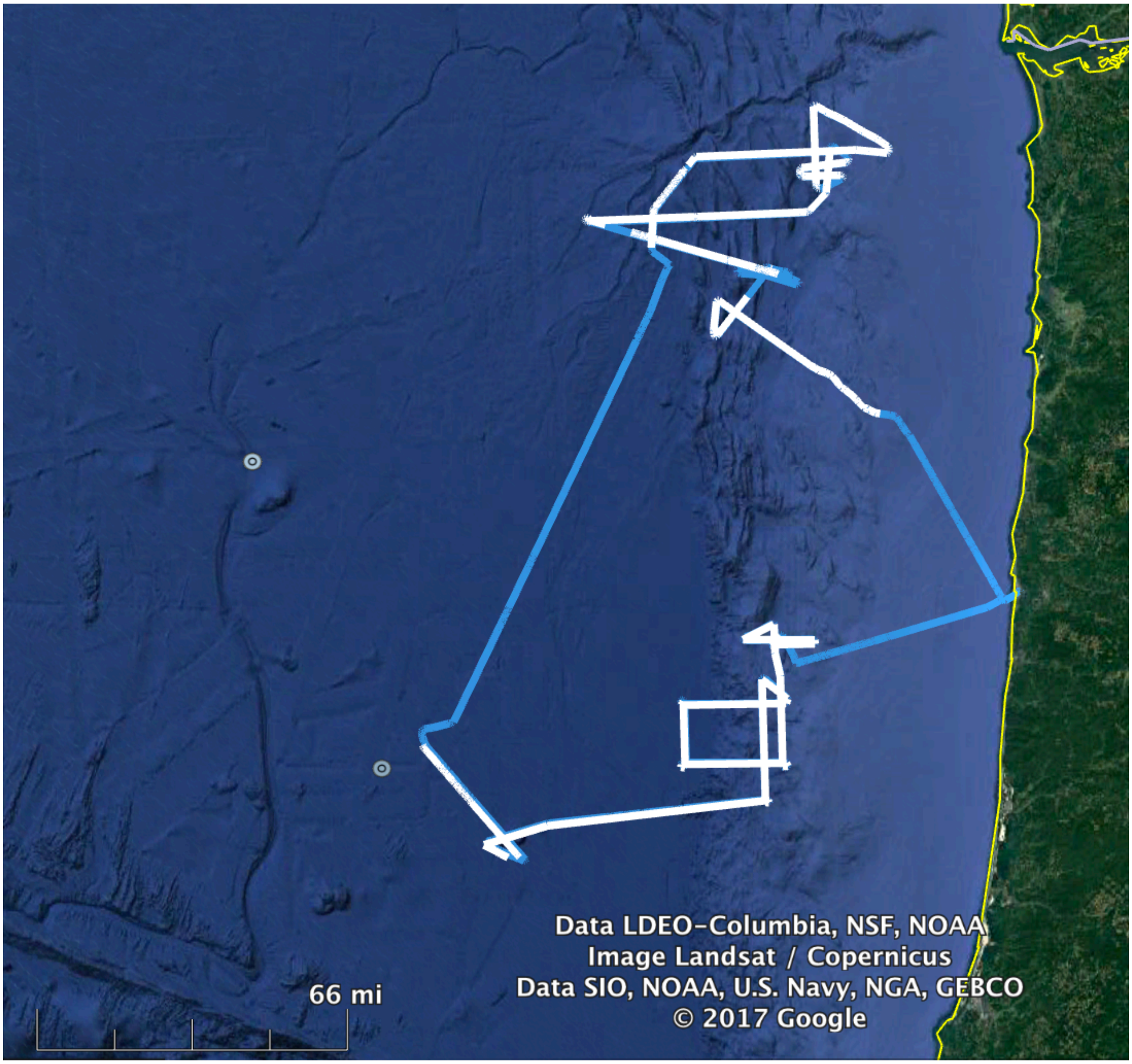

Figure 2. Track lines for the RR1718 Cruise. White track lines indicate an active acoustic source.

SCIENTIFIC PERSONNEL

The scientific party consisted of thirty-four participants. The three Protected Speicies Observers (PSO) were on board during the survey cruise to conduct the protected species mitigation and monitoring procedures. All three observers were accredited by NMFS, having previous training and experience with marine mammal surveys in the Pacific Ocean and marine seismic surveys. In addition, all observers had experience in field identification of sea turtles and sea birds.

Table 1. Scientific party list

LAST NAME	FIRST NAME	AFFILIATION	FUNCTION
Mountain	Greg	Rutgers University	Principal Investigator
Trehu	Anne	Oregon State University	Principal Investigator
Tominaga	Masako	Texas A&M University	Chief Scientist
Lyle	Mitch	Oregon State University	Co-Chief Scientist
Ellett	Lee	UCSD/SIO	Geophysical Engineer
Pedrie	Kolby	UCSD/SIO	Geophysical Engineer
Meyer	Jon	UCSD/SIO	Computer Engineer
Shadle	Keith	UCSD/SIO	Marine Technician
Collins	John	UCSD/SIO	Geophysical Engineer
Phrampus	Benjamin	Oregon State University	Scientist
Davenport	Kathy	Oregon State University	Scientist
Fowler	Rebecca	Freelance Science Writer	Scientist
Wright	Alexis	USGS, Colorado School of Mines	Scientist
Long	Asley	Coastal Carolina University	Scientist
Lenz	Brandi	Ohio State University	Scientist
Philip	Brendan	University of Washington	Scientist
Reilly	Brendan	Oregon State University	Scientist
Hearn	Casey	University of Rhode Island	Scientist
Brandl	Collin	University of New Mexico	Scientist
Schottenfels	Emily	Boston University	Scientist
Estefania	Ortiz	Texas A&M	Scientist
Filina	Irina	University of Nebraska at Lincoln	Scientist
Saunders	Jessie	UCSD/SIO	Scientist
DeSanto	John	UCSD/SIO	Scientist
Somchat	Kittipong	Texas A&M University	Scientist
Walczak	Maureen	Oregon State University	Scientist
Sprinkle	Parker	North Carolina State University	Scientist
Shreedharan	Srisharan	Penn State University	Scientist
Yelisetti	Subbarao	Texas A&M University	Scientist
Sahakian	Valerie	USGS	Scientist
Schmelz	William	Rutgers University	Scientist
Bisson	Lauren	LGL	Protected Species Observer
Holst	Meike	LGL	Protected Species Observer
Abgrall	Patrick	LGL	Protected Species Observer

SCIENTIFIC SOUND SOURCES

The Revelle towed a pair of 45-in^3 GI airguns and an 800-m streamer containing hydrophones along predetermined lines. Seismic pulses were emitted at intervals of ~8–10 s (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 were 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 3.4 bar-m (230.6 dB re 1 µPa·m); peak-peak is 6.2 bar-m (235.8 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 receives 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 is much higher than the limit of 5º per minute for a seismic vessel towing a streamer of more typical length (>>1 km), ~20º. Thus, the maneuverability of the vessel is not 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. In this case, that would be ~224.6 dB re 1µPa-m peak or 229.8 dB re 1µPa-m peak-to-peak. 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

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

μPa_p, and to ~176–178 dB re 1 μPa_{p-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 marine seismic survey were 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 $1\mu Pa_{rms}$) for Level B takes. Received sound levels have been predicted by L-DEO's model (Diebold et al. 2010, provided as Appendix H in the 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.

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[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 µPa2 · 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.

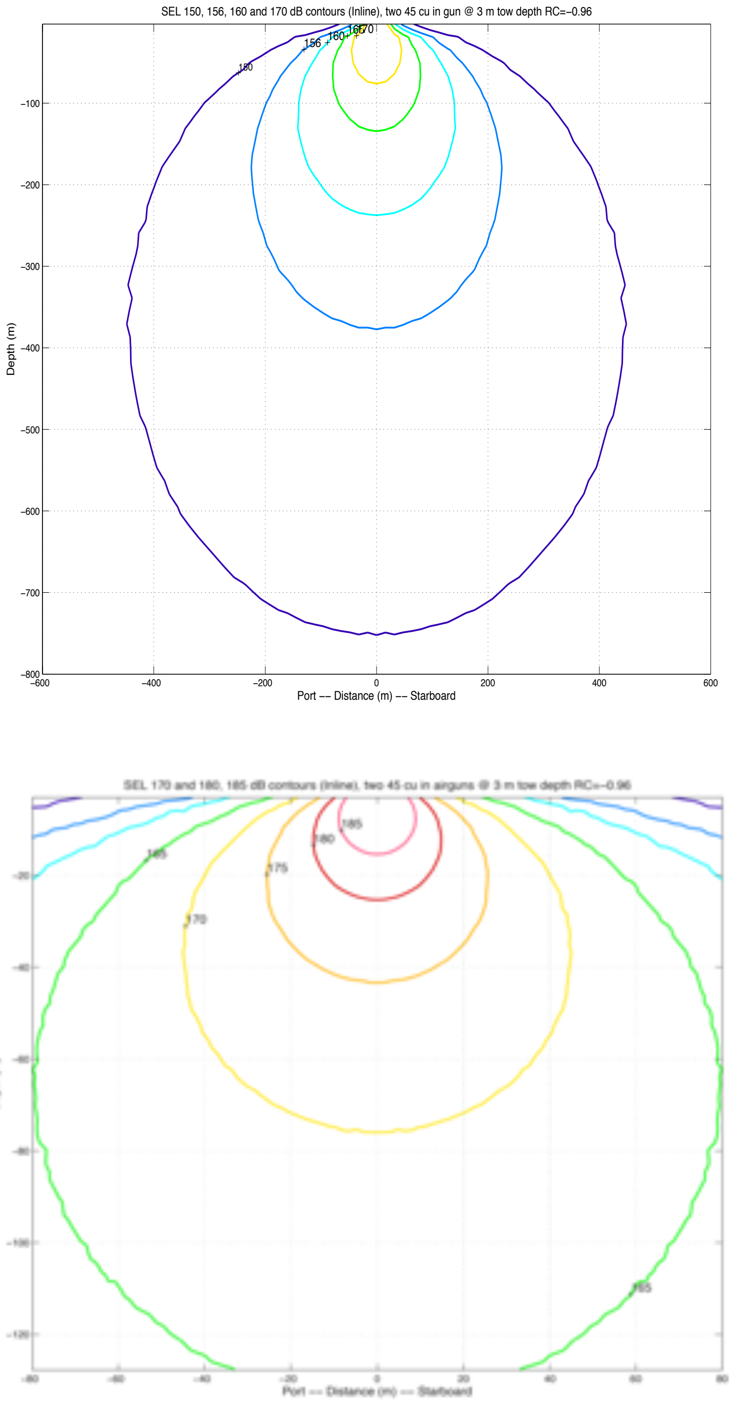

Figure 3. Modeled deep-water received sound exposure levels (SELs) from the two 45-in3 GI guns planned for use during the proposed surveys in the northeastern Pacific Ocean at a 3-m tow depth. Received rms levels (SPLs) are expected to be ~10 dB higher. The radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The lower plot is a zoomed-in version of the upper plot.

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 survey acquired data with two 45-in^3 GI guns at a tow depth of 3 m. For deep water (>1000 m), we use the deep-water radii obtained from L-DEO model results down to a maximum water depth of 2000 m (Fig. 3).

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 2 shows the distances at which the 160- and 166-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 166-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[3] 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 SELcum and SPLflat, 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 (SELcum over 24 hours) and peak sound pressure levels (SPLflat). 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

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

(SELcum or Peak SPLflat) was used to calculate takes and Level A threshold distances. The new guidance did not alter the current threshold, 160 dB re 1µParms, for Level B harassment (behavior).

The SELcum and Peak SPL for the *Revelle* 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

Table 2. Level B predicted distances to the 160 dB re 1 µParms and 175-dB sound levels that could be received from two 45-in3 GI guns (at a tow depth of 3 m) that were 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.

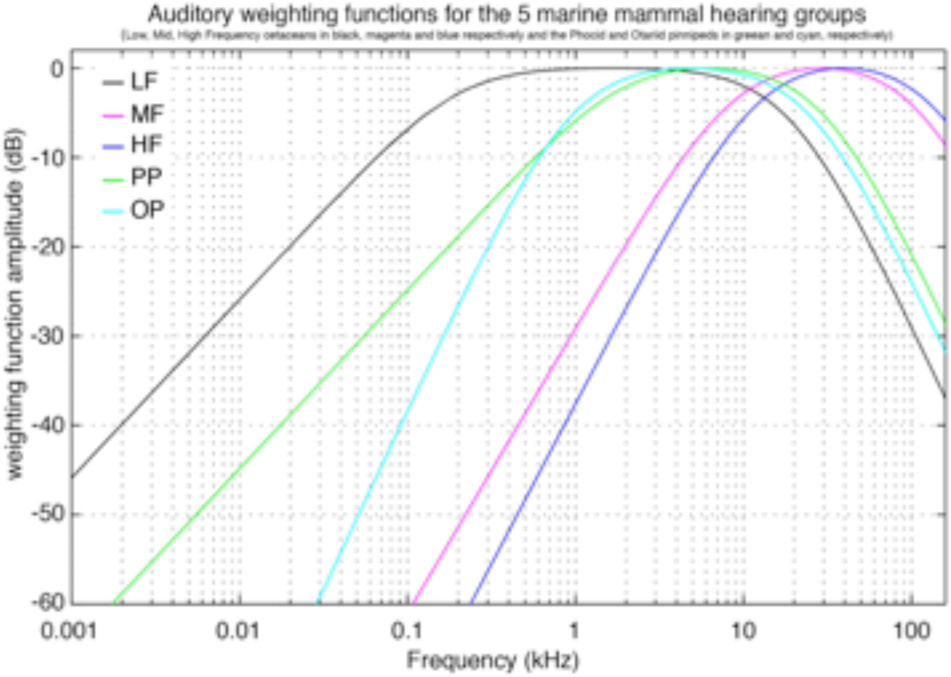


Figure 4. Auditory weighting functions from NMFS technical guidance

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 SELcum 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 SELcum 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 SELcum 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 5 shows the impact of weighting functions by hearing group. Figures 6–7 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure 8 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans.

Table 3. 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 SELcum threshold is the largest. A propagation is of 20 log10 (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.

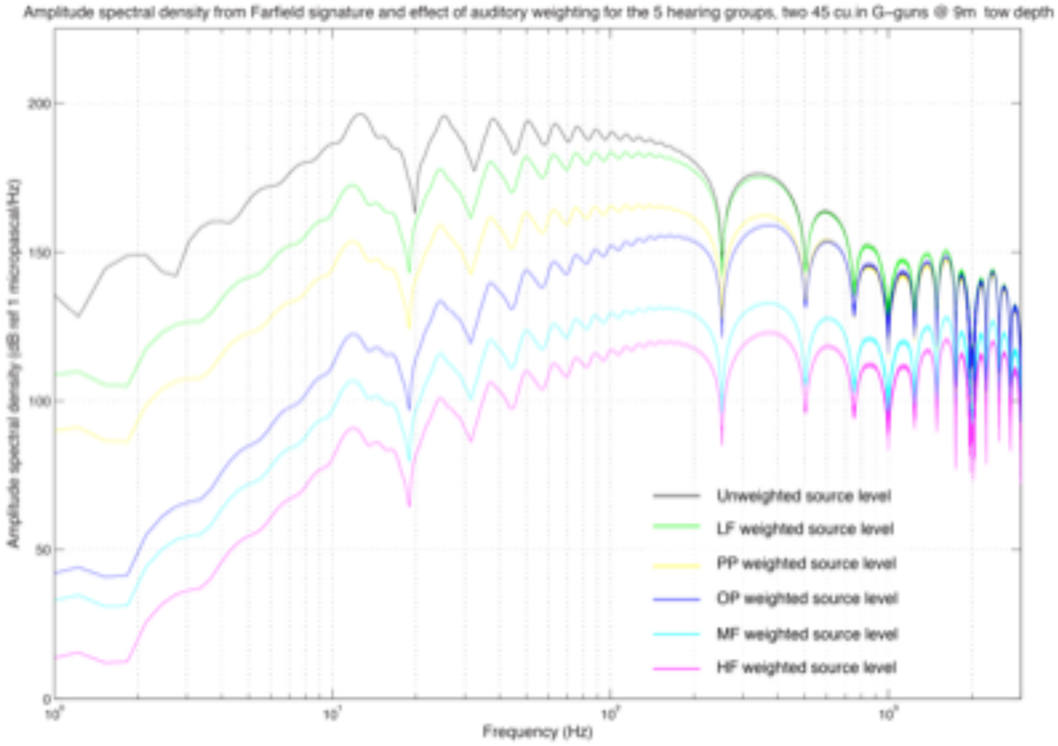
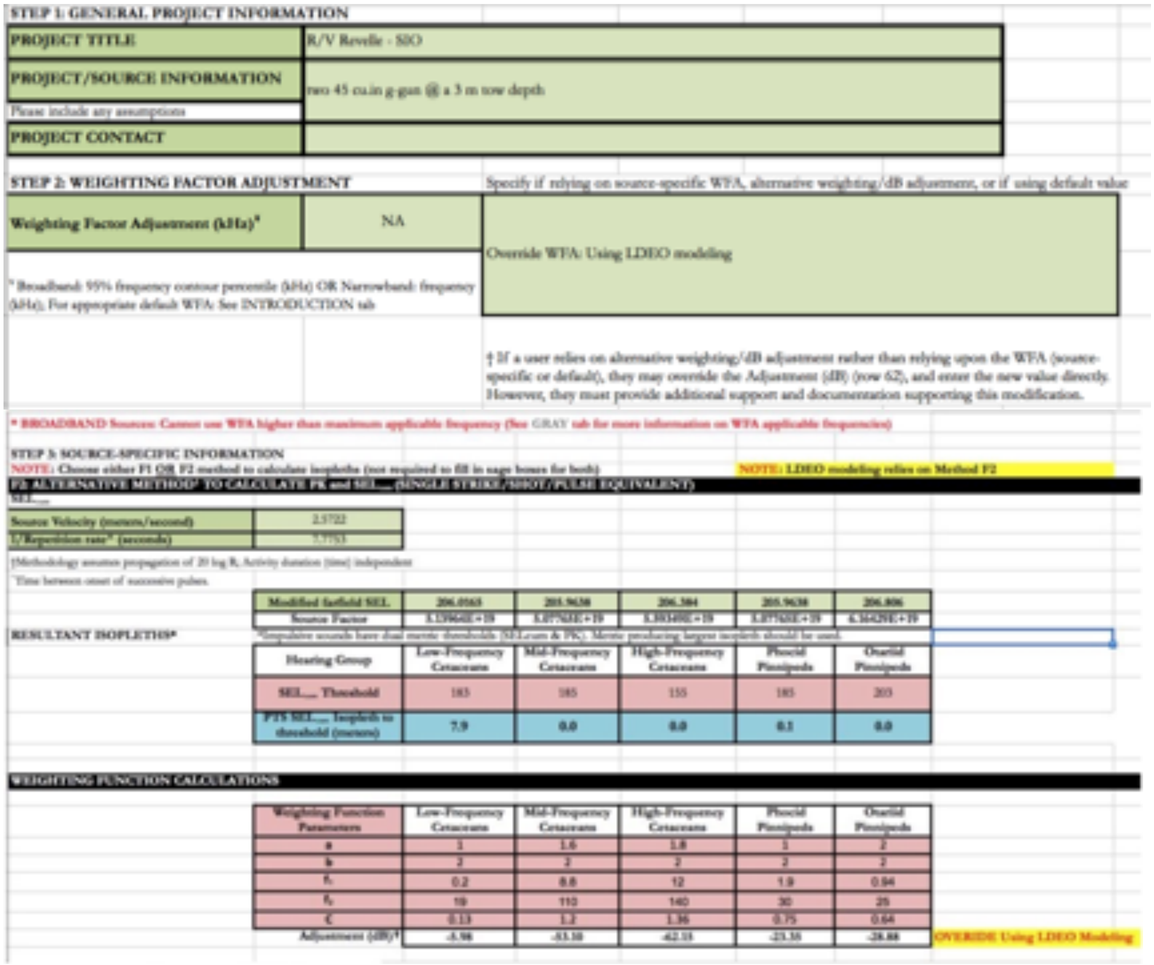


Figure 5. Modeled amplitude spectral density of the two GI guns farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral levels are used 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 4. NMFS User Spreadsheet. Results for single shot SEL source level modeling for the two GI guns with weighting function calculations for the SELcum 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 SELcum (SINGLE STRIKE/SHOT/PULSE EQUIVALENT)

SELcum

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	206.0163	205.9638	206.384	205.9638	206.806
Source Factor	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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
SELcum Threshold	183	185	155	185	203
PTS SELcum 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)†	-3.98	-33.10	-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 5).

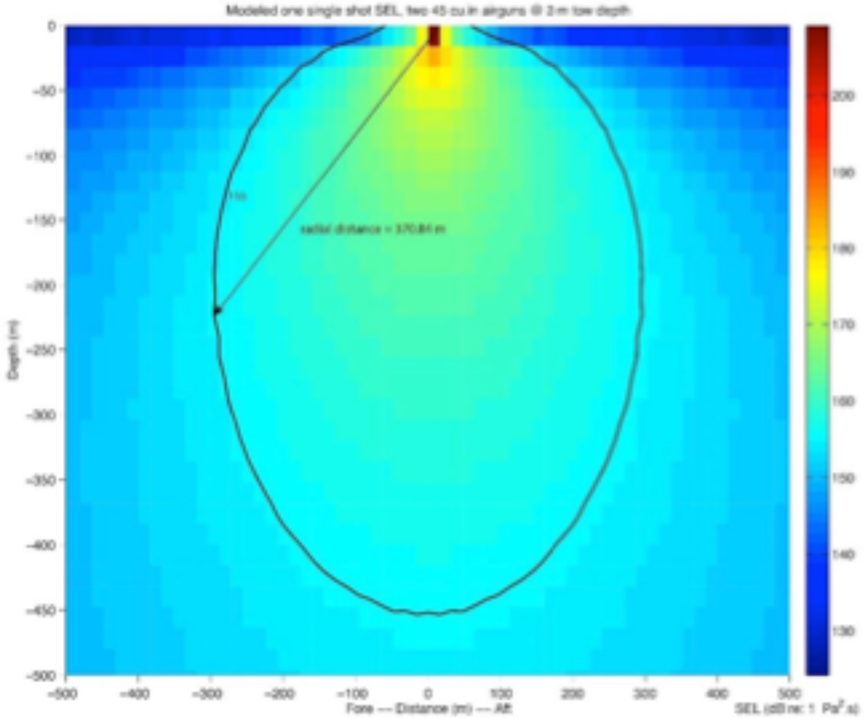


Figure 6. Modeled received sound levels (SELs) in deep water from the two 45 in3 GI guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (370.84 m).

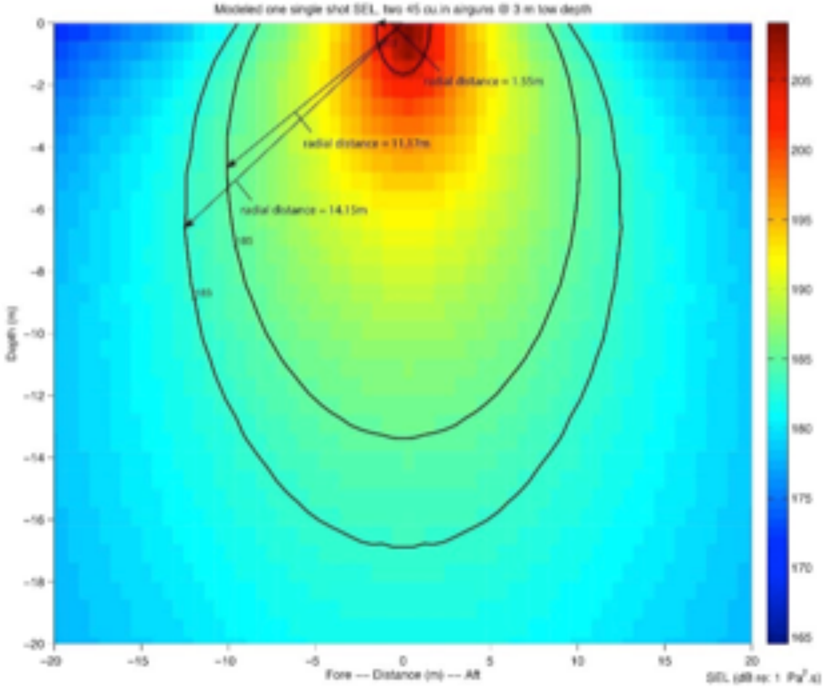


Figure 7. Modeled received sound levels (SELs) in deep water from the two 45 in3 GI guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183-, 185-, and 203-dB SEL isopleths.

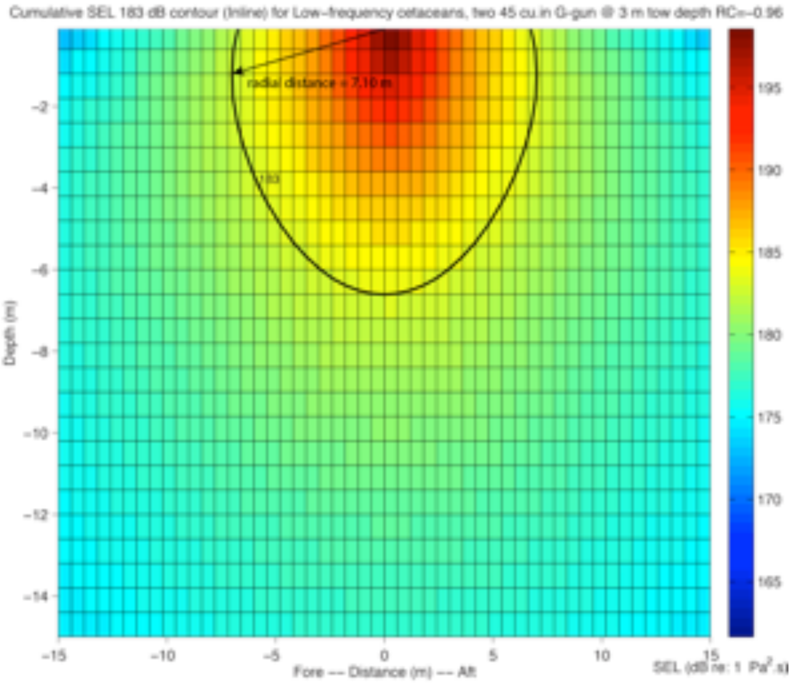


Figure 8. Modeled received sound exposure levels (SELs) from the two 45 in3 GI guns at a 3-m tow depth, after applying the auditory weighting function for the LF cetaceans following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SELcum isopleth for one shot. The difference 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 SPLflat 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 SPLflat 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 SPLflat 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 volume 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 was 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 were detected in or about to enter the appropriate EZ, the airguns were shut down immediately. 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 2).

Table 5. 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**	**Low-Frequency Cetaceans**	**Low-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.

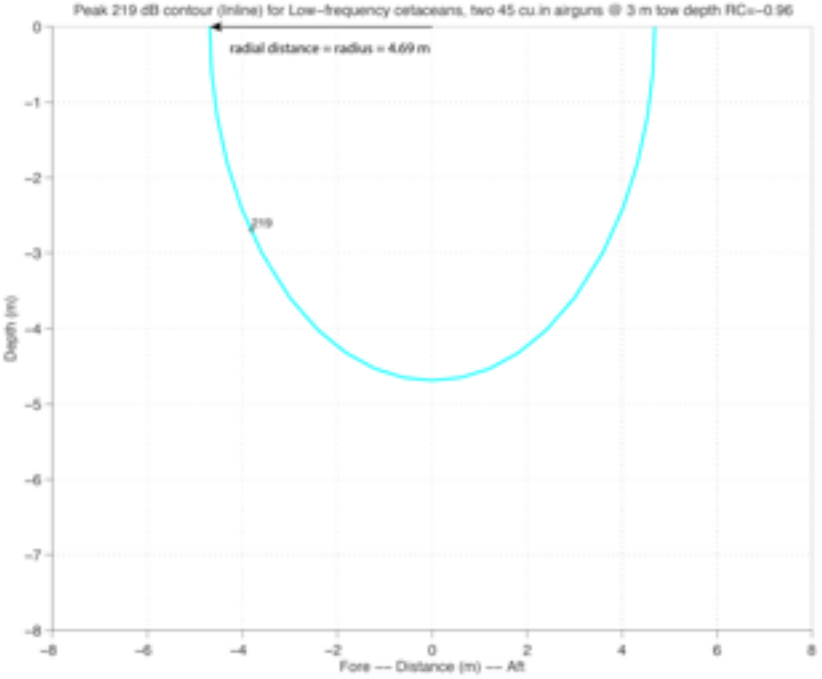


Figure 9. Modeled deep-water received Peak SPL from the two 45-in3 GI guns at 3-m tow depth after applying a high pass filter of 7 Hz for LF cetaceans as described in the NMFS Acoustic Guidance. The plot provides the radius to the 219-dB Peak SPL isopleth for one airgun shot that corresponds to the PTS Peak SPL threshold for LF cetaceans.

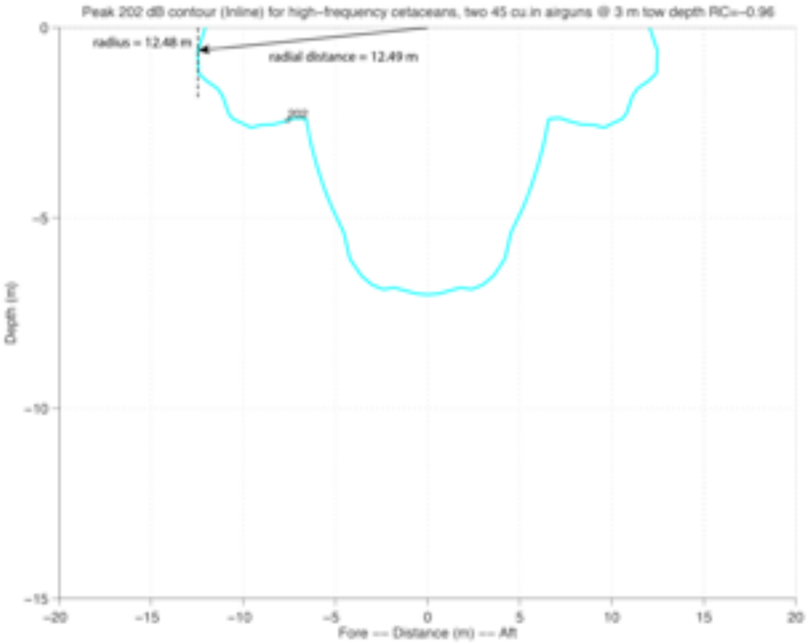


Figure 10. Modeled deep-water received Peak SPL from the two 45-in3 GI guns at 3-m tow depth after applying a high pass filter of 275 Hz for HF cetaceans as described in the NMFS Acoustic Guidance. The plot provides the radius to the 202-dB Peak SPL isopleth for one shot that corresponds to the PTS Peak SPL threshold for HF cetaceans.

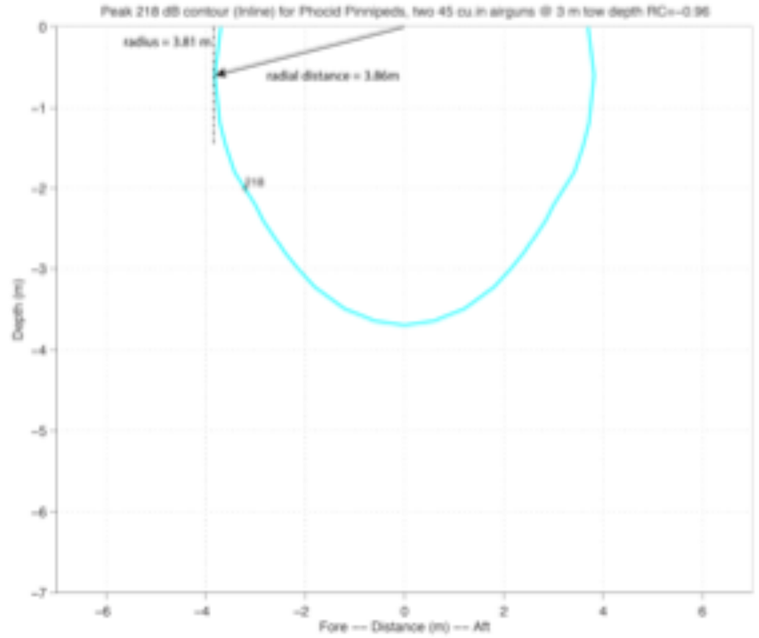


Figure 11. Modeled deep-water received Peak SPL from the two-45-in3 GI guns at 3-m tow depth after applying a high pass filter of 50 Hz for Phocids Underwater as described in the NMFS Acoustic Guidance. The plot provides the radius to the 218-dB Peak SPL isopleth for one shot that corresponds to the PTS Peak SPL threshold for Phocids.

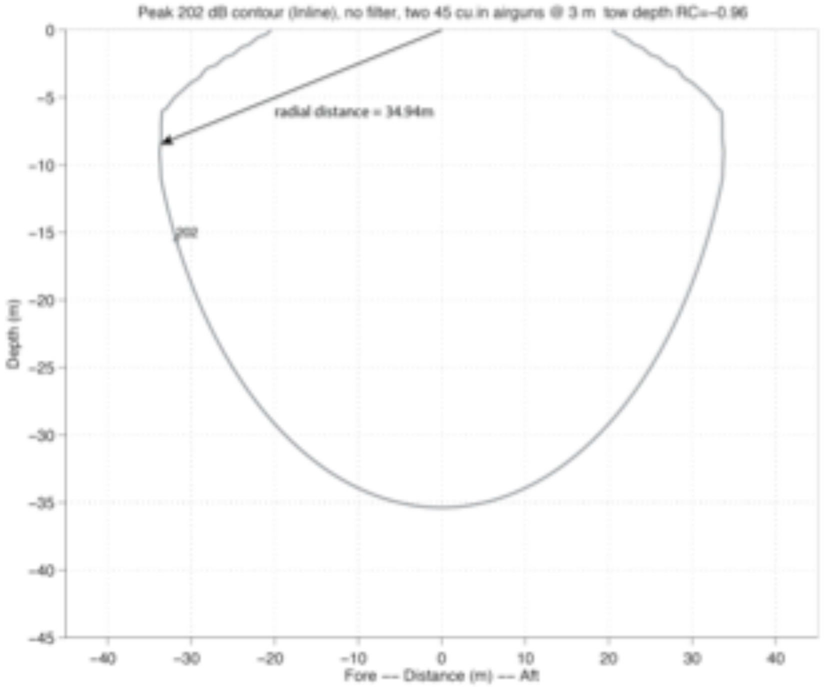


Figure 12. Modeled deep-water received Peak SPL from two 45-in3 GI guns at a 3-m tow depth. The plot provides the radial distance from the source geometrical center to the 202-dB peak isopleth (34.94 m).

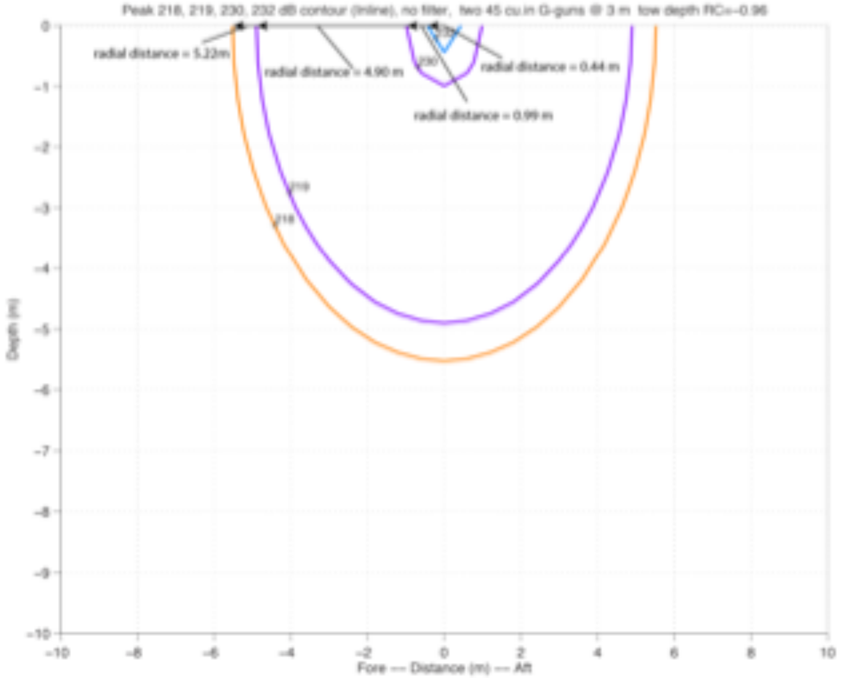


Figure 13. Modeled deep-water received Peak SPL from two 45 in3 GI guns at a 3-m tow depth. The plot provides the radial distances from the source geometrical center to the 218-, 219-, 230-, and 232-dB Peak isopleths.

Along with the airgun operations, two additional acoustical data acquisition systems were operated during the entire survey. The ocean floor was 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.

MITIGATION PROCEDURES

The primary responsibility of the protected species observers (PSOs) was to maintain a watch for marine mammals, sea turtles, and other protected marine animal species within the designated safety radii around the seismic GI gun source, and alert the seismic personnel on watch, who would then shut down the seismic source.

Mitigation watches by at least one observer were conducted 100% of the time during daylight hours. The observer platform was located one deck below and forward of the bridge (02 level, 12.5 meters above the waterline), affording relatively unobstructed 180-degree forward view. Aft views of the vessel could be obtained from a secondary station on the winch deck (Figure 14).

Before commencing seismic operations during daylight hours, two observers would maintain a 360-degree watch for all marine mammals and sea turtles for at least 30 minutes prior to start of the sound source. If no marine mammals or turtles were observed within the safety radius during this time, the observers would notify the seismic personnel of an “all clear” status.

Watch periods were typically scheduled as a 2-hour rotation. The observers continually scanned the water from the horizon to the ship’s hull, and forward of 90 degrees from the port and starboard beams. In the event of any marine mammal or sea turtle approaching or within the safety zone, the seismic personnel were contacted via hand held radios and/or telephone and the seismic source was secured for the duration of the animal’s presence within the safety zone. Seismic operations would resume only after the animals were seen to exit the safety radius, or after no further visual detection of the animal for 15 minutes (for small ondontocetes and pinnipeds) or 30 minutes (for mysticetes and large odontocetes).

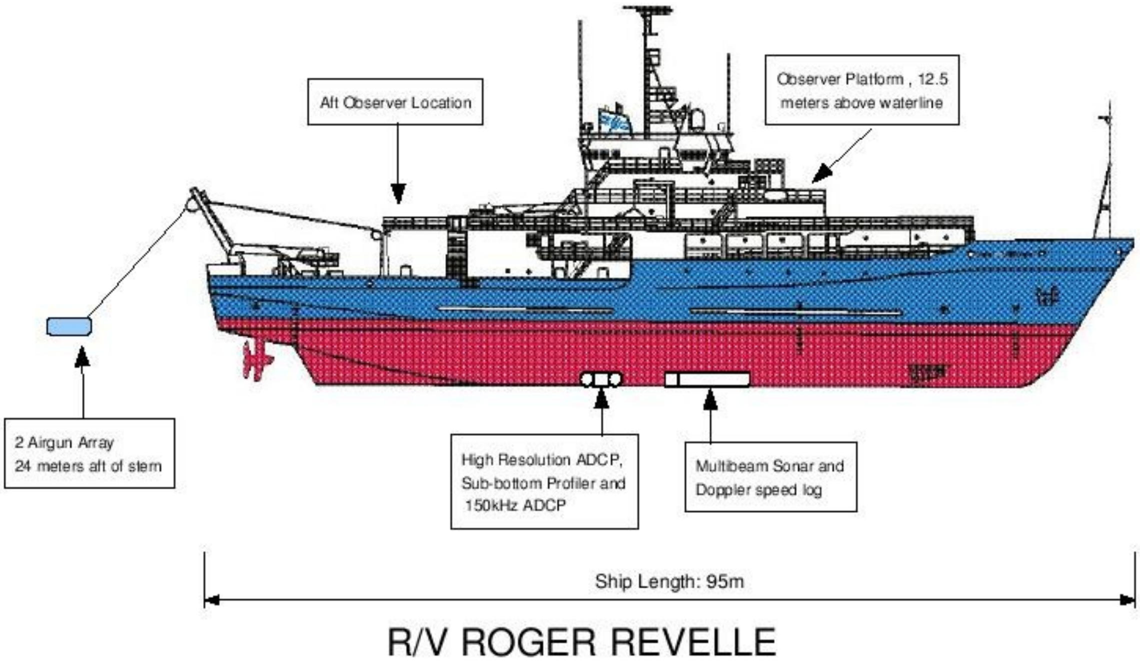
Observers utilized reticulated 25x150 big eye binoculars and 7x50 hand held binoculars to determine bearing and distance of sightings. A clinometer was used to determine distances of animals in close proximity to the vessel. These simple devices proved more reliable for open water sighting than the laser range finders, which were also provided.

The marine mammal observers provided training to the scientists and bridge crew at the beginning of the cruise. More importantly, the bridge officers and other crew were instructed to alert the observer on watch of any suspected marine mammal sighting. A hand held VHF radio was used by the observers for communication with the bridge crew. A phone and hand held radio were used to communicate with the seismic personnel in the lab spaces. If needed, the bridge was contacted in order to maneuver the ship to avoid interception with approaching marine mammals or sea turtles.

A laptop computer console was installed at the observer location with a GPS for ease of data entry. A customized data entry template was used based on the IHA data requirements. The data entry management consisted of an Effort Log and Sighting Log. Formulas were included to estimate the position of sightings based on the optics used.

For each sighting the Observer on watch would enter the bearing, distance and optics type then use a series of preconfigured drop down menus to quickly record the species, behavior and environmental conditions. A comments field was available to add additional context to sightings as necessary. At the end of each day sightings were checked for errors and edited as appropriate. An effort log was kept and populated with data whenever there was a change in sound source status, weather or observer on watch.

Figure 14. Outboard Profile of R/V Roger Revelle.



PROTECTED SPECIES EXPECTED IN THE SURVEY 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.

Table 6. 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).

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).

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[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

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) analyzed 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.

OBSERVATIONS

On September 26, 2017 the R/V Roger Revelle departed Newport, OR and returned to Newport, OR on October 02, 2017. During that time the marine seismic sources were active for a total track line distance of 939 kilometers (Table 10 and Figure 15). When the seismic sources were not active the vessel was in transit. The PSO's conducted observations during all daylight seismic operations. They also stood watch when the ship was underway during daylight hours and the seismic source was inactive.

There were an estimated 110 animals observed during within the 23 sightings on this project (Table 8). Of these 9 sightings were made while the sound sources were active. During the majority of the sightings the animals appeared to not take evasive action from the vessel (Table 8). There were 3 mitigation actions none of which resulted in the shut down of the sound source. The mitigations actions taken were two delay of ramp up due to Unidentified Dolphins and one course alteration to avoid two Fin Whales. There were 8 Pacific White Sided Dolphins observed within the predicted Level B harassment zone (Table 7). There was no shutdown as the animals approached the vessel and were bow riding.

Table 7. Takes Authorized by NMFS and observed species within predicted 160dB and 180dB radii.

Sighting #	Species	IHA Authorized Takes	Number of Animals Observed Within the Level B Harassment Zone	Number of Animals Observed Within the Level A harassment Zone	Comments
19	Pacific White-sided Dolphin	62	8	0	Closest Point of Approach (CPA) to acoustic source of 100m. No shutdown as dolphins approached the vessel and stayed bow riding and wave riding near vessel for approximately 6 min.

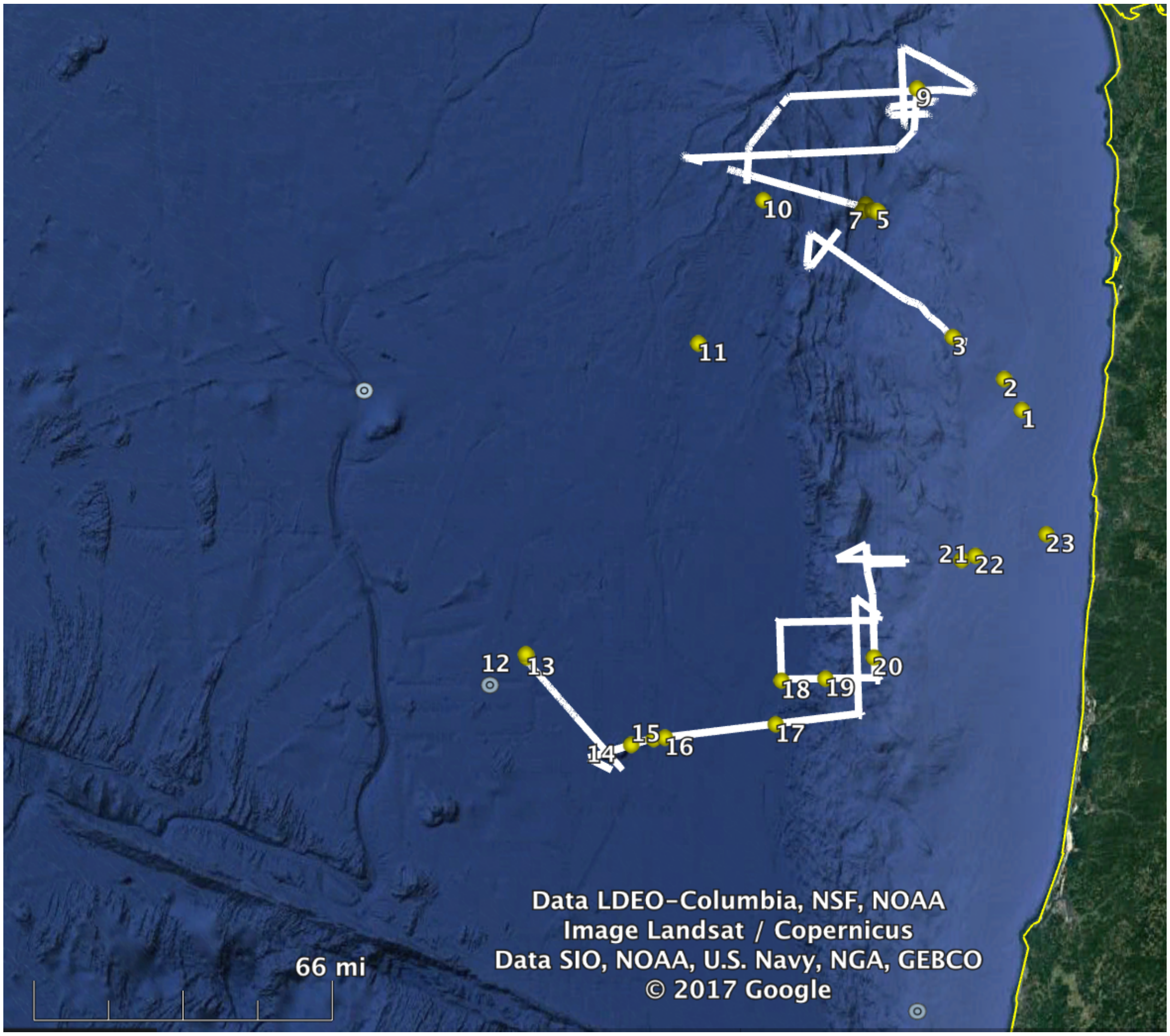

Figure 15. Plot of active source track lines with protected species sightings.

Table 8. Protected Species Sighting Log

ID	UTC Time	Species	Observation Heading (deg)	Heading (deg)	CPA Distance (m)	Cue	Behaviors	Pace	Count	Reaction	Latitude, Longitude (deg)	Mitigation Call Type	Sound Source State
1	09262017 21:46:15	Unidentified Sea Lion	330	360	60	Head	Dive, Swim	Moderate	1	Look	44.9458, -124.3836	None	Inactive
2	09262017 22:24:31	Unidentified Sea Lion	30	333	50	Splash	Porpoising, Swim	Vigorous	1	No Reaction Observed	45.0424, -124.4594	None	Inactive
3	09272017 02:05:26	Unidentified Whale	270	297	3000	Blow	Swim, Dive	Sedate	1	No Reaction Observed	45.1738, -124.6828	None	Active
4	09272017 17:54:47	Unidentified Baleen Whale	255	101	2984	Blow	Blow	Sedate	1	No Reaction Observed	45.5652, -125.0764	None	Inactive
5	09272017 19:44:26	Unidentified Baleen Whale	45	286	2984	Blow	Blow, Travel	Unknown	2	No Reaction Observed	45.5646, -125.0151	None	Inactive
6	09272017 22:05:24	Fin Whale	345	97	300	Blow	Blow, Swim	Sedate	2	No Reaction Observed	45.5855, -125.0617	Course alteration	Inactive
7	09272017 23:10:29	Fin Whale	90	262	346	Blow	Blow, Swim	Moderate	1	No Reaction Observed	45.5643, -125.0091	None	Inactive
8	09272017 23:29:20	Unidentified Baleen Whale	60	290	5000	Blow	Blow	Unknown	1	No Reaction Observed	45.5677, -125.0335	None	Inactive

ID	UTC Time	Species	Observation Heading (deg)	Heading (deg)	CPA Distance (m)	Cue	Behaviors	Pace	Count	Reaction	45.9456, -124.8295	Mitigation Call Type	Sound Source State
9	09282017 19:33:24	Unidentified Baleen Whale	345	9	4500	Blow	Blow	Unknown	1	No Reaction Observed	45.5996, -125.515	None	Active
10	09292017 22:48:45	Unidentified Baleen Whale	315	215	1072	Blow	Swim, Dive	Sedate	2	No Reaction Observed	45.1558, -125.7993	None	Inactive
11	09302017 02:00:39	Short-beaked Common Dolphin	270	208	5	Splash	Porpoising, Bowride	Vigorous	60	Bowride	44.1901, -126.5383	None	Inactive
12	09302017 08:30:00	Unidentified Dolphin	210	259	50	Splash	Porpoising, Swim	Vigorous	2	No Reaction Observed	44.1806, -126.5349	Delay ramp up	Inactive
13	09302017 08:40:00	Unidentified Dolphin	210	259	30	Splash	Porpoising, Swim	Vigorous	3	No Reaction Observed	43.9134, -126.0806	Delay ramp up	Inactive
14	09302017 20:00:43	Unidentified Baleen Whale	270	72	4000	Blow	Blow	Sedate	1	No Reaction Observed	43.9319, -125.9842	None	Active
15	09302017 20:58:59	Unidentified Baleen Whale	60	82	2900	Blow	Blow	Sedate	2	No Reaction Observed	43.9364, -125.936	None	Active
16	09302017 21:27:28	Fin Whale	315	83	886	Blow	Travel, Dive	Sedate	2	No Reaction Observed	43.9789, -125.4598	None	Active

ID	UTC Time	Species	Observation Heading (deg)	Heading (deg)	CPA Distance (m)	Cue	Behaviors	Pace	Count	Reaction	44.1142, -125.4351	Mitigation Call Type	Sound Source State
17	10012017 02:10:02	Gray Whale	300	85	1000	Blow	Travel, Fluked	Sedate	3	No Reaction Observed	44.1201, -125.2456	None	Active
18	10012017 19:27:14	Unidentified Baleen Whale	345	176	2984	Blow	Blow	Unknown	1	No Reaction Observed	44.1849, -125.0366	None	Active
19	10012017 21:51:36	Pacific White-sided Dolphin	345	96	100	Dorsal Fin	Porpoising, Bowride	Moderate	8	Bowride	44.4841, -124.6542	None	Active
20	10022017 01:28:03	Unidentified Whale	345	359	2984	Blow	Blow	Unknown	1	No Reaction Observed	44.4966, -124.5933	None	Active
21	10022017 16:35:34	Unidentified Dolphin	285	74	10	Splash	Swim	Moderate	3	No Reaction Observed	44.5603, -124.2831	None	Inactive
22	10022017 16:49:51	Unidentified Whale	300	76	2288	Blow	Swim, Dive	Sedate	1	No Reaction Observed	Latitude, Longitude (deg)	None	Inactive
23	10022017 18:04:30	Killer Whale	30	76	75	Dorsal Fin	Travel, Blow	Moderate	10	No Reaction Observed	44.9458, -124.3836	None	Inactive

Table 9. Sound source activity log

UTC TIME	Activity	Latitude (deg)	Longitude (deg)	Number of Guns	Water Depth (m)	Bft	Visibility (km)	Glare	Cloud Cover (%)	Speed (kts)	Course (deg)
20170927.0025.00	Ramp Up	45.157736	-124.62505	1	430	6	10	Severe	5	3	316
20170927.0142.00	Monitoring	45.203621	-124.727471	2	432	6	10	Severe	5	4	278
20170927.1239.00	Shut Down	45.512183	-125.174249	0	1834	4	0.25	None	5	4	29
20170927.1824.45	Monitoring	45.707088	-125.733158	0	2309	3	0.25	None	0	5	285
20170927.2011.00	Monitoring	45.579393	-125.087512	0	1644	2	10	Severe	10	4	286
20170927.2048.001	Ramp Up	45.5824	-125.1033	1	1357	2	10	Little	5	4	296
20170927.2053.001	Shut down	45.5871	-125.0737	0	1477	2	10	Moderate	5	4	106
20170927.2240.00	Ramp Up	45.572565	-125.052574	1	1653	3	10	Severe	10	3	102
20170927.2252.00	Monitoring	45.5682	-125.0025	2	1640	3	10	Severe	10	4	206
20170928.0451.00	Shut Down	45.695771	-125.675808	0	2396	2	0.25	None	0	5	287
20170928.0555.00	Ramp Up	45.717642	-125.786878	1	2389	2	0.25	None	0	5	287
20170928.1552.00	Monitoring	45.763002	-124.914744	2	1447	4	6	Moderate	0	4	88
20170928.1835.00	Shut Down	45.947727	-124.829113	0	872	5	10	Severe	5	4	4
20170928.1950.00	Ramp Up	45.920558	-124.752503	1	616	5	9	Moderate	5	4	43
20170928.2356.00	Shut Down	45.856948	-124.780277	0	913	2	10	Little	90	5	87
20170929.0058.00	Ramp Up	45.827279	-124.875948	1	590	2	8	None	100	4	232
20170929.1554.00	Monitoring	45.9234	-125.3137	1	1343	5	8	None	80	5	265
20170929.1615.00	Shut Down	45.894119	-125.436187	0	1891	6	9	Little	60	5	269

Table 9. Sound source activity log

UTC TIME	**Activity**	**Latitude (deg)**	**Longitude (deg)**	**Number of Guns**	**Water Depth (m)**	**Bft**	**Visibility (km)**	**Glare**	**Cloud Cover (%)**	**Speed (kts)**	**Course (deg)**
20170929.1626.00	ramp up	45.886112	-125.445338	1	1880	6	9	Little	60	5	269
20170929.2000.00	Shut Down	45.649319	-125.589648	0	2271	4	10	Severe	60	4	188
20170930.0857.00	Ramp Up	44.163378	-126.525967	1	2945	4	0.25	None	80	4	259
20170930.0911.00	monitoring	44.209283	-126.513067	2	2972	4	0.25	None	80	4	260
20170930.1347.15	Monitoring	43.8971	-126.1969	2	2369	2	0.1	None	70	4	136
20170930.1454.00	Shut Down	43.834555	-126.118301	0	2493	5	0.5	None	30	4	263
20170930.1558.00	Ramp Up	43.83356	-126.166728	1	3037	2	10	Severe	70	5	135
20170930.1617.00	Monitoring	43.839219	-126.188149	2	3038	2	10	None	60	4	290
20170930.1714.24	monitoring	43.839	-126.1875	2	3032	2	10	None	80	3	286
20171001.0501.00	monitoring	43.9925	-125.3056	2	2961	3	0.05	None	40	4	84
20171002.1202.00	Shut Down	44.501703	-125.044042	0	1099	3	10	Severe	10	4	70

ANALYSIS

In order to minimize the potential impacts to incidental taking of protected species during the September - October 2017 seismic survey on R/V *Roger Revelle*, mitigation measures were implemented whenever these protected species were seen approaching, entering, or within the safety radii designated in the IHA. All mitigation and monitoring measures specified in the IHA were implemented during the cruise, as described in this report.

Visual observations alone cannot account for the true number of marine mammals and sea turtles present in a given area due to normal surfacing and dive behaviors, which limit visual detection capabilities. Marine mammals spend a significant portion of time subsurface, and visual detection of deep-diving cetaceans is limited, in the best of sighting conditions, by the short duration of their surface time compared to their dive time. The probability of detecting certain species of marine mammals also varies relative to an animal's size, distance from the vessel, and regional population density.

All potential marine mammal takes (8) represents .4 percent of the total takes authorized for marine mammals for the survey. Observation conditions were highly variable during the survey, with some monitoring conducted during poor conditions, therefore it is unlikely that Protected Species Observers detected all animals during survey operations, especially given there were night time operations. However, in spite of this, the monitoring and mitigation measures required by the IHA appear to have been an effective means to protect the marine species encountered during this survey.

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