Application #2

Request by Lamont-Doherty Earth Observatory for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during a Marine Geophysical Survey by the R/V *Marcus G. Langseth* in the Northeast Pacific Ocean, June–July 2012

submitted by

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

to

National Marine Fisheries Service
Office of Protected Resources
1315 East–West Hwy, Silver Spring, MD 20910-3282

Application Prepared by

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

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SUMMARY

Lamont-Doherty Earth Observatory (L-DEO), with research funding from the National Science Foundation (NSF), plans to conduct a marine seismic survey in the northeastern Pacific Ocean off the coasts of Washington and Oregon in June–July 2012. The seismic surveys will take place in International Waters and the Exclusive Economic Zones of the U.S. and Canada, in water depths ~50–3000 m. The airgun array will consist of 36 airguns with a total volume of ~6600 in^3. L-DEO requests that it be issued an Incidental Harassment Authorization (IHA) allowing non-lethal takes of marine mammals incidental to the planned seismic survey. This request is submitted pursuant to Section 101 (a)(5)(D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371 (a) (5).

Numerous species of cetaceans and pinnipeds inhabit the proposed survey area in the northeast Pacific. Several of these species or stocks are listed as ***endangered*** or ***threatened*** under the U.S. ESA, including the North Pacific right, humpback, sei, fin, blue, sperm, and killer whales, and the Steller sea lion. ESA-listed sea turtle species that could occur in the survey area include the ***endangered*** leatherback turtles, and the ***threatened*** green, loggerhead, and olive ridley turtles. Listed seabirds that could be encountered in the area include the ***endangered*** short-tailed albatross and the ***threatened*** marbled murrelet and western snowy plover.

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

I. OPERATIONS TO BE CONDUCTED

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

Overview of the Activity

L-DEO plans to conduct a seismic survey in the northeast Pacific Ocean off the coasts of Washington and Oregon at ~43–48°N and ~124–130°W (Fig. 1). Water depths in the survey area are ~50–3000 m. The project is scheduled to occur ~11 June–5 July 2012. Some minor deviation from these dates is possible, depending on logistics and weather.

L-DEO plans to use conventional seismic methodology over the Juan de Fuca plate at the Cascadia subduction zone to characterize the evolution and state of hydration of the Juan de Fuca plate crust and shallow mantle, from formation at the mid-ocean Juan de Fuca ridge, through alteration and hydration

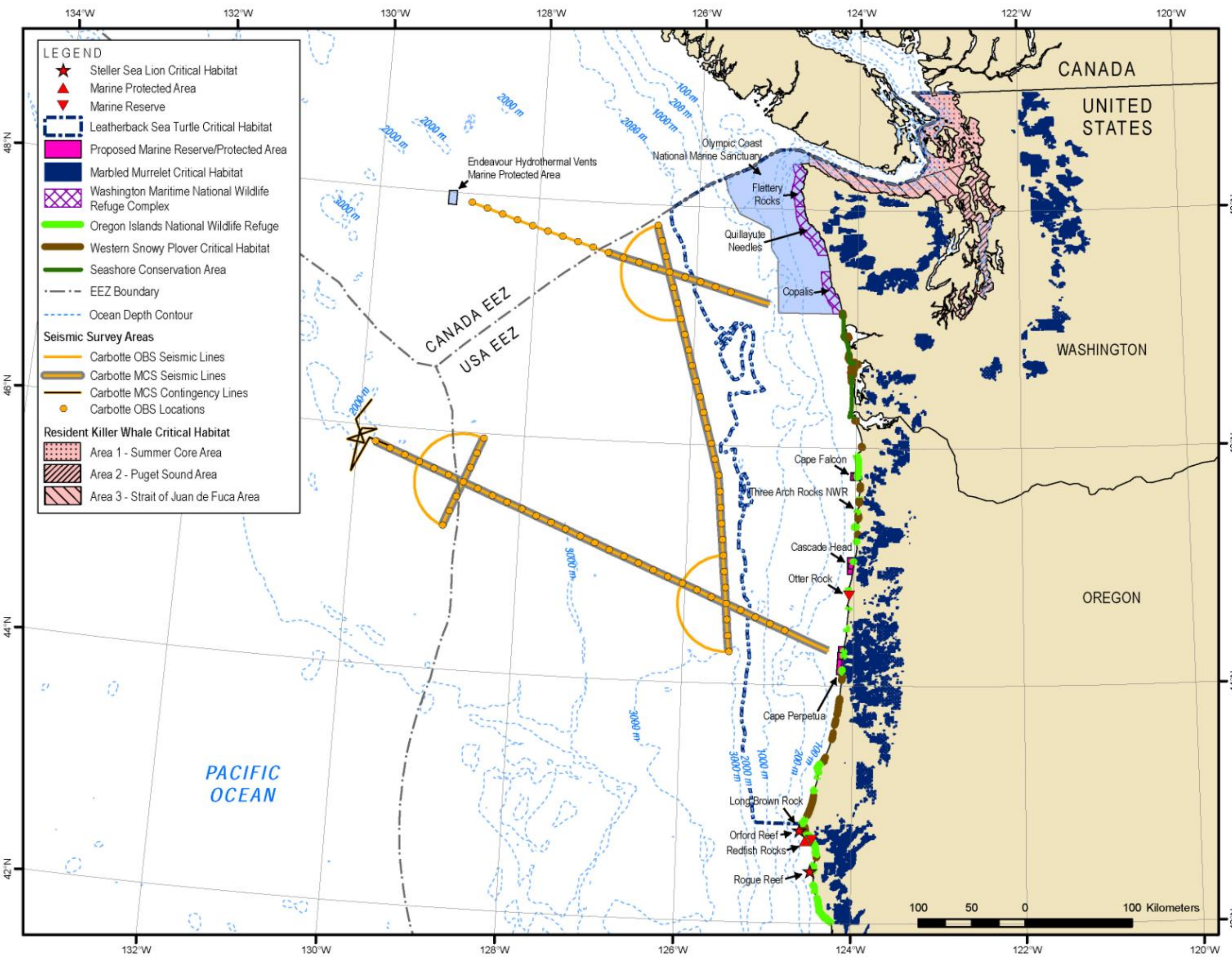

FIGURE 1. Proposed survey area for the seismic survey in the northeastern Pacific Ocean planned for 11 June–5 July 2012 with OBS instrument placements and seismic tracklines. EEZ = exclusive economic zone.

within the plate interior, to subduction at the Cascadia trench. The survey will include two ridge-to-trench transects, the first complete such transects ever acquired of an oceanic plate. It is expected that differences in hydration of the down-going plate from Oregon to Washington may play a significant role in the seismic hazard of the Cascadia subduction zone along this heavily populated Pacific northwest margin.

The survey will involve one source vessel, the R/V *Marcus G. Langseth*. The *Langseth* will deploy a 36-airgun array as an energy source. The receiving system will consist of one 8-km long hydrophone streamer and/or ocean bottom seismometers (OBSs). As the airgun array is towed along the survey lines, the hydrophone streamer will receive the returning acoustic signals and transfer the data to the on-board processing system. The OBSs record the returning acoustic signals internally for later analysis.

Three long transect lines and three semi-circular arcs will be shot using short-period OBSs as the receivers, and most of those long lines will be shot again in multichannel seismic (MCS) mode using an 8-km streamer as the receiver. Additional offshore lines will be shot in MCS mode using an 8-km streamer, if time permits (Fig. 1). The total survey effort including contingency will consist of ~2878 km of transect lines in depths >1000 m, 102 km in depths 100–1000 m, and 71 km in water depths <100 m. The northern and southern onshore-offshore lines are 70–310 and 15–450 km from shore, respectively.

In addition to the operations of the airgun array, a multibeam echosounder (MBES) and a sub-bottom profiler (SBP) will also be operated from the *Langseth* continuously throughout the cruise. All planned geophysical data acquisition activities will be conducted by L-DEO with on-board assistance by the scientists who have proposed the study. The Principal Investigators (PIs) are Drs. S. Carbotte and H. Carton (L-DEO) and Dr. P Canales (Woods Hole Oceanographic Institution, WHOI). The vessel will be self-contained, and the crew will live aboard the vessel for the entire cruise.

Source Vessel Specifications

The R/V *Marcus G. Langseth* will be used as the source vessel. The *Langseth* will tow the 36-airgun array and streamer along predetermined lines (Fig. 1). When the *Langseth* is towing the airgun array as well as the hydrophone streamer, the turning rate of the vessel while the gear is deployed is limited to five degrees per minute. Thus, the maneuverability of the vessel is limited during operations with the streamer.

The *Langseth* has a length of 71.5 m, a beam of 17.0 m, and a maximum draft of 5.9 m. The *Langseth* was designed as a seismic research vessel, with a propulsion system designed to be as quiet as possible to avoid interference with the seismic signals. The ship is powered by two Bergen BRG-6 diesel engines, each producing 3550 hp, which drive the two propellers directly. Each propeller has four blades, and the shaft typically rotates at 600 or 750 revolutions per minute (rpm). The vessel also has an 800 hp bowthruster, which is not used during seismic acquisition. The operation speed during seismic acquisition will be 8.5 km/h. When not towing seismic survey gear, the *Langseth* typically cruises at 18.5 km/h. The *Langseth* has a range of 25,000 km.

The *Langseth* will also serve as the platform from which vessel-based protected species observers (PSOs) will watch for marine mammals and sea turtles before and during airgun operations, as described in § XIII, below.

Other details of the *Langseth* include the following:

Owner:	National Science Foundation
Operator:	Lamont-Doherty Earth Observatory of Columbia University
Flag:	United States of America
Date Built:	1991 (Refitted in 2006)
Gross Tonnage:	3834
Accommodation Capacity:	55 including ~35 scientists

OBS Description and Deployment

For the study, 46 OBSs will be deployed along the northern line and the along-shore line (Fig. 1). Once those lines have been shot, the OBSs will be retrieved and 39 of them will be deployed along the southern line then retrieved once the line is shot.

WHOI "D2" OBSs will be used during the cruise. This type of OBS has a height of ~1 m and a maximum diameter of 50 cm. The anchor is made of hot-rolled steel and weighs 23 kg. The anchor dimensions are 2.5×30.5×38.1 cm.

Once an OBS is ready to be retrieved, an acoustic release transponder interrogates the instrument at a frequency of 9–11 kHz, and a response is received at a frequency of 9–13 kHz. The burn-wire release assembly is then activated, and the instrument is released from the anchor to float to the surface.

OBS deployment and retrieval will be carried out by the R/V *Oceanus*. The *Oceanus* will return to port at Astoria between deployments and retrievals. The *Oceanus* has a length of 54 m, a beam of 10 m, and a maximum draft of 5.3 m. The ship is powered by a single 3000-hp EMD diesel engine driving a single, controllable-pitch screw through a clutch and reduction gear, and an electric, 350-hp trainable bow thruster. The *Oceanus* cruises at 20.4 km/h (11 knots) and has a maximum speed of 26 km/h (14 knots). It has a normal operating range of ~13,300 km.

Other details of the *Oceanus* include the following:

Owner:	National Science Foundation
Operator:	Oregon State University (previously by Woods Hole Oceanographic Institution)
Flag:	United States of America
Date Built:	1975 (overhauled in 1994)
Gross Tonnage:	261
Accommodation Capacity:	12 crew plus 15 scientists

Airgun Description

During the survey, the airgun array to be used will consist of 36 airguns, with a total volume of ~6600 in^3. The airgun array will consist of a mixture of Bolt 1500LL and Bolt 1900LLX airguns. The airguns will be configured as four identical linear arrays or "strings" (Fig. 2). Each string will have ten airguns; the first and last airguns in the strings are spaced 16 m apart. Nine airguns in each string will be fired simultaneously, whereas the tenth is kept in reserve as a spare, to be turned on in case of failure of another airgun. The four airgun strings will be towed ~100 m behind the *Langseth* and will distributed across an area of ~24×16 m. The shot interval will be relatively short (37.5 m or ~16 s) for multichannel seismic (MCS) surveying with the hydrophone streamer, and long (500 m or ~200 s) when recording data on the OBSs. The firing pressure of the array is 1900 psi. During firing, a brief (~0.1 s) pulse of sound is emitted. The airguns will be silent during the intervening periods.

The tow depth of the array will be 9 m during MCS surveys and 12 m during OBS surveys. Because the actual source is a distributed sound source (36 airguns) rather than a single point source, the highest sound levels measurable at any location in the water will be less than the nominal source level. In addition, the effective source level for sound propagating in near-horizontal directions will be substantially lower than the nominal source level applicable to downward propagation because of the directional nature of the sound from the airgun array.

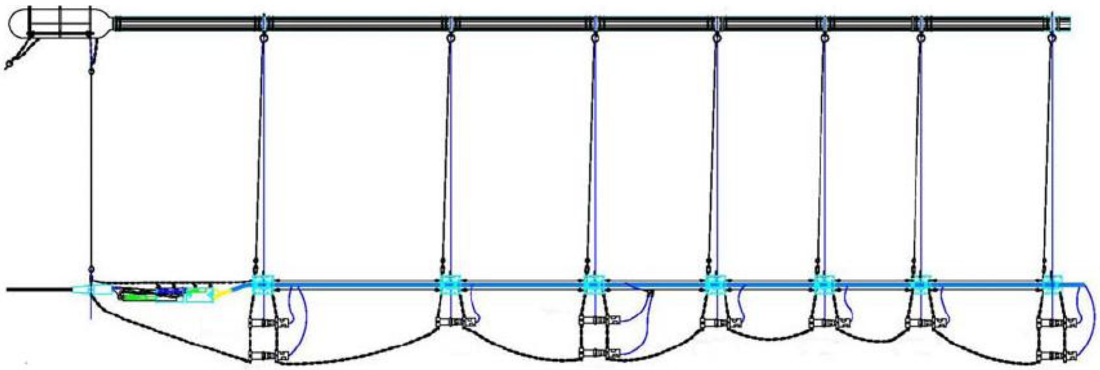

FIGURE 2. One linear airgun array or string with ten airguns, nine of which would be operating.

36-Airgun Array Specifications

Energy Source	Thirty-six 1900 psi Bolt airguns of 40–360 in^3, in four strings each containing nine operating airguns
Source output (downward)	0-pk is 84 bar-m (259 dB re 1 μPa·m); pk-pk is 177 bar·m (265 dB)
Air discharge volume	~6600 in^3
Dominant frequency components	2–188 Hz

Acoustic Measurements

Received sound levels have been predicted by L-DEO's model, in relation to distance and direction from the airguns, for the 36-airgun array and for a single 1900LL 40-in^3 airgun, which will be used during power downs. Results were reported for propagation measurements of pulses from the 36-airgun array in two water depths (~1600 m and 50 m) in the Gulf of Mexico in 2007–2008 (Tolstoy et al. 2009). However, measurements were not reported for a single airgun, although the sound levels in deep water have been modeled (Fig. 3). A detailed description of the modeling effort is provided in Appendix A of the Environmental Assessment (EA).

The predicted sound contours for the 40-in^3 mitigation airgun are shown in Figure 3 as sound exposure levels (SEL) in decibels (dB) re 1 μPa^2·s. SEL is a measure of the received energy in the pulse and represents the sound pressure level (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 (see Appendix B of the EA). The advantage of working with SEL is that the SEL measure accounts for the total received energy in the pulse, and biological effects of pulsed sounds are believed to depend mainly on pulse energy (Southall et al. 2007). In contrast, SPL for a given pulse depends greatly on pulse duration. A pulse with a given SEL can be long or short depending on the extent to which propagation effects have "stretched" the pulse duration. The SPL will be low if the duration is long and higher if the duration is short, even though the pulse energy (and presumably the biological effects) are the same.

Although SEL is now believed to be a better measure than SPL when dealing with biological effects of pulsed sound, SPL is the measure that has been most commonly used in studies of marine mammal reactions to airgun sounds and in NMFS guidelines concerning levels above which "taking" might occur. SPL is often referred to as rms or "root mean square" pressure, averaged over the pulse

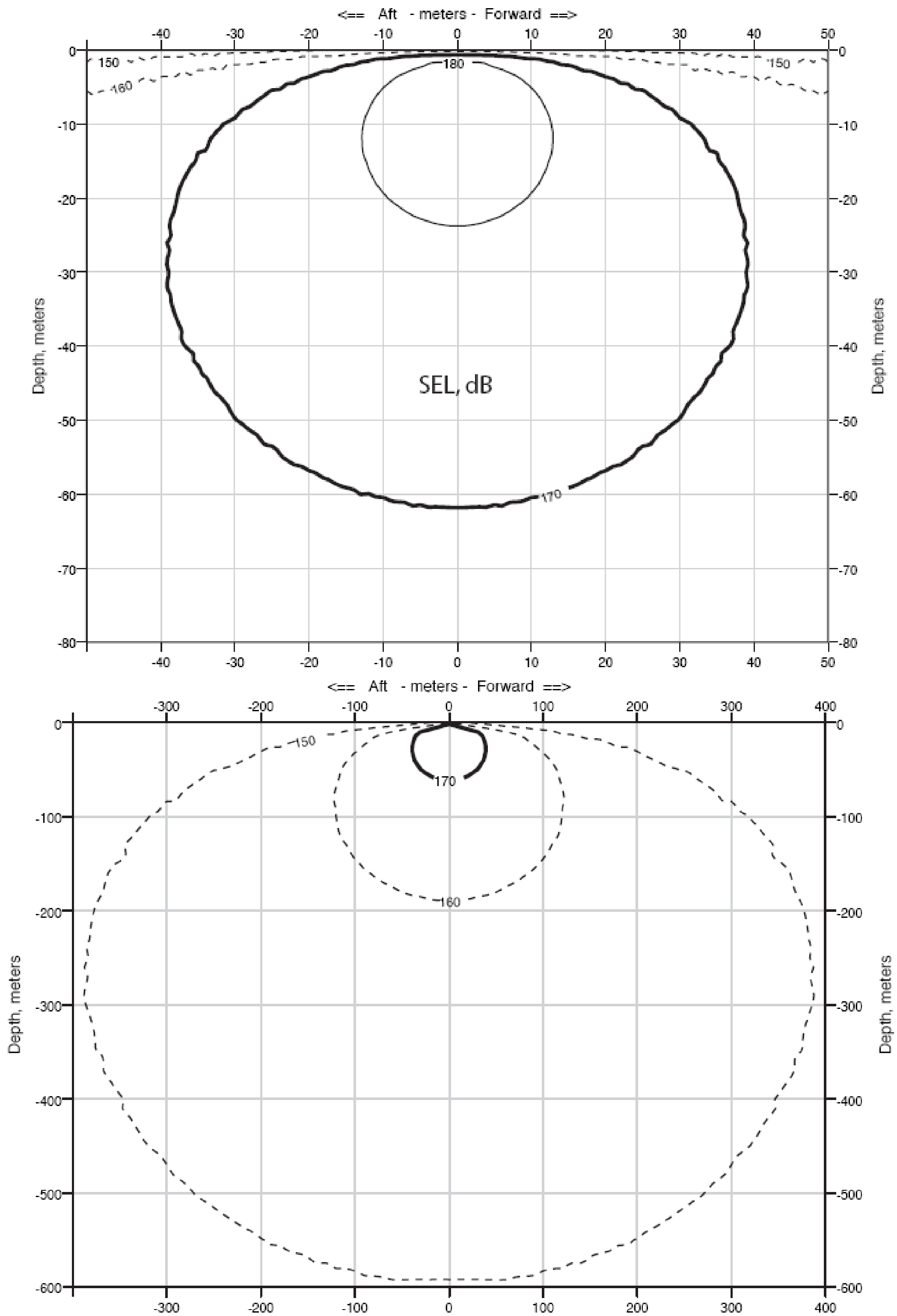

FIGURE 3. Modeled received sound levels (SELs) from a single 40-in^3 airgun operating in deep water, which is planned for use during the survey in the northeast Pacific during June–July 2012. Received rms levels (SPLs) are expected to be ~10 dB higher.

duration. As noted above, the rms received levels that are used as impact criteria for marine mammals are not directly comparable to pulse energy (SEL). At the distances where rms levels are 160–190 dB re 1 μPa, the difference between the SEL and SPL values for the same pulse measured at the same location usually average ~10–15 dB, depending on the propagation characteristics of the location (Greene 1997; McCauley et al. 1998, 2000a; Appendix B of the EA). In this IHA Application, we assume that rms pressure levels of received seismic pulses will be 10 dB higher than the SEL values predicted by L-DEO's model. Thus, we assume that 170 dB SEL ≈ 180 dB re 1 μPa_{rms}. It should be noted that neither the SEL nor the SPL (=rms) measure is directly comparable to the peak or peak-to-peak pressure levels normally used by geophysicists to characterize source levels of airguns. Peak and peak-to-peak pressure levels for airgun pulses are always higher than the rms dB referred to in much of the biological literature (Greene 1997; McCauley et al. 1998, 2000a). For example, a measured received level of 160 dB re 1 μPa_{rms} in the far field typically would correspond to a peak measurement of ~170–172 dB re 1 μPa, and to a peak-to-peak measurement of ~176–178 dB re 1 μPa, as measured for the same pulse received at the same location (Greene 1997; McCauley et al. 1998, 2000a). (The SEL value for the same pulse would normally be 145–150 dB re 1 $\mu Pa^2 \cdot s$). The precise difference between rms and peak or peak-to-peak values for a given pulse 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 and (for an airgun-type source at the ranges relevant here) higher than the SEL value.

Predicted Sound Levels

Results of the propagation measurements showed that radii around the airguns for various received levels varied with water depth (Tolstoy et al. 2009). In addition, propagation varies with array tow depth. The empirical values that resulted from Tolstoy et al. (2009) are used here to determine exclusion zones for the 36-airgun array. However, the depth of the array was different in the Gulf of Mexico calibration study (6 m) than in the proposed survey (9 or 12 m); thus, correction factors have been applied to the distances reported by Tolstoy et al. (2009). The correction factors used were the ratios of the 160-, 180-, and 190-dB distances from the modeled results for the 6600-in^3 airgun array towed at 6 m vs. 9 and 12 m, from LGL (2009): 1.285, 1.338, and 1.364, respectively, for 9 m; and 1.467, 1.577, and 1.545, respectively, for 12 m.

Using the corrected empirical measurements (array) or model (single airgun), Table 1 shows the distances at which three rms sound levels are expected to be received from the 36-airgun array and a single airgun. The 180- and 190-dB re 1 μPa_{rms} distances are the safety criteria as specified by NMFS (2000) and are applicable to cetaceans and pinnipeds, respectively. The 180-dB distance will also be used as the exclusion zone for sea turtles, as required by NMFS in most other recent seismic projects (e.g., Smultea et al. 2004; Holst et al. 2005a,b; Holst and Beland 2008; Holst and Smultea 2008; Hauser et al. 2008; Holst 2009; Antochiw et al. n.d.). If marine mammals or sea turtles are detected within or about to enter the appropriate exclusion zone, the airguns will be powered down (or shut down if necessary) immediately.

Southall et al. (2007) made detailed recommendations for new science-based noise exposure criteria. L-DEO will be prepared to revise its procedures for estimating numbers of mammals "taken", exclusion zones, etc., as may be required by any new guidelines established by NMFS as a result of these recommendations. However, currently the procedures are based on best practices noted by Pierson et al. (1998) and Weir and Dolman (2007), as NMFS has not yet specified a new procedure for determining exclusion zones.

TABLE 1. Measured (array) or predicted (single airgun) distances to which sound levels ≥190, 180, and 160 dB re 1 μPa$_{rms}$ are expected to be received during the proposed survey in the northeastern Pacific Ocean, 11 June–5 July 2012. Radii for the array are based on empirical data in Tolstoy at al. (2009), corrected for tow depth using model results, and predicted radii for a single airgun are based on L-DEO's model, assuming that received levels on an RMS basis are, numerically, 10 dB higher than the SEL values shown in Figure 3.

Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted RMS Radii (m)		
			190 dB	180 dB	160 dB
Single Bolt airgun 40 in^{3}	6–12[1]	>1000 m	12	40	385
		100–1000 m	18	60	578
		<100	150	296	1050
4 strings 36 airguns 6600 in^{3}	9	>1000 m	400	940	3850
		100–1000 m	550	1540	12,200
		<100	680	2140	20,550
	12	>1000 m	460	1100	4400
		100–1000 m	615	1810	13,935
		<100	770	2520	23,470

[1] The tow depth has minimal effect on the maximum near-field output and the shape of the frequency spectrum for the single airgun.

Description of Operations

The source vessel, the R/V *Marcus G. Langseth*, will deploy an array of 36 airguns as an energy source at a tow depth of 9 or 12 m. The receiving system will consist of one 8-km long hydrophone streamer and/or ocean bottom seismometers (OBSs). As the airgun array is towed along the survey lines, the hydrophone streamer will receive the returning acoustic signals and transfer the data to the on-board processing system. For the study, 46 OBSs will be deployed along the northern line and the along-shore line (Fig. 1). Once those lines have been shot, the OBSs will be retrieved and 39 of them will be deployed along the southern line then retrieved once the line is shot. OBS deployment and retrieval will be carried out by the R/V *Oceanus*. The *Oceanus* will return to port at Astoria between deployments and retrievals.

Three long transect lines and three semi-circular arcs will be shot using OBSs as the receivers, and most of those long lines will be shot again in multichannel seismic (MCS) mode using an 8-km streamer as the receiver. Additional offshore lines will be shot in MCS mode using an 8-km streamer, if time permits (Fig. 1). The total survey effort including contingency will consist of ~2878 km of transect lines in depths >1000 m, 102 km in depths 100–1000 m, and 71 km in depths <100 m. There will be additional seismic operations in the survey area associated with turns, airgun testing, and repeat coverage of any areas where initial data quality is sub-standard. In our calculations (see § VI), 25% has been added for those additional operations. In addition to the operations of the airgun array, a Kongsberg EM 122 multibeam echosounder (MBES) and a Knudsen Chirp 3260 sub-bottom profiler (SBP) will also be operated from the *Langseth* continuously throughout the cruise. The *Oceanus* will operate a Knudsen Chirp 3260 SBP and/or a Knudsen 320B/R SBP while deploying and retrieving OBSs; *Oceanus* does not have an MBES.

Multibeam Echosounder and Sub-bottom Profilers

The Kongsberg EM 122 MBES operates at 10.5–13 (usually 12) kHz and is hull-mounted on the *Langseth*. The transmitting beamwidth is 1 or 2° fore–aft and 150° athwartship. The maximum source level is 242 dB re 1 μPa · m_{rms}. Each "ping" consists of eight (in water >1000 m deep) or four (<1000 m) successive fan-shaped transmissions, each ensonifying a sector that extends 1° fore–aft. Continuous-wave (CW) pulses increase from 2 to 15 ms long in water depths up to 2600 m, and FM chirp pulses up to 100 ms long are used in water >2600 m. The successive transmissions span an overall cross-track angular extent of about 150°, with 2-ms gaps between the pulses for successive sectors.

The Knudsen Chirp 3260 SBP is normally operated by the *Langseth* to provide information about the sedimentary features and the bottom topography that is being mapped simultaneously by the MBES. The SBP is capable of reaching depths of 10,000 m. The beam is transmitted as a 27º cone, which is directed downward by a 3.5-kHz transducer in the hull of the *Langseth*. The nominal power output is 10 kW, but the actual maximum radiated power is 3 kW or 222 dB re 1 μPa · m. The ping duration is up to 64 ms, and the ping interval is 1 s. A common mode of operation is to broadcast five pulses at 1-s intervals followed by a 5-s pause.

The Knudsen 320B/R SBP is a dual-frequency transceiver designed to operate at 3.5 and/or 12 kHz. The energy from the SBP is directed downward via a 3.5-kHz transducer array mounted in the hull of the R/V *Oceanus*. The maximum power output of the 320B/R is 10 kilowatts for the 3.5-kHz section and 2 kilowatts for the 12-kHz section. The pulse length for the 3.5-kHz section of the 320B/R is 0.8–24 ms, controlled by the system operator in regards to water depth and reflectivity of the bottom sediments, and will usually be 6, 12, or 24 ms at the water depths at the study sites and in transit from Astoria. The system produces one sound pulse and then waits for its return before transmitting again. Thus, the pulse interval is directly dependent upon water depth, and in this survey is 0.8–1.5 sec. Using the Sonar Equations and assuming 100% efficiency in the system (impractical in real world applications), the source level for the 320B/R is calculated to be 211 dB re 1 μPa · m. In practice, the system is rarely operated above 80% power level.

II. Dates, Duration, and Region of Activity

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

The survey will encompass the area ~43–48°N and ~124–130°W in International Waters and the Exclusive Economic Zones of the U.S. and Canada (Fig. 1). Water depths in the survey area are ~50–3000 m. The exact dates of the activities depend on logistics and weather conditions. The R/V *Langseth* will depart from Astoria, OR, on 11 June 2012 and return there on 8 July 2012. Seismic operations will be carried out for an estimated 17 days.

III. Species and Numbers of Marine Mammals in Area

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

Thirty-two marine mammal species could occur in the northeast Pacific survey area. To avoid redundancy, we have included the required information about the species and (insofar as it is known) numbers of these species in § IV, below.

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

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

Sections III and IV are integrated here to minimize repetition.

Thirty-two marine mammal species could occur in the northeastern Pacific survey area, including mysticetes (baleen whales), odontocetes (toothed cetaceans, such as dolphins), pinnipeds (seals) and the sea otter (Table 2). Information on the occurrence, population size, and conservation status for each of the 32 species is presented in Table 2. The status of these species is based on the ESA, the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2011), and the Convention on International Trade in Endangered Species in Wild Fauna and Flora (CITES; UNEP-WCMC 2011). Six of the species that could occur in the proposed survey areas are listed under the ESA as ***Endangered***, including sperm, humpback, sei, fin, blue, and North Pacific right whales. Two other listed stocks could occur in the proposed survey areas: the ***Threatened*** Eastern U.S. Stock of the Steller sea lion, and the ***Endangered*** Southern Resident Stock of the killer whale.

The proposed survey areas are located ~15–470 km offshore from Washington and Oregon over water depths ~50–3000 m (Fig. 1). The sea otter is not expected in the proposed survey areas because its occurrence off Washington and Oregon is limited to very shallow (<30 m depth), coastal (<4 km from shore) waters (Laidre et al. 2009). Vagrant ringed seals, hooded seals, and ribbon seals have been sighted or stranded on the coast of California (see Mead 1981; Reeves et al. 2002) and presumably passed through Oregon waters. A vagrant beluga whale was seen off the coast of Washington (Reeves et al. 2002). Those five species are not addressed in the summaries below.

Mysticetes

North Pacific Right Whale (*Eubalaena japonica*)

The North Pacific right whale is listed as ***Endangered*** under the ESA and is considered by NMFS (1991) to be the most endangered baleen whale in the world. It is listed as ***Endangered*** on the IUCN Red List of Threatened Species (IUCN 2011) and is listed in CITES Appendix I (UNEP-WCMC 2011) (Table 2). Although protected from commercial whaling since 1935, there has been little indication of recovery. The pre-exploitation stock could have exceeded 11,000 animals (NMFS 1991). Wada (1973) estimated a total population of 100–200 in the North Pacific based on sighting data. Based on photographic and genetic mark-recapture data, right whale abundance in the Bering Sea and Aleutian Islands was estimated at 31 and 28, respectively. The total northeastern Pacific population is unlikely to be much larger (Wade et al. 2010).

North Pacific right whales summer 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 that 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). In April 1996, a right whale was sighted off Maui, representing the first documented sighting of a right whale in Hawaiian waters since 1979 (Herman et al. 1980; Rowntree et al. 1980). The individual seen in Hawaii was one of the whales subsequently seen in the southeastern Bering Sea on several occasions, and represents the first high to low latitude North Pacific right whale match (Allen and Angliss 2011).

TABLE 2. The habitat, abundance, and conservation status of marine mammals that could occur in or near the proposed seismic survey areas in the northeastern Pacific Ocean off Washington and Oregon.

Species	Occurrence in survey areas	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	Common*	Coastal, shallow shelf	19,126[6]	DL	LC	I
Humpback whale	Common*	Mainly nearshore and banks	20,800[7]	EN	LC	I
Minke whale	Rare	Nearshore, offshore	9000[8]	NL	LC	I
Sei whale	Rare	Mostly pelagic	12,620[9]	EN	EN	I
Fin whale	Common	Slope, pelagic	13,620–18,680[10]	EN	EN	I
Blue whale	Rare	Pelagic and coastal	2497	EN	EN	I
Odontocetes						
Sperm whale	Common	Pelagic, steep topography	24,000[11]	EN	VU	I
Pygmy sperm whale	Rare	Deep, off shelf	N.A.	NL	DD	II
Dwarf sperm whale	Rare	Deep, shelf, slope	N.A.	NL	DD	II
Cuvier's beaked whale	Common	Pelagic	2143	NL	LC	II
Baird's beaked whale	Common	Pelagic	907	NL	DD	I
Blainville's beaked whale	Rare	Pelagic	1024[12]	NL	DD	II
Hubb's beaked whale	Rare	Slope, offshore	1024[12]	NL	DD	II
Stejneger's beaked whale	Common	Slope, offshore	1024[12]	NL	DD	II
Common bottlenose dolphin	Rare	Coastal, shelf, deep	1006[13]	NL	LC	II
Striped dolphin	Rare	Off continental shelf	10,908	NL	LC	II
Short-beaked common dolphin	Common	Shelf, pelagic, mounts	411,211	NL	LC	II
Pacific white-sided dolphin	Abundant	Offshore, slope	26,930	NL	LC	II
Northern right whale dolphin	Common	Slope, offshore waters	8,334	NL	LC	II
Risso's dolphin	Common	Shelf, slope, mounts	6,272	NL	LC	II
False killer whale	Rare	Pelagic	N.A.	NL	DD	II
Killer whale	Common	Widely distributed	2250–2700	NL/EN[13]	DD	II
Short-finned pilot whale	Rare	Pelagic, high-relief	760	NL	DD	II
Harbor porpoise	Abundant	Coastal and inland waters	55,255[14]	NL	LC	II
Dall's porpoise	Abundant	Shelf, slope, offshore	42,000	NL	LC	II
Pinnipeds						
Northern fur seal	Common	Pelagic, offshore	653,171[6]	NL	VU	NL
California sea lion	Rare	Coastal, shelf	296,750	NL	LC	NL
Steller sea lion	Common*	Coastal, shelf	58,334–72,223[6]	T	EN	NL
Harbor seal	Abundant*	Coastal	24,732[15]	NL	LC	NL
Northern elephant seal	Common	Coastal, pelagic in migration	124,000[16]	NL	LC	NL
Fissiped						
Northern sea otter	Absent	Nearshore, coastal	1125[17]	NL	EN	I

N.A. - Data not available or species status was not assessed.
* In nearshore survey areas, rare elsewhere.
[1] Abundance given for the California/Oregon/Washington or Eastern North Pacific stock (Carretta et al. 2011a,b), unless otherwise stated.
[2] Endangered Species Act: EN = Endangered, T = Threatened, DL = Delisted, NL = Not listed
[3] Codes for IUCN (2011): EN = Endangered; VU = Vulnerable; LC = Least Concern; DD = Data Deficient
[4] CITES (UNEP-WCMC 2011): Appendix I = threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled, NL = Not Listed
[5] Bering Sea (Wade et al. 2010)
[6] Eastern North Pacific (Allen and Angliss 2011)
[7] North Pacific (Barlow et al. 2009)
[8] North Pacific (Wada 1976)
[9] North Pacific (Tillman 1977)
[10] North Pacific (Ohsumi and Wada 1974)
[11] Eastern Temperate North Pacific (Whitehead 2002a)
[12] All mesoplodont whales
[13] Offshore stock (Carretta et al. 2011a)

[14] The Eastern North Pacific Southern Resident Stock of killer whales is listed as Endangered under the ESA.
[15] Northern Oregon/Washington Coast and Northern California/Southern Oregon stocks
[16] Oregon/Washington Coastal Stock (Carretta et al. 2011a)
[17] California population (Carretta et al. 2011a)
[18] Minimum population estimate, WA (NMFS 2008a)

Whaling records indicate that right whales once ranged across the entire North Pacific north of 35ºN and occasionally occurred as far south as 20ºN. 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 on 24 May 1992, 65 km west of Cape Elizabeth, Washington, over water depths of ~1200 m; the same whale was subsequently photographically identified again ~6 hr later 48 km to the west over water depths of ~500 m. Despite many miles of systematic aerial and ship-based surveys for marine mammals off the coasts of Oregon/Washington/California over the years, only seven documented sightings of right whales were made from 1990 to 2000 (Waite et al. 2003). 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 even small numbers will be present in the proposed survey areas during the planned period of operations in June–July, and therefore no takes are anticipated or requested.

Gray Whale (*Eschrichtius robustus*)

In the North Pacific, gray whales have distinct eastern and western stocks. Although both populations were severely reduced by whaling and the western population has remained highly depleted, the eastern North Pacific population is generally considered to have recovered (Lang et al. 2010). The eastern North Pacific stock was ***Delisted*** from the ESA in 1994. The species is listed as ***Least Concern*** on the IUCN Red List of Threatened Species (IUCN 2011), and is listed in CITES Appendix I (UNEP-WCMC 2011). The population estimate for this stock is 19,126 for 2006/2007 (Allen and Angliss 2011).

The eastern North Pacific gray whale breeds and winters in Baja, California, and migrates north to summer feeding grounds in the northern Bering Sea, the Chukchi Sea, and the western Beaufort Sea (Rice and Wolman 1971; Jefferson et al. 2008); a small portion of the population also summers along the Pacific coast from Vancouver to central California (Rice and Wolman 1971; Nerini 1984; Calambokidis and Quan 1999). Whales observed foraging in these more southern locations are referred as ‘resident’ (Newell and Cowles 2006). In October and November, 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 (Braham 1984; Rugh et al. 2001).

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). Gray whales are known to move farther offshore between the entrance to Prince William Sound and the southern part of the Alaska Peninsula (Consiglieri et al. 1982). They migrate closest to the Washington/Oregon coastline during the spring months (April–June) when most strandings are observed (Norman et al. 2004).

Gray whales usually migrate alone, with the exception of cow/calf pairs, and groups of >6 whales are unusual (Rice and Wolman 1971; Leatherwood et al. 1982). Foraging gray whales commonly dive to depths of 50–60 m, and the maximum known dive depth is 170 m (Jones and Swartz 2009). Migrating gray whales typically dive for 3–5 min and spend 1–2.5 min on the surface between dives (Jones and Swartz 2009).

Resident gray whales have been observed foraging off the coast of Oregon from May to October (Newell and Cowles 2006). At least 28 gray whales were observed near Depoe Bay (~44.8°N) for three successive summers (Newell and Cowles 2006). 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. 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 (Ortega-Ortiz and Mate 2008). The migration paths of tracked whales seemed to follow a constant depth rather than the shoreline. Calambokidis et al. (2004a) estimated annual abundance of gray whales that remained between Oregon and B.C. in summer at 197–256 using photo-identification methods.

Humpback Whale (*Megaptera novaeangliae*)

The humpback whale is found throughout all of the oceans of the world (Clapham 2009). The species is listed as ***Endangered*** under the ESA and ***Least Concern*** on the IUCN Red List of Threatened Species (IUCN 2011), and it is listed in CITES Appendix I (UNEP-WCMC 2011) (Table 2). The world-wide population of humpback whales 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).

The entire North Pacific stock has been recently estimated at 18,302, excluding calves (Calambokidis et al. 2008). Barlow et al. (2009) provided a bias-corrected abundance estimate of 20,800. Overall, the North Pacific stock is increasing (Calambokidis et al. 2008).

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), and winter in three different breeding areas: (1) the eastern North Pacific along the coast of Mexico and Central America, and near the Revillagigedo Islands; (2) around the main Hawaiian Islands; and (3) in the western Pacific, particularly around the Ogasawara and Ryukyu islands in southern Japan and the northern Philippines (Perry et al. 1999a; Calambokidis et al. 2008). There is a low level of interchange of whales among the three main wintering areas and among feeding areas (e.g., Darling and Cerchio 1993; Salden et al. 1999; Calambokidis et al. 2001, 2008).

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). The diving behavior of humpback whales is related to time of year and whale activity. On winter breeding grounds, humpback dives have been recorded at depths >100 m (Baird et al. 2000). In summer feeding areas, humpbacks typically forage in the upper 120 m of the water column, with a maximum recorded dive depth of 500 m (Dolphin 1987; Dietz et al. 2002).

Humpback whales are often sighted singly or in small groups, and up to 20 or more while on their breeding and feeding ranges (Jefferson et al. 2008). Loose feeding aggregations of up to 35 have been sighted over the continental shelf off Oregon/Washington (Green et al. 1992). Barlow (2003) reported mean group sizes of 1.1–2.3 during surveys in 1991, 1993, 1996, and 2001 off California, Oregon, and Washington. Male humpbacks sing a characteristic song when on the wintering grounds (Winn and Reichley 1985).

The humpback whale is the most common species of large cetacean reported off the coasts of Oregon and Washington from May to November, with highest numbers reported from May to September; no humpbacks have been observed there in the winter (Green et al. 1992; Calambokidis et al. 2000, 2004b). Shifts in seasonal abundance observed off Oregon and Washington suggest north–south movement (Green et al. 1992). Off Oregon/Washington, humpbacks occur primarily over the continental shelf and slope during the summer and fall, with few reported in offshore pelagic waters (Green et al. 1992, Calambokidis et al. 2004b). 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 >200 m deep. That sighting was ~70 km west of Cape Blanco during the spring (Green et al. 1992). Encounter rates off Oregon/Washington during the summer were highest over the slope followed by shelf waters, with no sightings in offshore waters (Green et al. 1992). At least 12 humpback whale sightings were reported during the Oregon/Washington portions of the survey in summer/fall 2008 (Barlow 2010). Based on surveys conducted in 1991–2008, the estimated abundance of humpback whales off the coasts of Oregon and Washington is 260 (Barlow 2010). The abundance estimate for humpback whales off the coasts of Oregon/Washington/California is 2034 (Carretta et al. 2011a).

Minke Whale (*Balaenoptera acutorostrata*)

The minke whale has a cosmopolitan distribution that spans polar, temperate, and tropical regions (Jefferson et al. 2008). 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). Wada (1976) estimated the abundance of minke whales in the North Pacific at ~9000.

The minke whale is relatively solitary, but can occur in aggregations of up to 100 when food resources are concentrated (Jefferson et al. 2008). The small size, inconspicuous blows, and brief surfacing times of minke whales mean that they are easily overlooked in heavy sea states, although they are known to approach vessels in some circumstances (Stewart and Leatherwood 1985). Little is known about the diving behavior of minke whales, but they are not known to make prolonged deep dives (Leatherwood and Reeves 1983). One study of four minke whales equipped with speed-depth recorders off northern Norway and Svalbard reported minke whale foraging dives to 65 m (Blix and Folkow 1995).

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 resident in coastal waters off the U.S. west coast (Dorsey et al. 1990). Minke whales strandings have been reported in all seasons in Washington. Most strandings (52%) occurred in spring (March–May); 29% of strandings occurred in summer (June–August; Norman et al. 2004). Forney (2007) estimated and abundance of 957 minke whales during a 2005 ship survey off California, Oregon, and Washington, whereas the most recent survey in 2008 did not record any minke whales while on survey effort (Barlow 2010). Based on surveys conducted in 1991–2008, the estimated abundance of minke whales off the coasts of Oregon and Washington is 147 (Barlow 2010).

Sei Whale (*Balaenoptera borealis*)

The sei whale is listed as ***Endangered*** under the ESA and on the IUCN Red List of Threatened Species (IUCN 2011), and is listed in CITES Appendix I (UNEP-WCMC 2011) (Table 2). Sei whale populations were depleted by whaling, and the current status of this species is generally uncertain (Horwood 1987). The global population is thought to be ~80,000 (Horwood 2009), with up to ~12,620 in the North Pacific (Tillman 1977). The sei whale is poorly known because of confusion with Bryde's whale and unpredictable distribution patterns; it can be common in an area for several years and then seemingly disappear (Schilling et al. 1992; Jefferson et al. 2008).

The sei whale is pelagic and generally not found in coastal waters (Harwood and Wilson 2001). 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 are frequently seen in groups of 2–5 (Leatherwood et al. 1982; Jefferson et al. 2008), although larger groups sometimes form on feeding grounds (Gambell 1985a). Sei whales generally do not dive deeply, and dive durations are 15 min or longer (Gambell 1985a).

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. 2008). 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 about 20°N, and sightings have been made between southern Baja California and the Islas Revillagigedo (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 are known for California, Oregon, and Washington during extensive surveys from 1991–2008 (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. 2011a). Based on surveys conducted in 1991–2008, the estimated abundance of sei whales off the coasts of Oregon and Washington is 52 (Barlow 2010).

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° to 70° north and south of the Equator (Perry et al. 1999b). It is listed as ***Endangered*** under the ESA and on the IUCN Red List of Threatened Species (IUCN 2011), and is listed in CITES Appendix I (UNEP-WCMC 2011) (Table 2). Probably at least in part because of its initially high abundance, wide distribution, and diverse feeding habits, the fin whale does not seem to have been as badly depleted as the other large whales in the North Pacific. Northern and southern fin whale populations are distinct and are sometimes recognized as different subspecies (Aguilar 2009). Abundance estimates are 13,620–18,680 for the North Pacific (Ohsumi and Wada 1974).

Fin whales occur in coastal, shelf, and oceanic waters. Moore et al. (2002) reported that in the eastern Bering Sea, sighting rates were more than twice as high in water >100 m deep than in water 50–100 m deep; no sightings occurred in water <50 m deep. 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 can be found as individuals or groups of 2–7, but can form much larger feeding aggregations, sometimes with humpback and minke whales (e.g., Waite 2003; Jefferson et al. 2008). Barlow (2003) reported mean group sizes of 1.1–4.0 during surveys in 1991, 1993, 1996, and 2001 off California, Oregon, and Washington. Foraging fin whales have mean dive depths and times of 98 m and 6.3 min, and non-foraging fin whales have mean dive depths and times of 59 m and 4.2 min (Croll et al. 2001). Panigada et al. (1999, 2003) reported variations in dive depths coinciding with the diel migration of krill. Daytime dives were shallower (<100m) and night dives were deeper (>400m). Fin whales in southern California were reported diving 60% of their time to water depth >225 m; the other 40% of time was spent near the surface (<50 m; Goldbogen et al. 2006).

Fin whales appear to have complex seasonal movements and are likely seasonal migrants (Gambell 1985b). They mate and calve in temperate waters during the winter and migrate to feed at northern latitudes during the summer (Mackintosh 1965 *in* Gambell 1985b). The North Pacific population summers from the Chukchi Sea to California and winters from California southwards (Gambell 1985b). Recent information about the seasonal distribution of fin whales in the North Pacific has been obtained from the reception of fin whale calls by bottom-mounted, offshore hydrophone arrays along the U.S. Pacific coast, in the central North Pacific, and in the western Aleutian Islands (Moore et al. 1998, 2006; Watkins et al. 2000a,b; Stafford et al. 2007, 2009). Fin whale calls are detected year-round in the Northern Pacific (Moore et al. 2006; Stafford et al. 2007, 2009).

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). Vocalizations from fin whales have been detected year-round off northern California, Oregon, and Washington (Moore et al. 1998). Fin whale abundance off the coasts of California/Oregon/Washington was estimated at 3044 based on summer/autumn ship surveys conducted in 2005 and 2008 (Carretta et al. 2011a). Based on survey conducted in 1991–2008, the estimated abundance of fin whales off the coasts of Oregon and Washington is 416 (Barlow 2010). At least 20 fin whale sightings were reported during the Oregon/Washington portions of the survey in 2008; several sightings occurred near the proposed survey areas (Barlow 2010).

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. 2008). It is listed as ***Endangered*** under the ESA and on the IUCN Red List of Threatened Species (IUCN 2011), and is listed in CITES Appendix I (UNEP-WCMC 2011) (Table 2). All blue whale populations have been exploited commercially, and many have been severely depleted as a result. 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 (including the California area) during summer and fall may winter in the eastern tropical Pacific (ETP) (Stafford et al. 1999, 2001). The western North Pacific stock includes whales that are found around Hawaii during winter. Blue whale abundance has been estimated at ~2497 off the U.S. west coast based on photo-identification data from 2005–2008 (Carretta et al. 2011a).

Blue whales are typically found singly or in groups of two or three (Yochem and Leatherwood 1985; Jefferson et al. 2008). Barlow (2003) reported mean group sizes of 1.0–1.9 during surveys in 1991, 1993, 1996, and 2001 off California, Oregon, and Washington. Croll et al. (2001) reported mean dive depths and times of 140 m and 7.8 min for foraging blue whales, and 68 m and 4.9 min for non-foraging individuals. Four satellite-radio-tagged blue whales in the northeast Pacific Ocean spent 94% of their time underwater; 72% of dives were <1 min long, and "true" dives (>1 min) were 4.2–7.2 min long. Shallow (<16-m) dives were most common (75%), and the average depth of deep (>16-m) dives was 105 m (Lagerquist et al. 2000). Dives of up to 300 m were recorded for tagged blue whales (Calambokidis et al. 2003).

The distribution of the species, at least during times of the year when feeding is a major activity, is in areas that provide large seasonal concentrations of euphausiids, which are the whale's main prey (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). Blue whales also have been heard off Oregon (McDonald et al. 1995; Stafford et al. 1998; Von Saunder and Barlow 1999), but sightings in the area are rare.

Barlow and Forney (2007) estimated an abundance of 603 blue whales in California, Oregon, and Washington waters, based on line-transect data collected during summer and fall 2001. Barlow (2010) estimated 442 blue whales for California, Oregon, and Washington, based on line-transect surveys conducted during summer and fall 2008. The estimate of population abundance off California, Oregon, and Washington based on mark-recapture data collected in 2004–2006 is 2842 (Calambokidis et al. 2007). Carretta et al. (2011a) noted that this represented the best estimate for the population in the area. Blue whales are considered rare off Oregon and Washington (Buchanan et al. 2001). Based on surveys conducted in 1991–2008, the estimated abundance of blue whales off the coasts of Oregon and Washington was 58 (Barlow 2010). Four blue whale sightings were reported during the Oregon/Washington portions of the survey in 2008: one sighting occurred near (~45°N, 128°W) the southern survey area (Barlow 2010).

Odontocetes

Sperm Whale (*Physeter macrocephalus*)

The sperm whale is the largest of the toothed whales, with an extensive worldwide distribution (Rice 1989). The species is listed as ***Endangered*** under the U.S. ESA, but on a worldwide basis it is abundant and not biologically endangered. It is listed as ***Vulnerable*** on the IUCN Red List of Threatened Species (IUCN 2011), and is listed in CITES Appendix I (UNEP-WCMC 2011) (Table 2). There currently is no accurate estimate for the size of any sperm whale population (Whitehead 2002b). Best estimates probably are those of Whitehead (2002a), who provided a sperm whale population size of 24,000 for the eastern temperate North Pacific.

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). They spend periods of at least months on the breeding grounds, moving between mixed groups of ~20–30 animals (Whitehead 1993, 2003). Barlow (2003) reported mean group sizes of 2.0–11.8 during surveys in 1991, 1993, 1996, and 2001 off

California, Oregon, and Washington. The mean group size off the coasts of Oregon and Washington in 2008 was 1.0 (Barlow 2010).

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). A recent study of tagged male sperm whales off Norway found that foraging dives extended to highly variable maximum depths, ranging from 14 to 1860 m, with a median of 175 m (Teloni et al. 2008). During a foraging dive, sperm whales typically travel ~3 km horizontally and 0.5 km vertically (Whitehead 2003). Whales in the Galápagos Islands typically dove for ~40 min and then spent 10 min at the surface (Papastavrou et al. 1989). Davis et al. (2007) reported that sperm whales in the Gulf of California foraged throughout a 24-h period, and rarely dove to the sea-floor bottom (>1000 m); dive depths (100–500 m) overlapped with depth distributions of jumbo squid.

Sperm whales are distributed widely across the North Pacific (Carretta et al. 2011a). Off Oregon, they are seen in every season except winter (Green et al. 1992). In contrast, sperm whales are found off California 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). Based on surveys conducted in 1991–2008, the estimated abundance of sperm whales off the coasts of Oregon and Washington is 329 (Barlow 2010). Three sperm whale sightings were reported in water depths >2000 m during the Oregon/ Washington portions of the survey in 2008 (Barlow 2010).

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

The pygmy sperm whale and dwarf sperm whale 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).

Pygmy sperm whales could inhabit waters beyond the continental shelf edge, whereas dwarf sperm whales are thought to inhabit the shelf edge and slope waters (Rice 1998; Wang et al. 2002; MacLeod et al. 2004). Barros et al. (1998) suggested that dwarf sperm whales could be more pelagic and dive deeper than pygmy sperm whales. Dwarf sperm whale could prefer warmer waters than pygmy sperm whales (e.g., Wade and Gerrodette 1993; Muñioz-Hincapié et al. 1998; McAlpine 2009). Pygmy sperm whales occur in small groups of up to six, and dwarf sperm whales can form groups of up to 10 (Caldwell and Caldwell 1989). Mean group size for the dwarf sperm whale was 2.3 in Hawaii (Barlow 2006) and 1.6–1.7 for the ETP (Wade and Gerrodette 1993; Jackson et al. 2008). The mean group size of the pygmy sperm whale in Hawaiian waters was 1.0 (Barlow 2006), and for the ETP was 1.3 (Jackson et al. 2008).

Pygmy sperm whales feed mainly on various species of squid in the deep zones of the continental shelf and slope (McAlpine et al. 1997). In the Gulf of California, median dive and surface times for dwarf sperm whales or unidentified *Kogia* sp. were 8.6 min and 1.2 min, and dives of up to 25 min and surface times up to 3 min were common (J. Barlow, pers. comm. *in* Willis and Baird 1998). Little is known about dive depths of *Kogia* spp. A satellite-tagged pygmy sperm whale released off Florida made longer dives (>8 min and up to ~18 min) at night and on overcast days, and shorter dives (usually 2–

5 min) on clear days, probably because of the distribution of their prey, vertically-migrating squid (Scott et al. 2001).

Eight strandings of pygmy sperm whales have been recorded for Oregon and Washington, five of which occurred during autumn and winter months (Norman et al. 2004). Although there are few useful estimates of abundance for pygmy or dwarf sperm whales anywhere in their range, they are thought to be fairly common in some areas (Jefferson et al. 2008). For waters off Oregon and Washington, Barlow (2010) used data collected in 1991–2008 to estimate an abundance of 229 *Kogia* sp., which were thought to be pygmy sperm because no dwarf sperm whales had been identified on the west coast since the early 1970s.

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. 2008) and is most common in water depths >1000 m (Heyning 1989). Ferguson et al. (2006a) reported that in the ETP, the mean water depth where Cuvier's beaked whales were sighted was ~3.4 km. It is rarely observed at sea and is mostly known from strandings. It 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).

Adult males of this species usually travel alone, but these whales can be seen in groups of up to 7 (Heyning and Mead 2009), with a mean group size of 2.3 (MacLeod and D'Amico 2006). Barlow (2010) reported a mean group size of 1.3 for California/Oregon/Washington in 2008. Cuvier's beaked whale dives generally last 30–60 min, but dives of 85 min have been recorded (Tyack et al. 2006). The maximum dive depth recorded by Baird et al. (2006) was 1450 m.

It is the most common beaked whale off the U.S. west coast (Barlow 2010), and the beaked whale species that stranded most frequently on the coasts of Oregon and Washington. Most (75%) Cuvier's beaked whale strandings reported occurred in Oregon (Norman et al. 2004). The abundance estimate for the U.S. west coast, based on survey data from 2005 and 2008, is 2143 (Carretta et al. 2011a). Four beaked whale sightings were reported in water depths >2000 m during the Oregon/Washington portions of the survey in 2008 (Barlow 2010), none was seen in 1996 or 2001 (Barlow 2003), and several were recorded there from 1991 to 1995 (Barlow 1997). The abundance estimate for Oregon and Washington waters, based on data from 1991–2008, is 137 (Barlow 2010).

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). It has been suggested that Baird's beaked whales can be divided into three distinct stocks: the Sea of Japan Stock, the Okhotsk Sea Stock, and the Bering Sea/Eastern North Pacific Stock (Balcomb 1989; Reyes 1991). Any animals in the vicinity of the proposed survey areas likely would be from the Bering Sea/Eastern North Pacific stock. The mean abundance estimate for the U.S west coast based on 2005–2008 ship surveys is 907 (Carretta et al. 2011a).

Baird's beaked whales feed on deep-water and bottom-dwelling fish, cephalopods, and crustaceans (Jefferson et al. 1993), and some pelagic fish (Reyes 1991; Kasuya 2009). Typical water depths for sightings are 1000–3000 m. Baird's beaked whales can stay submerged for up to 67 min (Kasuya 2009). That makes it very difficult to sight and to visually track them. Baird's beaked whales live in pods of 5–

20, although larger groups are sometimes seen. There appears to be a calving peak in March and April (Jefferson et al. 2008).

Baird's beaked whales sometimes are seen close to shore where deep water approaches the coast, but their primary habitat is over or near the continental slope and oceanic seamounts (Jefferson et al. 2008). Along the U.S. west coast, they have been sighted primarily along the continental slope from late spring to early fall (Green et al. 1992; Carretta et al. 2011a). 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.

For Oregon/Washington waters, Barlow (2010) estimated an abundance of 380 Baird's beaked whales based on survey data collected in 1991–2008. 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. Two groups were sighted during summer/fall 2008 surveys off Washington/Oregon, both near the southern survey area in waters >2000 m deep (Barlow 2010).

Mesoplodont Beaked Whales

Three species of *Mesoplodon* can occur off the coasts of Oregon and Washington: Blainville's beaked whale (*M. densirostris*), Stejneger's beaked whale (*M. stejnegeri*), and Hubb's beaked whale (*M. carlhubbsi*). In addition, records exist for Perrin's beaked whale (*M. perrini*) and the lesser beaked whale (*M. peruvianus*) and gingko-toothed beaked whale (*M. ginkgodens*) off the coast of California and/or Baja California (MacLeod et al. 2006). However, those species are unlikely to be seen in the proposed survey areas, and will not be discussed further.

Almost everything that is known regarding most mesoplodont species has come from stranded animals (Pitman 2009). Because of the scarcity of sightings, most are thought to be rare. The different mesoplodont species are difficult to distinguish in the field, and confirmed at-sea sightings are rare (Mead 1989; Jefferson et al. 2008; Carretta et al. 2011a).

Mesoplodonts are distributed primarily in deep waters (>2000 m) and along continental slopes at depths 200–2000 m; they are rarely found in continental shelf waters (Pitman 2009). Most mesoplodonts identified to species are known from strandings involving single individuals (Jefferson et al. 2008); thus, it is not possible to identify spatial or seasonal patterns in their distribution (Carretta et al. 2011a). Dive depths of most of these species are undocumented.

Typical group sizes range from one to six (Pitman 2009). Because of the scarcity of sightings, most are thought to be rare. However, based on stranding records, Blainville's beaked whale appears to be widespread and fairly common (Pitman 2009). In 1996, the estimated abundance of mesoplodont beaked whales was 2169 for Oregon and Washington, and in 2001, it was zero (Barlow 2003). In 2005, the estimated abundance in the area was 841, and in 2008, it was zero (Barlow 2010). The abundance of *Mesoplodon* species for Oregon and Washington waters is estimated at 565 based on data from 1991–2008 (Barlow 2010).

Blainville's beaked whale.—This species is found in tropical and temperate waters of all oceans (Jefferson et al. 2008). Blainville's beaked whale has the widest distribution throughout the world of all *Mesoplodon* species (Mead 1989). There is no evidence that Blainville's beaked whale undergoes seasonal migrations. It is most often found in singles or pairs, but also in groups of 3–7 (Jefferson et al. 2008). Barlow (2006) reported a mean group size of 2.3 for Hawaii.

Like other beaked whales, Blainville's beaked whales are generally found in waters 200–1400 m deep (Gannier 2000; Jefferson et al. 2008). Maximum dive depths have been reported as 1251 m (Tyack et al. 2006) and 1408 m (Baird et al. 2006), and dives have lasted as long as 54 min (Baird et al. 2006) to 57 min (Tyack et al. 2006). They also can occur in coastal areas and have been known to spend long periods of time at depths <50 m (Jefferson et al. 2008).

Occasional occurrences in cooler, higher-latitude waters are presumably related to warm-water incursions (Reeves et al. 2002). Strandings and sighting records in the eastern Pacific range from 37.3°N to 41.5°S (McLeod et al. 2006). None of the 36 beaked whale-stranding records in Oregon and Washington during 1930–2002 were Blainville's beaked whale (Norman et al. 2004). For California, Oregon, and Washington waters, Barlow (1997) estimated an abundance of 360 Blainville's beaked whales. It is unlikely to be present in the proposed survey areas, as its main distribution is south of there (Carretta et al. 2011a).

Stejneger's beaked whale.—This species 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). This species occurs in groups of 3 to 4, ranging to ~15 (Reeves et al. 2002). 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).

Hubb's beaked whale.—This species occurs in temperate waters of the North Pacific (Mead 1989). Most of the records are from California, but it has been sighted as far north as Prince Rupert, British Columbia (Mead 1989). Two strandings are known from Washington/Oregon (Norman et al. 2004). The distribution of the species appears to be correlated with the deep subarctic current (Mead et al. 1982). Hubb's beaked whales are often killed in drift gillnets off California (Reeves et al. 2002).

Common Bottlenose Dolphin (*Tursiops truncatus*)

The bottlenose dolphin is distributed worldwide. It is found mainly where surface temperatures are 10–32ºC (Reeves et al. 2002). Generally, 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). As well as inhabiting different areas, these ecotypes differ in their diving abilities (Klatsky 2004) and prey types (Mead and Potter 1995). Bottlenose dolphins have been reported to dive regularly to depths >450 m for periods of >5 min, and even to depths of 600–700 m for up to 12 min (Klatsky et al. 2007). Mean group size was 8.02 for California, Oregon, and Washington in 2008 (Barlow 2010).

Bottlenose dolphins occur frequently off the coast of California, and sightings have been made as far north as 41ºN (Carretta et al. 2011a). The most recent abundance estimate of offshore bottlenose dolphins for California/Oregon/Washington is 1006 (Carretta et al. 2011a). In the proposed survey areas, it is possible that offshore bottlenose dolphins could be encountered during warm-water periods (see Carretta et al. 2002), although none have been sighted in waters off Oregon or Washington (Barlow 2010). No takes of bottlenose dolphins are anticipated or requested.

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). In the eastern North Pacific, its distribution extends as far north as Washington, although there have been few sightings (Appler et al. 2004). 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). It is fairly gregarious (groups of 20 or more are common) and active at the surface (Whitehead et al. 1998). Barlow (2010) reported a mean group size of 15.0 for California/Oregon/Washington in 2008. For the ETP, reported mean group sizes were 52–61 (Wade and Gerrodette 1993; Ferguson et al. 2006b; Jackson et al. 2008).

Off California, striped dolphins have been sighted within 185–556 km of the coast (Carretta et al. 2002). They also occur in coastal waters (Isaksen and Syvertsen 2002). There are 10 stranding records of this species in Oregon and two in Washington during 1930–2002 (Norman et al. 2004). The abundance of striped dolphins off the coasts of California/Oregon/Washington appears to be variable among years and could be affected by oceanographic conditions (Carretta et al. 2011a). The 1991–1996 average abundance estimate for was 20,235 (Barlow 1997), and the 2008 estimate was 4655 (Barlow 2010). Based on survey data from 2005 and 2008, the mean abundance estimate for California, Oregon, and Washington waters is 10,908 (Carretta et al. 2011a). However, very few sightings have been reported for Oregon or Washington, with the exception of a survey by Barlow (2003) in 1996. No striped dolphins were sighted off Washington and Oregon during the summer/fall survey in 2008 (Barlow 2010). Barlow (2010) gave an abundance estimate of 12 for waters off Oregon and Washington, based on data collected in 1991–2008.

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). There are two species of common dolphin: the short-beaked common dolphin (*D. delphis*) and the long-beaked common dolphin (*D. capensis*). The long-beaked common dolphin is less abundant, and only recently has been recognized as a separate species (Heyning and Perrin 1994). Short-beaked common dolphins have been sighted as far as 550 km from shore, and are likely present farther offshore (Barlow et al. 1997). Long-beaked common dolphins are usually found within 90 km of shore (Barlow et al. 1997), are not found north of central California (Carretta et al. 2011a). Common dolphins found in the survey area likely would be the short-beaked species.

Common dolphins often travel in large groups; schools of hundreds or even thousands are common. The groups are thought to be composed of smaller subunits of perhaps 20–30 closely related individuals (Evans 1994). Barlow (2010) reported a mean group size of 178 for the U.S. west coast in 2008. Common dolphins are easily identified from their fast swimming speed (typically 40 km/h) and their propensity for bow riding. Perrin (2009) reported foraging dives to 200 m.

The distribution of short-beaked common dolphins along the U.S. west coast is variable and likely is related to oceanographic changes (Heyning and Perrin 1994; Forney and Barlow 1998). The short-beaked common dolphin is the most abundant cetacean off California, but it is not abundant off Oregon and Washington (Carretta et al. 2011a). There were single sightings in 2001 and 2005 of common dolphins in Oregon/Washington, both off southern Oregon (Forney 2007). Only one sighting was reported off Oregon and Washington during the summer/fall survey in 2008 (Barlow 2010). Based on survey data in 2005 and 2008, the mean abundance in the area is estimated at 411,211 (Carretta et al. 2011a). The abundance estimates for waters off Oregon/Washington alone is 3312 for pooled 1991–2008 surveys (Barlow 2010).

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 marine mammal species, occurring primarily in shelf and slope waters (Green et al. 1993; Barlow 2003; Barlow 2010). It is known to occur close to shore in certain regions, including (seasonally) southern California (Brownell et al. 1999).

Pacific white-sided dolphins are very gregarious, commonly occurring in groups of 10–100, and occasionally in groups of thousands (Reeves et al. 2002). They often associate with other species, including cetaceans, pinnipeds, and seabirds. In particular, they are frequently seen in mixed-species schools with Risso's and northern right whale dolphins (Green et al. 1993). Barlow (2010) reported a mean group size of 72.4 for California/Oregon/Washington in 2008.

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; Carretta et al. 2002). During winter, this species is most abundant in California slope and offshore areas; as northern marine waters begin to warm in the spring, it appears to move north to slope and offshore waters off Oregon/Washington (Green et al. 1992, 1993; Forney 1994; Forney et al. 1995; Buchanan et al. 2001; Barlow 2003). Seasonal abundance estimates off the coast of California are an order of magnitude higher in February–April than in August–November, whereas the highest abundance estimates off Oregon and Washington are in April–May.

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). The highest encounter rates were associated with the 1992 El Niño year. Mean group sizes were significantly higher in slope (11.6) *vs*. offshore waters (6.7). 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 the second most abundant species reported during the 2008 survey (Barlow 2010). Its abundance off the coasts of California/Oregon/Washington was estimated at 26,930 based on summer/autumn ship surveys conducted in 2005 and 2008 (Carretta et al. 2011a). The abundance estimate for pooled 1991–2008 surveys off Oregon/Washington was 11,250 (Barlow 2010).

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 m to >2000 m deep (Green et al. 1993; Carretta et al. 2002; 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).

Northern right whale dolphins are gregarious, and groups of several hundred to over a thousand are not uncommon (Reeves et al. 2002). Barlow (2010) reported a mean group size of 23.7 for California, Oregon, and Washington in 2008. Northern right whale dolphins are often seen in mixed-species schools with Pacific white-sided dolphins. Calving appears to occur primarily in July and August (Reeves et al. 2002). The species presumably feeds primarily at night on small fish and squid that migrate vertically in the water column.

Recent 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; Carretta et al. 2002). 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.

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 waters 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. The abundance off the coasts of California, Oregon, and Washington was estimated at 8334 based on summer/autumn ship surveys conducted in 2005 and 2008 (Carretta et al. 2011a). The abundance estimate for pooled 1991–2008 surveys off Oregon/Washington was 4152 (Barlow 2010).

Risso's Dolphin (*Grampus griseus*)

Risso's dolphin is primarily a tropical and mid-temperate species distributed worldwide. It occurs between 60ºN and 60ºS, where surface water temperatures are at least 10ºC (Kruse et al. 1999). Water temperature appears to be an important factor affecting its distribution (Kruse et al. 1999; see also Becker 2007). 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).

Risso's dolphins are pelagic, mostly occurring on the upper continental slope shelf edge in waters 350–1000 m deep (Baumgartner 1997; Davis et al. 1998). They occur individually or in small to moderate-sized groups, normally 10–50, although groups as large as 4000 have been sighted (Baird 2009a). The majority of groups consist of <50 individuals (Kruse et al. 1999; Miyashita 1993). Mean group size was 20.3 for California/Oregon/Washington (Barlow 2010). Risso's dolphins in the Gulf of Mexico were distributed non-uniformly with respect to depth and depth gradient, occurring mainly in the steep sections of upper continental slope bounded by the 350 m and 975 m isobaths (Baumgartner 1997). Prey items collected in the stomach of stranded Risso's dolphins suggested they feed on the middle slope at depths 600–800 m (Blanco et al. 2006).

Throughout the region from California to Washington, the distribution and abundance of Risso's dolphin are highly variable, presumably in response to changing oceanographic conditions on both annual and seasonal time scales (Forney and Barlow 1998; Buchanan et al. 2001; Carretta et al. 2002). 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 that most Risso's dolphin groups sighted off Oregon were primarily at ~45–47ºN. Risso's dolphin sightings during ship surveys in summer/fall 2008 were mostly from ~30º N to ~38ºN; none were reported in Oregon/Washington (Barlow 2010). The mean abundance off the coasts of California/Oregon/Washington was estimated at 6272 based on summer/autumn ship surveys conducted in 2005 and 2008 (Carretta et al. 2011a). The abundance estimate for pooled 1991–2008 surveys off Oregon and Washington was 3607 (Barlow 2010).

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). False killer whales travel in groups of 20–100 (Baird 2009b), although groups of several hundred are sometimes observed. Mean group sizes were 10 for Hawaii (Barlow 2006) and 11–12 for the ETP (Wade and Gerrodette 1993; Ferguson et al. 2006b; Jackson et al. 2008).

In the eastern North Pacific, the species has been reported only rarely north of Baja California (Leatherwood et al. 1982, 1987; Mangels and Gerrodette 1994). Their occurrence in Washington/Oregon is associated with warm-water incursion years (Buchanan et al. 2001). They were not seen 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). Two were reported stranded along the Washington coast during 1930–2002, both in El Niño years (Norman et al. 2004). No takes of false killer whales are anticipated or requested.

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 B.C. through parts of southeast Alaska; (3) Southern Residents, mainly in inland waters of Washington State and southern B.C.; (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. 2011a). Individuals from the Southern Resident Stock, the Offshore Stock, and the West Coast Transient Stock could be encountered in the proposed survey areas. Movements of resident groups between different geographic areas have also been documented (Leatherwood et al. 1990; Dahlheim et al. 1997; Matkin et al. 1997, 1999 *in* Angliss and Allen 2011). Most killer whale stocks in the northeast Pacific are not listed under the ESA; the Southern Resident Killer Whale Stock, occurring in inland waters of Washington and southern British Columbia, is listed as ***Endangered*** under the ESA. The northeast Pacific population is estimated at 2250–2700 (NMFS 2011).

High densities of the species occur in high latitudes, especially in areas where prey is abundant. Although resident in some parts of its range, the killer whale can also be transient. Killer whale movements generally appear to follow the distribution of their prey, which includes marine mammals, fish, and squid. Killer whales are large and conspicuous, often traveling in close-knit matrilineal groups of a few to tens of individuals (Dahlheim and Heyning 1999). Group sizes of residents are 5–50, whereas those of transients are 1–7 (Bigg et al. 1987). The mean group size off killer wales off California, Oregon, and Washington was 14.8 (Barlow 2010). The maximum depth to which seven tagged free-ranging killer whales dove off B.C. was 228 m, but only an average of 2.4 % of their time was spent deeper than 30 m (Baird et al. 2003). Diving studies on killer whales have been undertaken mainly on "resident" (fish-eating) killer whales in Puget Sound and may not be applicable across all populations of killer whales. Marine mammal-eating killer whales could display different dive patterns.

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. Barlow (1997) estimated the number of killer whales within 550 km of the coasts of California, Oregon, and

Washington to be 819, of which perhaps 35% were offshore whales (Carretta et al. 2011a). Six of the 17 (35%) stranded killer whales in Washington and Oregon were confirmed as southern residents (Osborne 1999 *in* Norman et al. 2004). Two of the stranded killer whales in Oregon were confirmed as transient (Stevens et al. 1989 *in* Norman et al. 2004). Barlow (2010) reported a mean abundance estimate of 536 for pooled 1991–2008 surveys off Oregon and Washington.

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. 2008). Pilot whales are generally nomadic, but may be resident in certain locations, including California and Hawaii (Olson 2009). It is an occasional visitor as far north as the Alaska Peninsula. In the southern California Bight, the occurrence of short-finned pilot whales was associated with high-relief topography (Hui 1985).

Pilot whales are very social and are usually seen in groups of 20–90 with matrilineal associations (Olson 2009). Mean group sizes have been reported as 22.5 for Hawaii (Barlow 2006) and 18.0–18.3 for the ETP (Wade and Gerrodette 1993; Ferguson et al. 2006b; Jackson et al. 2008). Both pilot whale species (short-finned and long-finned) are known for single and mass strandings. Long-finned pilot whales outfitted with time-depth recorders dove to depths up to 828 m, although most of their time was spent above depths of 7 m (Heide-Jørgensen et al. 2002). The species' maximum recorded dive depth is 971 m (Baird pers. comm. *in* DoN 2005).

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. 2002). 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). Only two groups of pilot whales (of 26 and 43 animals) were seen during the two most recent ship surveys conducted off California, Oregon, and Washington in 2005 and 2008 (Barlow 2010). The mean abundance off the coasts of California/Oregon/Washington was estimated at 760 based on summer/autumn ship surveys conducted in 2005 and 2008 (Carretta et al. 2011a). The abundance estimate for pooled 1991–2008 surveys off Oregon/Washington was 0 (Barlow 2010). No takes of short-finned pilot whales are anticipated or requested.

Harbor Porpoise (*Phocoena phocoena*)

The harbor porpoise inhabits temperate, subarctic, and arctic waters. In the eastern North Pacific, the harbor porpoise's usual 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) the Washington Inland Waters Stock, (2) the Northern Oregon/Washington Coast Stock, (3) the Northern California/Southern Oregon Stock, (4) the San Francisco-Russian River Stock, (5) the Monterey Bay Stock, and (6) the Morro Bay Stock (Carretta et al. 2011b). Harbor porpoises from the Northern Oregon/Washington and the Northern California/Southern Oregon stocks could occur in the proposed survey areas; the abundance estimates for those stocks are 15,674 and 39,581, respectively (Carretta et al. 2011a,b).

Harbor porpoises feed primarily near the seafloor but also in the water column, consuming schooling fish such as herring, capelin, sprat, and silver hake (Reeves et al. 2002). They also prey on squid and octopus, and their seasonal changes in abundance and distribution could be related to the movements of squid (Green et al. 1992). Harbor porpoises are normally found in small groups of up to 3 that often contain at least one mother-calf pair. Larger groups of 6–8 are not uncommon, and rarely, much larger aggregations are seen. Mean group size was 2.65 for northern California (Carretta et al. 2001). Harbor porpoises are generally not found in water deeper than 100 m, and abundance declines linearly as depth increases (Barlow 1988; Angliss and Outlaw 2011). Tagged harbor porpoises in the Bay of Fundy dove to mean depths of 14–41 m for mean durations of 44–103 s, and to a maximum depth of 226 m (Westgate et al. 1995).

The harbor porpoise inhabits shallow coastal and inland waters (Reeves et al. 2002; Carretta et al. 2011a). Based on year-round surveys spanning coastal to offshore waters of Oregon/Washington, Green et al. (1992) reported that 96% of harbor porpoise sightings occurred in coastal waters <100 m deep, with a few sightings made on the slope near the 200-m isobath. 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), south of the proposed survey areas, to California, from fall through spring. During summer, the reported encounter rates decreased notably from inner shelf to offshore waters.

Dall's Porpoise (*Phocoenoides dalli*)

Dall's porpoise is found only in temperate to cold, ice-free waters of the North Pacific and adjacent seas. It is widely distributed across the North Pacific over the continental shelf and slope waters, and over deep (>2500 m) oceanic waters (Hall 1979; Angliss and Allen 2011). 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; Jefferson et al. 2008). The most recent estimate of Dall's porpoise abundance in the eastern Pacific U.S. EEZ is 42,000, based on the mean of estimates from 2005 and 2008 summer/autumn surveys of California, Oregon, and Washington waters (Carretta et al. 2011a).

Dall's porpoises are typically seen in groups of 2–12; groups of >20–30 are uncommon, and aggregations of several thousands have been reported (Jefferson et al. 2008). In the Bering Sea, average group size was 2.7–3.7 (Moore et al. 2002). Mean group size on the U.S. west coast was 4.2 in 2008 (Barlow 2010). They are fast swimming and active porpoises, and readily approach vessels to ride the bow wave. Data from one tagged Dall's porpoise showed a mean dive depth of 33.4 m for a mean duration of 1.3 min (Hanson and Baird 1998).

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; Carretta et al. 2011a). 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).

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. 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). 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). The abundance estimate for pooled 1991–2008 surveys off Oregon/Washington was 27,010 (Barlow 2010).

Pinnipeds

Northern Fur Seal (*Callorhinus ursinus*)

The northern fur seal is endemic to the North Pacific Ocean, and it occurs from southern California to the Bering Sea, the Okhotsk Sea, and Honshu Island, Japan (Angliss and Allen 2011). Two stocks are recognized in U.S. waters: the Eastern Pacific and the San Miguel Island 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. 2011a; Angliss and Allen 2011). 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 653,171 (Angliss and Allen 2011). They were subjected to large-scale harvests on the Pribilof Islands to supply a lucrative fur trade. Abundance of the Eastern Pacific Stock has been decreasing at the Pribilof Islands since the 1940s and increasing on Bogoslof Island. The San Miguel Island stock is much smaller, estimated at 9968 (Carretta et al. 2011a).

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 British Columbia, Washington, Oregon, and California before migrating north again to the rookeries in spring (Ream et al. 2005). 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). The San Miguel Island stock is believed to remain predominantly offshore from California year round (Carretta et al. 2011a).

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, 2002a). The remainder of its life is spent on or near rookery islands or haulouts on rocky shorelines (Carretta et al. 2011a). Adult males usually occur on shore from May to August, though some may be present until November, and females are usually found ashore from June to November. 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 2002a). Kooyman and Goebel (1986) reported that the mean dive depth for tagged females was 32–207 m. The mean dive depth for tagged juvenile males was 17.5 m, with a maximum depth of 175 m. Deeper diving tended to occur on the shelf, with shallower diving off the shelf (Sterling and Ream 2004).

Bonnell et al. (1992) noted the presence of northern fur seals year-round off Oregon and 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). During the proposed survey period (June–July), only juveniles would be at sea.

California Sea Lion (*Zalophus californianus*)

The California sea lion is distributed along the mainland and offshore islands of the eastern North Pacific Ocean from British Columbia, Canada, to central Mexico, including the Gulf of California (Jefferson et al. 2008). The species is occasionally recorded outside of its normal range, as far as Alaska to the north (Maniscalco et al. 2004) and southern Mexico to the south (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. Five genetically distinct geographic populations have recently been identified: (1) Pacific Temperate (which includes rookeries within U.S. waters and the Coronados Islands), (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 survey areas. Based on a 2008 pup count, the California sea lion population is estimated at 296,750 (Carretta et al. 2011b).

In California and Baja California, births occur on land from mid May to late June. Females are ready to breed and actively solicit mates ~3 weeks after giving birth (Odell 1984; Trillmich 1986). Males establish territories that they defend from other males. Pups are able to swim soon after birth, and at 2–3 weeks of age, they form groups with other young pups. During August and September, after the mating season, the adult males migrate northward to feeding areas in Oregon, Washington, and B.C. (Lowry et al. 1992). They remain there until spring (March–May), when they migrate back to the breeding colonies (Lowry et al. 1992; Weise et al. 2006). The distribution of immature 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 immature seals are presumed to remain near the rookeries for most of the year (Lowry et al. 1992). Adult females remain near the rookeries throughout the year.

California sea lions are coastal animals that often haul out on shore throughout the year. 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 (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). Most dives of tagged females on San Miguel Island were <80 m deep, and less than 5% of dives were in water depths >200 m. The deepest dive recorded was estimated at 274 m (Feldkamp et al. 1989).

Off Oregon/Washington, most California sea lions occur in the fall (Bonnell et al. 1992). California sea lions are likely to be rare in the proposed survey areas during the planned June–July survey period, and no takes are anticipated or requested.

Steller Sea Lion (*Eumetopias jubatus*)

The Steller sea lion ranges along the North Pacific Rim from northern Japan to California (Loughlin et al. 1984). The species is listed under the ESA as ***Threatened*** in the eastern portion of its range and as ***Endangered*** in the western portion, west of 144°W. It is listed as ***Endangered*** on the IUCN Red List of Threatened Species (IUCN 2011). The major anthropogenic factors that likely contributed to a decline of the western population are by-catch in fisheries, commercial hunting of sea lions, and legal and illegal shooting of sea lions (Atkinson et al. 2008). Minimum population sizes of the U.S. Eastern Stock, including animals in Alaska, B.C., Washington, Oregon, and California, and the U.S. Western Stock are estimated at 58,334–72,223 and 42,366, respectively (Allen and Angliss 2011). The eastern stock is thought to be increasing at a rate of 3.1% annually (Pitcher et al. 2007).

In August–September 2010, the states of Oregon and Washington and the State of Alaska petitioned NMFS to delist the Eastern Designated Population Segment (DPS) of Steller sea lions. In a 90-

day petition finding issued on 13 December 2010, NMFS found that the petitions' action could be warranted (NMFS 2010a). The federal agency is now in the ESA process of determining whether or not delisting is indeed warranted.

Breeding adults occupy rookeries from late May to early July (NMFS 2008b). The eastern stock of Steller sea lion rookeries are located in southeast Alaska, British Columbia, Oregon, and California (Allen and Angliss 2011). Males arrive at rookeries in May to establish their territory and are soon followed by females. Non-breeding males use haulouts or occupy sites at the periphery of rookeries during the breeding season (NRC 2003). Pupping occurs from mid May to mid July (Pitcher and Calkins 1981) and peaks in June (Pitcher et al. 2002). In Oregon, breeding occurs during the months of June and July (USFWS 2011).

Territorial males fast and remain on land during the breeding season (NMFS 2008b). 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 2008b). 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). 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, with the farthest sighting ~40 km from shore; all sightings occurred near or in waters <200 m deep.

Three rookeries and seven haul-out sites are located in Oregon; several haul-out sites are also located in Washington (NMFS 2008b). Jeffries et al. (2000) identified four haul-out sites in the Split Rock area (47.4°N); animals at these haulout locations are assumed to be immatures and non-breeding adults associated with rookeries in Oregon and British Columbia (Pitcher et al. 2007). The mean count of non-pups on Washington haul-out sites during 16 June–15 July 2001 was 516. The total number of Steller sea lions at rookeries and haul-out sites in Oregon in 2002 was estimated at 5076–5753 (NMFS 2008b).

The Steller sea lion rookery closest to the survey area is the Three Arch Rocks rookery (Fig. 1) located ~130 km from the southern survey area and ~210 km from the northern survey area. Two other rookeries, Orford Reef and Rogue Reef, are designated as Critical Habitat; they are located ~160 and ~205 km south of the southern survey area, respectively. The eastern boundary of the southern seismic survey line is located ~15 km from shore, potentially within Stellar sea lion foraging range.

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. 2011a). Three separate stocks of harbor seals are recognized along the U.S. west coast: (1) Washington Inland Waters Stock, (2) Oregon and Washington Coastal Stock from Cape Flaherty (~48.4°N) to ~42°N, and (3) California Stock (Carretta et al. 2011a). The Oregon and Washington Coast Stock occurs in the proposed survey areas. The most recent estimate for the Oregon/Washington coastal stock is 24,732 (based on counts in 1999). The 1999 count of harbor seals along the outer Olympic Peninsula region alone was 7117 (Jeffries et al. 2003).

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). Juvenile harbor seals can travel significant distances (525 km) to forage or disperse, whereas adults were generally found within 190 km of their tagging location in PWS (Lowry et al. 2001). The smaller home range used by adults is suggestive of a strong site fidelity (Pitcher and Calkins 1979; Pitcher and McAllister 1981; Lowry et al. 2001). Pups tagged in the 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 PWS 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). Most diving activity occurs at night (Hastings et al. 2004). Bowen et al. (1999) found that lactating females from Sable Island, Nova Scotia, spent 45% of time on land with their pups, 55% of time at sea, and only 9% of the total time actively diving. Median depth and duration of dive are positively correlated with body mass; large adult male harbor seals in Monterey Bay generally dove deeper (mean 51.9 m) and longer than smaller adult females (mean 39.8 m). Most dives were to <100 m (Eguchi and Harvey 2005).

Female harbor seals give birth to a single pup while hauled out on shore or on glacial ice flows; pups are born from May to mid July. The mother and pup remain together until weaning occurs at 3–6 weeks (Bigg 1969). Little is known about breeding behavior in harbor seals. When molting, which occurs primarily in late August, seals spend the majority of the time hauled out on shore, glacial ice, or other substrates.

Harbor seals haul out on rocks, reefs, beaches, and offshore islands along the U.S. west coast (Carretta et al. 2011b). Jeffries et al. (2000) documented several harbor seal rookeries and haulouts along the Washington coastline. This is the only pinniped species that breeds in Washington State. 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. 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).

Given their preference for coastal waters, harbor seals are unlikely to be encountered in deep offshore waters, where most of the survey lines are located.

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 was later 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 124,000 in 2005 (Carretta et al. 2011a).

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. Females spend only ~34 days on shore. Juvenile elephant seals typically leave the rookeries in April or May and head north, traveling an average of 900–1000 km. Most elephant seals return to their natal rookeries when they start breeding (Huber et al. 1991).

When not 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). Elephant seals feed on deep-water fish and squid (Condit and Le Boeuf 1984). Davis et al. (2001) recorded an average dive depth of 186 m with range of 8–430 m for an elephant seal returning to the beach. Hindell (2009) noted that traveling likely takes place at depths >200 m.

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 British Columbia (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). Most elephant seal sightings at sea were during June, July, and September off Washington; sightings recorded from November through May were off southern Oregon (Bonnell et al. 1992). During the survey period in June–July, occurrence in the offshore survey areas would include adult females, juveniles, and pups of the year.

V. TYPE OF INCIDENTAL TAKE AUTHORIZATION REQUESTED

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

L-DEO requests an IHA pursuant to Section 101 (a)(5)(D) of the Marine Mammal Protection Act (MMPA) for incidental take by harassment during its planned seismic survey in the central Pacific Ocean during June–July 2012.

The operations outlined in § I have the potential to take marine mammals by harassment. Sounds will be generated by the airguns used during the survey, by echosounders, and by general vessel operations. "Takes" by harassment will potentially result when marine mammals near the activities are exposed to the pulsed sounds generated by the airguns or echosounders. The effects will depend on the species of marine mammal, the behavior of the animal at the time of reception of the stimulus, as well as the distance and received level of the sound (see § VII). Disturbance reactions are likely amongst some of the marine mammals near the tracklines of the source vessel. No take by serious injury is anticipated, given the nature of the planned operations and the mitigation measures that are planned (see § XI, MITIGATION MEASURES). No lethal takes are expected.

VI. NUMBERS OF MARINE MAMMALS THAT COULD BE TAKEN

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

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

VII. ANTICIPATED IMPACT ON SPECIES OR STOCKS

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

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

- First we summarize the potential impacts on marine mammals of airgun operations, as called for in § VII. A more comprehensive review of the relevant background information appears in Appendix B of the EA that supports this application.
- Then we discuss the potential impacts of operations by the echosounders.
- Finally, we estimate the numbers of marine mammals that could be affected by the proposed survey in the northeastern Pacific Ocean during June–July 2012. This section includes a description of the rationale for the estimates of the potential numbers of harassment "takes" during the planned survey, as called for in § VI.

Summary of Potential Effects of Airgun Sounds

The effects of sounds from airguns could include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and at least in theory, temporary or permanent hearing impairment, or non-auditory physical or physiological effects (Richardson et al. 1995; Gordon et al. 2004; Nowacek et al. 2007; Southall et al. 2007). Permanent hearing impairment, in the unlikely event that it occurred, would constitute injury, but temporary threshold shift (TTS) is not an injury (Southall et al. 2007). Although the possibility cannot be entirely excluded, it is unlikely that the project would result in any cases of temporary or especially permanent hearing impairment, or any significant non-auditory physical or physiological effects. Some behavioral disturbance is expected, but this would be localized and short-term.

Tolerance

Numerous studies have shown that pulsed sounds from airguns are often readily detectable in the water at distances of many kilometers. For a summary of the characteristics of airgun pulses, see Appendix B (3) in the EA. Several studies have shown that marine mammals at distances more than a few kilometers from operating seismic vessels often show no apparent response—see Appendix B (5) in the EA. That is often true even in cases when the pulsed sounds must be readily audible to the animals based on measured received levels and the hearing sensitivity of that mammal group. Although various baleen whales and toothed whales have been shown to react behaviorally to airgun pulses under some conditions, at other times mammals of both types have shown no overt reactions. The relative responsiveness of baleen and toothed whales are quite variable.

Masking

Masking effects of pulsed sounds (even from large arrays of airguns) on marine mammal calls and other natural sounds are expected to be limited, although there are very few specific data on this. Because of the intermittent nature and low duty cycle of seismic pulses, animals can emit and receive sounds in the relatively quiet intervals between pulses. However, in exceptional situations, reverberation occurs for much or all of the interval between pulses (e.g., Simard et al. 2005; Clark and Gagnon 2006) which could mask calls. Some baleen and toothed whales are known to continue calling in the presence of seismic pulses, and their calls usually can be heard between the seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999a,b; Nieukirk et al. 2004; Smultea et al. 2004; Holst et al. 2005a,b, 2006; Dunn and Hernandez 2009). However, Clark and Gagnon (2006) reported that fin whales in the northeast Pacific Ocean went silent for an extended period starting soon after the onset of a seismic survey in the area. Similarly, there has been one report that sperm whales ceased calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994). However, more recent studies found that they continued calling in the presence of seismic pulses (Madsen et al. 2002; Tyack et al. 2003; Smultea et al. 2004; Holst et al. 2006; Jochens et al. 2008). Dolphins and porpoises commonly are heard calling while airguns are operating (e.g., Gordon et al. 2004; Smultea et al. 2004; Holst et al. 2005a,b; Potter et al. 2007). The sounds important to small odontocetes are predominantly at much higher frequencies than are the dominant components of airgun sounds, thus limiting the potential for masking. In general, masking effects of seismic pulses are expected to be minor, given the normally intermittent nature of seismic pulses. Masking effects on marine mammals are discussed further in Appendix B (4) of the EA.

Disturbance Reactions

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

Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors (Richardson et al. 1995; Wartzok et al. 2004; Southall et al. 2007; Weilgart 2007). If a marine mammal does react briefly to an underwater sound by changing its behavior or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or population. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on individuals and populations could be significant (e.g., Lusseau and Bejder 2007; Weilgart 2007). Given the many uncertainties in predicting the quantity and types of impacts of noise on marine mammals, it is common practice to estimate how many mammals would be present within a particular distance of industrial activities and/or exposed to a particular level of industrial sound. In most cases, this approach likely overestimates the numbers of marine mammals that would be affected in some biologically-important manner.

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

Baleen Whales.—Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to pulses from large arrays of airguns at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, as reviewed in Appendix B (5) of the EA, baleen whales exposed to strong noise pulses from airguns often react by deviating from their normal migration route and/or interrupting their feeding and moving away. In the cases of migrating gray and bowhead whales, the observed changes in behavior appeared to be of little or no biological consequence to the animals. They simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors.

Studies of gray, bowhead, and humpback whales have shown that seismic pulses with received levels of 160–170 dB re 1 μPa_{rms} seem to cause obvious avoidance behavior in a substantial fraction of the animals exposed (Richardson et al. 1995). In many areas, seismic pulses from large arrays of airguns diminish to those levels at distances ranging from 4 to 15 km from the source. A substantial proportion of the baleen whales within those distances may show avoidance or other strong behavioral reactions to the airgun array. Subtle behavioral changes sometimes become evident at somewhat lower received levels, and studies summarized in Appendix B (5) of the EA have shown that some species of baleen whales, notably bowhead and humpback whales, at times show strong avoidance at received levels lower than 160–170 dB re 1 μPa_{rms}.

Responses of *humpback whales* to seismic surveys have been studied during migration, on summer feeding grounds, and on Angolan winter breeding grounds; there has also been discussion of effects on the Brazilian wintering grounds. McCauley et al. (1998, 2000a) studied the responses of humpback whales off Western Australia to a full-scale seismic survey with a 16-airgun, 2678-in^3 array, and to a single 20-in^3 airgun with source level 227 dB re 1 $\mu Pa \cdot m_{p-p}$. McCauley et al. (1998) documented that avoidance reactions began at 5–8 km from the array, and that those reactions kept most pods ~3–4 km from the operating seismic boat. McCauley et al. (2000a) noted localized displacement during migration of 4–5 km by traveling pods and 7–12 km by more sensitive resting pods of cow-calf pairs. Avoidance distances with respect to the single airgun were smaller but consistent with the results from the full array in terms of the received sound levels. The mean received level for initial avoidance of an approaching airgun was 140 dB re 1 μPa_{rms} for humpback pods containing females, and at the mean closest point of approach (CPA) distance the received level was 143 dB re 1 μPa_{rms}. The initial avoidance response generally occurred at distances of 5–8 km from the airgun array and 2 km from the single airgun. However, some individual humpback whales, especially males, approached within distances of 100–400 m, where the maximum received level was 179 dB re 1 μPa_{rms}.

Data collected by observers during several seismic surveys in the Northwest Atlantic showed that sighting rates of humpback whales were significantly greater during periods of no seismic compared with periods when a full array was operating (Moulton and Holst 2010). In addition, humpback whales were more likely to swim away and less likely to swim towards a vessel during seismic vs. non-seismic periods (Moulton and Holst 2010).

Humpback whales on their summer feeding grounds in southeast Alaska did not exhibit persistent avoidance when exposed to seismic pulses from a 1.64-L (100-in^3) airgun (Malme et al. 1985). Some humpbacks seemed “startled” at received levels of 150–169 dB re 1 μPa. Malme et al. (1985) concluded that there was no clear evidence of avoidance, despite the possibility of subtle effects, at received levels up to 172 re 1 μPa on an approximate rms basis. However, Moulton and Holst (2010) reported that humpback whales monitored during seismic surveys in the Northwest Atlantic had lower sighting rates and were most often seen swimming away from the vessel during seismic periods compared with periods when airguns were silent.

It has been suggested that South Atlantic humpback whales wintering off Brazil may be displaced or even strand upon exposure to seismic surveys (Engel et al. 2004). The evidence for this was circumstantial and subject to alternative explanations (IAGC 2004). Also, the evidence was not consistent with subsequent results from the same area of Brazil (Parente et al. 2006), or with direct studies of humpbacks exposed to seismic surveys in other areas and seasons. After allowance for data from subsequent years, there was "no observable direct correlation" between strandings and seismic surveys (IWC 2007:236).

There are no data on reactions of *right whales* to seismic surveys, but results from the closely-related *bowhead whale* show that their responsiveness can be quite variable depending on their activity (migrating vs. feeding). Bowhead whales migrating west across the Alaskan Beaufort Sea in autumn, in particular, are unusually responsive, with substantial avoidance occurring out to distances of 20–30 km from a medium-sized airgun source at received sound levels of around 120–130 dB re 1 μPa_{rms} [Miller et al. 1999; Richardson et al. 1999; see Appendix B (5) of the EA]. However, more recent research on bowhead whales (Miller et al. 2005; Harris et al. 2007) corroborates earlier evidence that, during the summer feeding season, bowheads are not as sensitive to seismic sources. Nonetheless, subtle but statistically significant changes in surfacing–respiration–dive cycles were evident upon statistical analysis (Richardson et al. 1986). In summer, bowheads typically begin to show avoidance reactions at received levels of about 152–178 dB re 1 μPa_{rms} (Richardson et al. 1986, 1995; Ljungblad et al. 1988; Miller et al. 2005).

Reactions of migrating and feeding (but not wintering) *gray whales* to seismic surveys have been studied. Malme et al. (1986, 1988) studied the responses of feeding eastern Pacific gray whales to pulses from a single 100-in^3 airgun off St. Lawrence Island in the northern Bering Sea. They estimated, based on small sample sizes, that 50% of feeding gray whales stopped feeding at an average received pressure level of 173 dB re 1 μPa on an (approximate) rms basis, and that 10% of feeding whales interrupted feeding at received levels of 163 dB re 1 μPa_{rms}. Those findings were generally consistent with the results of experiments conducted on larger numbers of gray whales that were migrating along the California coast (Malme et al. 1984; Malme and Miles 1985), and western Pacific gray whales feeding off Sakhalin Island, Russia (Würsig et al. 1999; Gailey et al. 2007; Johnson et al. 2007; Yazvenko et al. 2007a,b), along with data on gray whales off British Columbia (Bain and Williams 2006).

Various species of *Balaenoptera* (blue, sei, fin, and minke whales) have occasionally been seen in areas ensonified by airgun pulses (Stone 2003; MacLean and Haley 2004; Stone and Tasker 2006), and calls from blue and fin whales have been localized in areas with airgun operations (e.g., McDonald et al. 1995; Dunn and Hernandez 2009; Castellote et al. 2010). Sightings by observers on seismic vessels off the United Kingdom from 1997 to 2000 suggest that, during times of good sightability, sighting rates for mysticetes (mainly fin and sei whales) were similar when large arrays of airguns were shooting vs. silent (Stone 2003; Stone and Tasker 2006). However, these whales tended to exhibit localized avoidance, remaining significantly further (on average) from the airgun array during seismic operations compared with non-seismic periods (Stone and Tasker 2006). Castellote et al. (2010) reported that singing fin whales in the Mediterranean moved away from an operating airgun array.

Ship-based monitoring studies of baleen whales (including blue, fin, sei, minke, and humpback whales) in the Northwest Atlantic found that overall, this group had lower sighting rates during seismic vs. non-seismic periods (Moulton and Holst 2010). Baleen whales as a group were also seen significantly farther from the vessel during seismic compared with non-seismic periods, and they were more often seen to be swimming away from the operating seismic vessel (Moulton and Holst 2010). Blue and minke whales were initially sighted significantly farther from the vessel during seismic operations compared to non-seismic periods; the same trend was observed for fin whales (Moulton and Holst 2010). Minke whales were most often observed to be swimming away from the vessel when seismic operations were underway (Moulton and Holst 2010).

Data on short-term reactions by cetaceans to impulsive noises are not necessarily indicative of long-term or biologically significant effects. It is not known whether impulsive sounds affect reproductive rate or distribution and habitat use in subsequent days or years. However, gray whales have continued to migrate annually along the west coast of North America with substantial increases in the population over recent years, despite intermittent seismic exploration (and much ship traffic) in that area for decades (Appendix A *in* Malme et al. 1984; Richardson et al. 1995; Allen and Angliss 2010). The western Pacific gray whale population did not seem affected by a seismic survey in its feeding ground during a previous year (Johnson et al. 2007). Similarly, bowhead whales have continued to travel to the eastern Beaufort Sea each summer, and their numbers have increased notably, despite seismic exploration in their summer and autumn range for many years (Richardson et al. 1987; Allen and Angliss 2010).

Toothed Whales.—Little systematic information is available about reactions of toothed whales to noise pulses. Few studies similar to the more extensive baleen whale/seismic pulse work summarized above and (in more detail) in Appendix B of the EA have been reported for toothed whales. However, there are recent systematic studies on sperm whales (e.g., Gordon et al. 2006; Madsen et al. 2006; Winsor and Mate 2006; Jochens et al. 2008; Miller et al. 2009). There is an increasing amount of information about responses of various odontocetes to seismic surveys based on monitoring studies (e.g., Stone 2003; Smultea et al. 2004; Moulton and Miller 2005; Bain and Williams 2006; Holst et al. 2006; Stone and Tasker 2006; Potter et al. 2007; Hauser et al. 2008; Holst and Smultea 2008; Weir 2008; Barkaszi et al. 2009; Richardson et al. 2009; Moulton and Holst 2010).

Seismic operators and marine mammal observers on seismic vessels regularly see dolphins and other small toothed whales near operating airgun arrays, but in general there is a tendency for most delphinids to show some avoidance of operating seismic vessels (e.g., Goold 1996a,b,c; Calambokidis and Osmek 1998; Stone 2003; Moulton and Miller 2005; Holst et al. 2006; Stone and Tasker 2006; Weir 2008; Barkaszi et al. 2009; Richardson et al. 2009; Moulton and Holst 2010). Some dolphins seem to be attracted to the seismic vessel and floats, and some ride the bow wave of the seismic vessel even when large arrays of airguns are firing (e.g., Moulton and Miller 2005). Nonetheless, small toothed whales more often tend to head away, or to maintain a somewhat greater distance from the vessel, when a large array of airguns is operating than when it is silent (e.g., Stone and Tasker 2006; Weir 2008; Barry et al. 2010; Moulton and Holst 2010). In most cases, the avoidance radii for delphinids appear to be small, on the order of 1 km less, and some individuals show no apparent avoidance. The beluga is a species that (at least at times) shows long-distance avoidance of seismic vessels. Aerial surveys conducted in the southeastern Beaufort Sea during summer found that sighting rates of beluga whales were significantly lower at distances 10–20 km compared with 20–30 km from an operating airgun array, and observers on seismic boats in that area rarely see belugas (Miller et al. 2005; Harris et al. 2007).

Captive bottlenose dolphins and beluga whales exhibited changes in behavior when exposed to strong pulsed sounds similar in duration to those typically used in seismic surveys (Finneran et al. 2000, 2002, 2005). However, the animals tolerated high received levels of sound before exhibiting aversive behaviors.

Results for porpoises depend on species. The limited available data suggest that harbor porpoises show stronger avoidance of seismic operations than do Dall's porpoises (Stone 2003; MacLean and Koski 2005; Bain and Williams 2006; Stone and Tasker 2006). Dall's porpoises seem relatively tolerant of airgun operations (MacLean and Koski 2005; Bain and Williams 2006), although they too have been observed to avoid large arrays of operating airguns (Calambokidis and Osmek 1998; Bain and Williams 2006). This apparent difference in responsiveness of these two porpoise species is consistent with their relative responsiveness to boat traffic and some other acoustic sources (Richardson et al. 1995; Southall et al. 2007).

Most studies of sperm whales exposed to airgun sounds indicate that the sperm whale shows considerable tolerance of airgun pulses (e.g., Stone 2003; Stone and Tasker 2006; Weir 2008; Moulton and Holst 2010). In most cases, the whales do not show strong avoidance, and they continue to call (see Appendix B of the EA for review). However, controlled exposure experiments in the Gulf of Mexico indicate that foraging behavior was altered upon exposure to airgun sound (Jochens et al. 2008; Miller et al. 2009; Tyack 2009).

There are almost no specific data on the behavioral reactions of beaked whales to seismic surveys. However, some northern bottlenose whales remained in the general area and continued to produce high-frequency clicks when exposed to sound pulses from distant seismic surveys (Gosselin and Lawson 2004; Laurinolli and Cochrane 2005; Simard et al. 2005). Most beaked whales tend to avoid approaching vessels of other types (e.g., Würsig et al. 1998). They may also dive for an extended period when approached by a vessel (e.g., Kasuya 1986), although it is uncertain how much longer such dives may be as compared to dives by undisturbed beaked whales, which also are often quite long (Baird et al. 2006; Tyack et al. 2006). Based on a single observation, Aguilar-Soto et al. (2006) suggested that foraging efficiency of Cuvier's beaked whales may be reduced by close approach of vessels. In any event, it is likely that most beaked whales would also show strong avoidance of an approaching seismic vessel, although this has not been documented explicitly. In fact, Moulton and Holst (2010) reported 15 sightings of beaked whales during seismic studies in the Northwest Atlantic; seven of those sightings were made at times when at least one airgun was operating. There was little evidence to indicate that beaked whale behavior was affected by airgun operations; sighting rates and distances were similar during seismic and non-seismic periods (Moulton and Holst 2010).

There are increasing indications that some beaked whales tend to strand when naval exercises involving mid-frequency sonar operation are ongoing nearby (e.g., Simmonds and Lopez-Jurado 1991; Frantzis 1998; NOAA and USN 2001; Jepson et al. 2003; Hildebrand 2005; Barlow and Gisiner 2006; see also the "Strandings and Mortality" subsection, later). These strandings are apparently at least in part a disturbance response, although auditory or other injuries or other physiological effects may also be involved. Whether beaked whales would ever react similarly to seismic surveys is unknown (see "Strandings and Mortality", below). Seismic survey sounds are quite different from those of the sonars in operation during the above-cited incidents.

Odontocete reactions to large arrays of airguns are variable and, at least for delphinids and Dall's porpoises, seem to be confined to a smaller radius than has been observed for the more responsive of the mysticetes, belugas, and harbor porpoises (Appendix B of the EA). A ≥170 dB re 1 μPa disturbance criterion (rather than ≥160 dB) is considered appropriate for delphinids, Dall's porpoise, and pinnipeds, which tend to be less responsive than the more responsive cetaceans.

Pinnipeds.—Pinnipeds are not likely to show a strong avoidance reaction to the airgun array. Visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds, and only slight (if any) changes in behavior—see Appendix B (5) of the EA. In the Beaufort Sea, some ringed seals avoided an area of 100 m to (at most) a few hundred meters around seismic vessels, but many seals remained within 100–200 m of the trackline as the operating airgun array passed by (e.g., Harris et al. 2001; Moulton and Lawson 2002; Miller et al. 2005). Ringed seal sightings averaged somewhat farther away from the seismic vessel when the airguns were operating than when they were not, but the difference was small (Moulton and Lawson 2002). Similarly, in Puget Sound, sighting distances for harbor seals and California sea lions tended to be larger when airguns were operating (Calambokidis and Osmek 1998). Previous telemetry work suggests that avoidance and other behavioral reactions may be stronger than evident to date from visual studies (Thompson et al. 1998).

Additional details on the behavioral reactions (or the lack thereof) by all types of marine mammals to seismic vessels can be found in Appendix B (5) of the EA.

Hearing Impairment and Other Physical Effects

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds. TTS has been demonstrated and studied in certain captive odontocetes and pinnipeds exposed to strong sounds (reviewed in Southall et al. 2007). However, there has been no specific documentation of TTS let alone permanent hearing damage, i.e., permanent threshold shift (PTS), in free-ranging marine mammals exposed to sequences of airgun pulses during realistic field conditions. Current NMFS policy regarding exposure of marine mammals to high-level sounds is that cetaceans should not be exposed to impulsive sounds with received levels ≥180 dB re 1 μPa_{rms} (NMFS 2000). This criterion has been used in establishing the exclusion (=shut-down) zones planned for the proposed seismic survey. However, this criterion was established before there was any information about minimum received levels of sounds necessary to cause auditory impairment in marine mammals. As discussed in Appendix B (6) of the EA and summarized here,

- the 180-dB criterion for cetaceans is probably quite precautionary, i.e., lower than necessary to avoid temporary auditory impairment let alone permanent auditory injury, at least for delphinids.
- TTS is not injury and does not constitute "Level A harassment" in U.S. MMPA terminology.
- the minimum sound level necessary to cause permanent hearing impairment ("Level A harassment") is higher, by a variable and generally unknown amount, than the level that induces barely-detectable TTS.
- the level associated with the onset of TTS is often considered to be a level below which there is no danger of permanent damage. The actual PTS threshold is likely to be well above the level causing onset of TTS (Southall et al. 2007).

Recommendations for new science-based noise exposure criteria for marine mammals, frequency-weighting procedures, and related matters have been published (Southall et al. 2007). Those recommendations have not, as of mid 2011, been formally adopted by NMFS for use in regulatory processes and during mitigation programs associated with seismic surveys. However, some aspects of the recommendations have been taken into account in certain environmental impact statements and small-take authorizations. NMFS has indicated that it may issue new noise exposure criteria for marine mammals that account for the now-available scientific data on TTS, the expected offset between the TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive (e.g., M-weighting or generalized frequency weightings for various groups of marine mammals, allowing for their functional bandwidths), and other relevant factors. Preliminary information about possible changes in the regulatory and mitigation requirements, and about the possible structure of new criteria, was given by Wieting (2004) and NMFS (2005).

Several aspects of the planned monitoring and mitigation measures for this project are designed to detect marine mammals occurring near the airgun array, and to avoid exposing them to sound pulses that might, at least in theory, cause hearing impairment (see § XI and § XIII). In addition, many cetaceans and (to a limited degree) sea turtles show some avoidance of the area where received levels of airgun sound are high enough such that hearing impairment could potentially occur. In those cases, the avoidance responses of the animals themselves will reduce or (most likely) avoid any possibility of hearing impairment.

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might (in theory) occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, and other types of organ or tissue damage. It is possible that some marine mammal species (i.e., beaked whales) may be especially susceptible to injury and/or stranding when exposed to strong transient sounds. However, as discussed below, there is no definitive evidence that any of these effects occur even for marine mammals in close proximity to large arrays of airguns. It is unlikely that any effects of these types would occur during the present project given the brief duration of exposure of any given mammal, and the planned monitoring and mitigation measures (see below). The following subsections discuss in somewhat more detail the possibilities of TTS, PTS, and non-auditory physical effects.

Temporary Threshold Shift.—TTS is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter 1985). While experiencing TTS, the hearing threshold rises and a sound must be stronger in order to be heard. At least in terrestrial mammals, TTS can last from minutes or hours to (in cases of strong TTS) days. For sound exposures at or somewhat above the TTS threshold, hearing sensitivity in both terrestrial and marine mammals recovers rapidly after exposure to the noise ends. Few data on sound levels and durations necessary to elicit mild TTS have been obtained for marine mammals, and none of the published data concern TTS elicited by exposure to multiple pulses of sound. Available data on TTS in marine mammals are summarized in Southall et al. (2007).

For toothed whales exposed to single short pulses, the TTS threshold appears to be, to a first approximation, a function of the energy content of the pulse (Finneran et al. 2002, 2005). Based on these data, the received energy level of a single seismic pulse (with no frequency weighting) might need to be ~186 dB re 1 $\mu Pa^2 \cdot s$ (i.e., 186 dB SEL or ~196–201 dB re 1 μPa_{rms}) in order to produce brief, mild TTS[1]. Exposure to several strong seismic pulses that each have received levels near 190 dB re 1 μPa_{rms} might result in cumulative exposure of ~186 dB SEL and thus slight TTS in a small odontocete assuming the TTS threshold is (to a first approximation) a function of the total received pulse energy; however, this 'equal-energy' concept is an oversimplification. The distances from the *Langseth*'s airguns at which the received energy level (per pulse, flat-weighted) would be expected to be ≥190 dB re 1 μPa_{rms} are estimated in Table 1. Levels ≥190 dB re 1 μPa_{rms} are expected to be restricted to radii no more than 770 m (Table 1). For an odontocete closer to the surface, the maximum radius with ≥190 dB re 1 μPa_{rms} would be smaller.

The above TTS information for odontocetes is derived from studies on the bottlenose dolphin and beluga. For the one harbor porpoise tested, the received level of airgun sound that elicited onset of TTS was lower (Lucke et al. 2009). If these results from a single animal are representative, it is inappropriate to assume that onset of TTS occurs at similar received levels in all odontocetes (*cf.* Southall et al. 2007). Some cetaceans apparently can incur TTS at considerably lower sound exposures than are necessary to elicit TTS in the beluga or bottlenose dolphin.

For baleen whales, there are no data, direct or indirect, on levels or properties of sound that are required to induce TTS. The frequencies to which baleen whales are most sensitive are assumed to be lower than those to which odontocetes are most sensitive, and natural background noise levels at those low frequencies tend to be higher. As a result, auditory thresholds of baleen whales within their frequency band of best hearing are believed to be higher (less sensitive) than are those of odontocetes at their best frequencies (Clark and Ellison 2004). From this, it is suspected that received levels causing TTS onset may also be higher in baleen whales (Southall et al. 2007). In any event, no cases of TTS are expected given three considerations: (1) the low abundance of baleen whales in the planned study area at the time of the

[1] If the low frequency components of the watergun sound used in the experiments of Finneran et al. (2002) are downweighted as recommended by Miller et al. (2005) and Southall et al. (2007) using their M_{mf}-weighting curve, the effective exposure level for onset of mild TTS was 183 dB re 1 $\mu Pa^2 \cdot s$ (Southall et al. 2007).

survey; (2) the strong likelihood that baleen whales would avoid the approaching airguns (or vessel) before being exposed to levels high enough for TTS to occur; and (3) the mitigation measures that are planned.

In pinnipeds, TTS thresholds associated with exposure to brief pulses (single or multiple) of underwater sound have not been measured. Initial evidence from more prolonged (non-pulse) exposures suggested that some pinnipeds (harbor seals in particular) incur TTS at somewhat lower received levels than do small odontocetes exposed for similar durations (Kastak et al. 1999, 2005; Ketten et al. 2001). The TTS threshold for pulsed sounds has been indirectly estimated as being an SEL of ~171 dB re 1 $\mu Pa^2 \cdot s$ (Southall et al. 2007), which would be equivalent to a single pulse with received level ~181–186 dB re 1 $\mu Pa_{rms,}$ or a series of pulses for which the highest rms values are a few dB lower. Corresponding values for California sea lions and northern elephant seals are likely to be higher (Kastak et al. 2005).

NMFS (1995, 2000) concluded that cetaceans and pinnipeds should not be exposed to pulsed underwater noise at received levels exceeding, respectively, 180 and 190 dB re 1 μPa_{rms}. Those sound levels are ***not*** considered to be the levels above which TTS might occur. Rather, they were the received levels above which, in the view of a panel of bioacoustics specialists convened by NMFS before TTS measurements for marine mammals started to become available, one could not be certain that there would be no injurious effects, auditory or otherwise, to marine mammals. As summarized above and in Southall et al. (2007), data that are now available imply that TTS is unlikely to occur in most odontocetes (and probably mysticetes as well) unless they are exposed to a sequence of several airgun pulses stronger than 190 dB re 1 μPa_{rms}. For the harbor seal and any species with similarly low TTS thresholds, TTS may occur upon exposure to one or more airgun pulses whose received level equals the NMFS "do not exceed" value of 190 dB re 1 μPa_{rms}. That criterion corresponds to a single-pulse SEL of 175–180 dB re 1 $\mu Pa^2 \cdot s$ in typical conditions, whereas TTS is suspected to be possible (in harbor seals) with a cumulative SEL of ~171 dB re 1 $\mu Pa^2 \cdot s$.

Permanent Threshold Shift.—When PTS occurs, there is physical damage to the sound receptors in the ear. In severe cases, there can be total or partial deafness, whereas in other cases, the animal has an impaired ability to hear sounds in specific frequency ranges (Kryter 1985).

There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal, even with large arrays of airguns. However, given the possibility that mammals close to an airgun array might incur at least mild TTS, there has been further speculation about the possibility that some individuals occurring very close to airguns might incur PTS (e.g., Richardson et al. 1995, p. 372*ff*; Gedamke et al. 2008). Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage, but repeated or (in some cases) single exposures to a level well above that causing TTS onset might elicit PTS.

Relationships between TTS and PTS thresholds have not been studied in marine mammals, but are assumed to be similar to those in humans and other terrestrial mammals. PTS might occur at a received sound level at least several decibels above that inducing mild TTS if the animal were exposed to strong sound pulses with rapid rise time—see Appendix B (6) of the EA. Based on data from terrestrial mammals, a precautionary assumption is that the PTS threshold for impulse sounds (such as airgun pulses as received close to the source) is *at least* 6 dB higher than the TTS threshold on a peak-pressure basis, and probably >6 dB (Southall et al. 2007). On an SEL basis, Southall et al. (2007:441-4) estimated that received levels would need to exceed the TTS threshold by at least 15 dB for there to be risk of PTS. Thus, for cetaceans they estimate that the PTS threshold might be an M-weighted SEL (for the sequence of received pulses) of ~198 dB re 1 $\mu Pa^2 \cdot s$ (15 dB higher than the M_{mf}-weighted TTS threshold, in a beluga, for a watergun impulse), where the SEL value is cumulated over the sequence of pulses. Additional assumptions had to be made to derive a corresponding estimate for pinnipeds, as the only available data on TTS-thresholds in pinnipeds pertain to non-impulse sound. Southall et al. (2007) estimate that the PTS threshold could be a cumulative M_{pw}-weighted SEL of ~186 dB re 1 μ$Pa^2 \cdot s$ in the harbor seal exposed to impulse sound. The PTS threshold for the California sea lion and northern elephant seal would probably be higher, given the higher TTS thresholds in those species.

Southall et al. (2007) also note that, regardless of the SEL, there is concern about the possibility of PTS if a cetacean received one or more pulses with peak pressure exceeding 230 or 218 dB re 1 μPa (peak), respectively. Thus, PTS might be expected upon exposure of cetaceans to *either* SEL ≥198 dB re 1 μ$Pa^2 \cdot s$ *or* peak pressure ≥ 230 dB re 1 μPa. Corresponding proposed dual criteria for pinnipeds (at least harbor seals) are ≥ 186 dB SEL and ≥ 218 dB peak pressure (Southall et al. 2007). These estimates are all first approximations, given the limited underlying data, assumptions, species differences, and evidence that the "equal energy" model may not be entirely correct. A peak pressure of 230 dB re 1 μPa (3.2 bar · m, 0-pk) would only be found within a few meters of the largest (360-in^3) airguns in the planned airgun array (e.g., Caldwell and Dragoset 2000). A peak pressure of 218 dB re 1 μPa could be received somewhat farther away; to estimate that specific distance, one would need to apply a model that accurately calculates peak pressures in the near-field around an array of airguns.

Given the higher level of sound necessary to cause PTS as compared with TTS, it is considerably less likely that PTS would occur. Baleen whales generally avoid the immediate area around operating seismic vessels, as do some other marine mammals and sea turtles. The planned monitoring and mitigation measures, including visual monitoring, passive acoustic monitoring (PAM) to complement visual observations (if practicable), power downs, and shut downs of the airguns when mammals are seen within or approaching the "exclusion zones", will further reduce the probability of exposure of marine mammals to sounds strong enough to induce PTS.

Stranding and Mortality.— Marine mammals close to underwater detonations of high explosives can be killed or severely injured, and the auditory organs are especially susceptible to injury (Ketten et al. 1993; Ketten 1995). However, explosives are no longer used for marine waters for commercial seismic surveys or (with rare exceptions) for seismic research; they have been replaced entirely by airguns or related non-explosive pulse generators. Airgun pulses are less energetic and have slower rise times, and there is no specific evidence that they can cause serious injury, death, or stranding even in the case of large airgun arrays. However, the association of strandings of beaked whales with naval exercises and, in one case, an L-DEO seismic survey (Malakoff 2002; Cox et al. 2006), has raised the possibility that beaked whales exposed to strong "pulsed" sounds may be especially susceptible to injury and/or behavioral reactions that can lead to stranding (e.g., Hildebrand 2005; Southall et al. 2007). Appendix B (6) of the EA provides additional details.

Specific sound-related processes that lead to strandings and mortality are not well documented, but may include (1) swimming in avoidance of a sound into shallow water; (2) a change in behavior (such as a change in diving behavior) that might contribute to tissue damage, gas bubble formation, hypoxia, cardiac arrhythmia, hypertensive hemorrhage or other forms of trauma; (3) a physiological change such as a vestibular response leading to a behavioral change or stress-induced hemorrhagic diathesis, leading in turn to tissue damage; and (4) tissue damage directly from sound exposure, such as through acoustically mediated bubble formation and growth or acoustic resonance of tissues. Some of these mechanisms are unlikely to apply in the case of impulse sounds. However, there are increasing indications that gas-bubble disease (analogous to "the bends"), induced in supersaturated tissue by a behavioral response to acoustic exposure, could be a pathologic mechanism for the strandings and mortality of some deep-diving cetaceans exposed to sonar. However, the evidence for this remains circumstantial and associated with exposure to naval mid-frequency sonar, not seismic surveys (Cox et al. 2006; Southall et al. 2007).

Seismic pulses and mid-frequency sonar signals are quite different, and some mechanisms by which sonar sounds have been hypothesized to affect beaked whales are unlikely to apply to airgun pulses. Sounds produced by airgun arrays are broadband impulses with most of the energy below 1 kHz. Typical military mid-frequency sonars emit non-impulse sounds at frequencies of 2–10 kHz, generally with a relatively narrow bandwidth at any one time. A further difference between seismic surveys and naval exercises is that naval exercises can involve sound sources on more than one vessel. Thus, it is not appropriate to assume that there is a direct connection between the effects of military sonar and seismic surveys on marine mammals. However, evidence that sonar signals can, in special circumstances, lead (at least indirectly) to physical damage and mortality (e.g., Balcomb and Claridge 2001; NOAA and USN 2001; Jepson et al. 2003; Fernández et al. 2004, 2005; Hildebrand 2005; Cox et al. 2006) suggests that caution is warranted when dealing with exposure of marine mammals to any high-intensity pulsed sound.

There is no conclusive evidence of cetacean strandings or deaths at sea as a result of exposure to seismic surveys, but a few cases of strandings in the general area where a seismic survey was ongoing have led to speculation concerning a possible link between seismic surveys and strandings. Suggestions that there was a link between seismic surveys and strandings of humpback whales in Brazil (Engel et al. 2004) were not well founded (IAGC 2004; IWC 2007). In September 2002, there was a stranding of two Cuvier's beaked whales in the Gulf of California, Mexico, when the L-DEO vessel R/V *Maurice Ewing* was operating a 20-airgun, 8490-in^3 airgun array in the general area. The link between the stranding and the seismic surveys was inconclusive and not based on any physical evidence (Hogarth 2002; Yoder 2002). Nonetheless, the Gulf of California incident plus the beaked whale strandings near naval exercises involving use of mid-frequency sonar suggests a need for caution in conducting seismic surveys in areas occupied by beaked whales until more is known about effects of seismic surveys on those species (Hildebrand 2005). No injuries of beaked whales are anticipated during the proposed study because of (1) the high likelihood that any beaked whales nearby would avoid the approaching vessel before being exposed to high sound levels, (2) the proposed monitoring and mitigation measures, and (3) differences between the sound sources operated by L-DEO and those involved in the naval exercises associated with strandings.

***Non-auditory Physiological Effects*.**—Non-auditory physiological effects or injuries that theoretically might occur in marine mammals exposed to strong underwater sound include stress, neurological effects, bubble formation, resonance, and other types of organ or tissue damage (Cox et al. 2006; Southall et al. 2007). Studies examining such effects are limited. However, resonance effects (Gentry 2002) and direct noise-induced bubble formation (Crum et al. 2005) are implausible in the case of exposure to an impulsive broadband source like an airgun array. If seismic surveys disrupt diving patterns of deep-diving species, this might perhaps result in bubble formation and a form of "the bends", as speculated to occur in beaked whales exposed to sonar. However, there is no specific evidence of this upon exposure to airgun pulses.

In general, very little is known about the potential for seismic survey sounds (or other types of strong underwater sounds) to cause non-auditory physical effects in marine mammals. Such effects, if they occur at all, would presumably be limited to short distances and to activities that extend over a prolonged period. The available data do not allow identification of a specific exposure level above which non-auditory effects can be expected (Southall et al. 2007), or any meaningful quantitative predictions of the numbers (if any) of marine mammals that might be affected in those ways. Marine mammals that show behavioral avoidance of seismic vessels, including most baleen whales, some odontocetes, and some pinnipeds are especially unlikely to incur non-auditory physical effects. Also, the planned mitigation measures (§ XI), including shut downs of the airguns, will reduce any such effects that might otherwise occur.

Possible Effects of Multibeam Echosounder Signals

The Kongsberg EM 122 MBES will be operated from the source vessel during the planned study. Information about this equipment was provided in § II. Sounds from the MBES are very short pulses, occurring for 2–15 ms once every 5–20 s, depending on water depth. Most of the energy in the sound emitted by this MBES is at frequencies near 12 kHz, and the maximum source level is 242 dB re 1 $\mu Pa_{rms} \cdot m$. The beam is narrow (1–2º) in fore-aft extent and wide (150º) in the cross-track extent. Each ping consists of eight (in water >1000 m deep) or four (<1000 m deep) successive fan-shaped transmissions (segments) at different cross-track angles. Any given mammal at depth near the trackline would be in the main beam for only one or two of the segments. Also, marine mammals that encounter the Kongsberg EM 122 are unlikely to be subjected to repeated pulses because of the narrow fore–aft width of the beam and will receive only limited amounts of pulse energy because of the short pulses. Animals close to the ship (where the beam is narrowest) are especially unlikely to be ensonified for more than one 2–15 ms pulse (or two pulses if in the overlap area). Similarly, Kremser et al. (2005) noted that the probability of a cetacean swimming through the area of exposure when an MBES emits a pulse is small. The animal would have to pass the transducer at close range and be swimming at speeds similar to the vessel in order to receive the multiple pulses that might result in sufficient exposure to cause TTS.

Navy sonars that have been linked to avoidance reactions and stranding of cetaceans (1) generally have a longer pulse duration than the Kongsberg EM 122, and (2) are often directed close to horizontally vs. more downward for the MBES. The area of possible influence of the MBES is much smaller—a narrow band below the source vessel. The duration of exposure for a given marine mammal can be much longer for a naval sonar. During L-DEO's operations, the individual pulses will be very short, and a given mammal would not receive many of the downward-directed pulses as the vessel passes by. Possible effects of an MBES on marine mammals are outlined below.

Masking

Marine mammal communications will not be masked appreciably by the MBES signals given the low duty cycle of the echosounder and the brief period when an individual mammal is likely to be within its beam. Furthermore, in the case of baleen whales, the MBES signals (12 kHz) do not overlap with the predominant frequencies in the calls, which would avoid any significant masking.

Behavioral Responses

Behavioral reactions of free-ranging marine mammals to sonars, echosounders, and other sound sources appear to vary by species and circumstance. Observed reactions have included silencing and dispersal by sperm whales (Watkins et al. 1985), increased vocalizations and no dispersal by pilot whales (Rendell and Gordon 1999), and the previously-mentioned beachings by beaked whales. During exposure to a 21–25 kHz "whale-finding" sonar with a source level of 215 dB re 1 $\mu Pa \cdot m$, gray whales reacted by orienting slightly away from the source and being deflected from their course by ~200 m (Frankel 2005). When a 38-kHz echosounder and a 150-kHz acoustic Doppler current profiler were transmitting during studies in the ETP, baleen whales showed no significant responses, whereas spotted and spinner dolphins were detected slightly more often and beaked whales less often during visual surveys (Gerrodette and Pettis 2005).

Captive bottlenose dolphins and a white whale exhibited changes in behavior when exposed to 1-s tonal signals at frequencies similar to those that will be emitted by the MBES used by L-DEO, and to shorter broadband pulsed signals. Behavioral changes typically involved what appeared to be deliberate attempts to avoid the sound exposure (Schlundt et al. 2000; Finneran et al. 2002; Finneran and Schlundt 2004). The relevance of those data to free-ranging odontocetes is uncertain, and in any case, the test sounds were quite different in duration as compared with those from an MBES.

Very few data are available on the reactions of pinnipeds to echosounder sounds at frequencies similar to those used during seismic operations. Hastie and Janik (2007) conducted a series of behavioral response tests on two captive gray seals to determine their reactions to underwater operation of a 375-kHz multibeam imaging echosounder that included significant signal components down to 6 kHz. Results indicated that the two seals reacted to the signal by significantly increasing their dive durations. Because of the likely brevity of exposure to the MBES sounds, pinniped reactions are expected to be limited to startle or otherwise brief responses of no lasting consequence to the animals.

Hearing Impairment and Other Physical Effects

Given recent stranding events that have been associated with the operation of naval sonar, there is concern that mid-frequency sonar sounds can cause serious impacts to marine mammals (see above). However, the MBES proposed for use by L-DEO is quite different than sonars used for navy operations. Pulse duration of the MBES is very short relative to the naval sonars. Also, at any given location, an individual marine mammal would be in the beam of the MBES for much less time given the generally downward orientation of the beam and its narrow fore-aft beamwidth; navy sonars often use near-horizontally-directed sound. Those factors would all reduce the sound energy received from the MBES rather drastically relative to that from the sonars used by the navy.

Given the maximum source level of 242 dB re 1 $\mu Pa \cdot m_{rms}$ (see § I), the received level for an animal within the MBES beam 100 m below the ship would be ~202 dB re 1 μPa_{rms}, assuming 40 dB of spreading loss over 100 m (circular spreading). Given the narrow beam, only one pulse is likely to be received by a given animal as the ship passes overhead. The received energy level from a single pulse of duration 15 ms would be about 184 dB re 1 $\mu Pa^2 \cdot s$, i.e., 202 dB + 10 log (0.015 s). That is below the TTS threshold for a cetacean receiving a single non-impulse sound (195 dB re 1 $\mu Pa^2 \cdot s$) and even further below the anticipated PTS threshold (215 dB re 1 $\mu Pa^2 \cdot s$) (Southall et al. 2007). In contrast, an animal that was only 10 m below the MBES when a ping is emitted would be expected to receive a level ~20 dB higher, i.e., 204 dB re 1 $\mu Pa^2 \cdot s$ in the case of the EM 122. That animal might incur some TTS (which would be fully recoverable), but the exposure would still be below the anticipated PTS threshold for cetaceans. As noted by Burkhardt et al. (2007, 2008), cetaceans are very unlikely to incur PTS from operation of scientific sonars on a ship that is underway.

In the harbor seal, the TTS threshold for non-impulse sounds is about 183 dB re 1 $\mu Pa^2 \cdot s$, as compared with ~195 dB re 1 $\mu Pa^2 \cdot s$ in odontocetes (Kastak et al. 2005; Southall et al. 2007). TTS onset occurs at higher received energy levels in the California sea lion and northern elephant seal than in the harbor seal. A harbor seal as much as 100 m below the *Langseth* could receive a single MBES ping with received energy level of ≥184 dB re 1 $\mu Pa^2 \cdot s$ (as calculated in the toothed whale subsection above) and thus could incur slight TTS. Species of pinnipeds with higher TTS thresholds would not incur TTS unless they were closer to the transducers when a ping was emitted. However, the SEL criterion for PTS in pinnipeds (203 dB re 1 $\mu Pa^2 \cdot s$) might be exceeded for a ping received within a few meters of the transducers, although the risk of PTS is higher for certain species (e.g., harbor seal). Given the intermittent nature of the signals and the narrow MBES beam, only a small fraction of the pinnipeds below (and close to) the ship would receive a ping as the ship passed overhead.

Possible Effects of the Sub-bottom Profiler Signals

An SBP will also be operated from the source vessel during the planned study and two SBPs will be operated from the vessel that deploys and retrieves the OBSs. Details about this equipment were provided in § I. Sounds from the SBPs are very short pulses, occurring for up to 64 ms once every second. Most of the energy in the sound pulses emitted by the SBPs is at 3.5 kHz, and the beam is directed downward. The sub-bottom profiler on the *Langseth* has a maximum source level of 222 dB re 1 µPa·m and the SBPs on the *Oceanus* have maximum source level of 211 and 222 dB re 1 µPa·m (see § I). Kremser et al. (2005) noted that the probability of a cetacean swimming through the area of exposure when a bottom profiler emits a pulse is small—even for an SBP more powerful than that on the *Langseth*—if the animal was in the area, it would have to pass the transducer at close range and in order to be subjected to sound levels that could cause TTS.

Masking

Marine mammal communications will not be masked appreciably by the SBP signals given the directionality of the signal and the brief period when an individual mammal is likely to be within its beam. Furthermore, in the case of most baleen whales, the SBP signals do not overlap with the predominant frequencies in the calls, which would avoid significant masking.

Behavioral Responses

Marine mammal behavioral reactions to other pulsed sound sources are discussed above, and responses to the SBP are likely to be similar to those for other pulsed sources if received at the same levels. However, the pulsed signals from the SBP are considerably weaker than those from the MBES. Therefore, behavioral responses are not expected unless marine mammals are very close to the source.

Hearing Impairment and Other Physical Effects

It is unlikely that the SBP produces pulse levels strong enough to cause hearing impairment or other physical injuries even in an animal that is (briefly) in a position near the source. The SBP is usually operated simultaneously with other higher-power acoustic sources. Many marine mammals will move away in response to the approaching higher-power sources or the vessel itself before the mammals would be close enough for there to be any possibility of effects from the less intense sounds from the SBP. In the case of mammals that do not avoid the approaching vessel and its various sound sources, mitigation measures that would be applied to minimize effects of other sources (see § XI) would further reduce or eliminate any minor effects of the SBP.

Possible Effects of Acoustic Release Signals

The acoustic release transponder used to communicate with the OBSs uses frequencies of 9–13 kHz. These signals will be used very intermittently. It is unlikely that the acoustic release signals would have a significant effect on marine mammals or sea turtles through masking, disturbance, or hearing impairment. Any effects likely would be negligible given the brief exposure at presumable low levels.

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

All anticipated takes would be "takes by harassment", involving temporary changes in behavior. The mitigation measures to be applied will minimize the possibility of injurious takes. (However, as noted earlier, there is no specific information demonstrating that injurious "takes" would occur even in the absence of the planned mitigation measures.) In the sections below, we describe methods to estimate the number of potential exposures to various received sound levels and present estimates of the numbers of marine mammals that could be affected during the proposed seismic program. The estimates are based on a consideration of the number of marine mammals that could be disturbed appreciably by operations with the 36-airgun array to be used during ~3050 km of seismic surveys in the northeast Pacific Ocean. The sources of distributional and numerical data used in deriving the estimates are described in the next subsection.

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

Basis for Estimating "Take by Harassment"

Extensive systematic aircraft- and ship-based surveys have been conducted for marine mammals offshore from Oregon and Washington (e.g., Bonnell et al. 1992; Green et al. 1992, 1993; Barlow 1997, 2003; Barlow and Taylor 2001; Calambokidis and Barlow 2004; Barlow and Forney 2007; Barlow 2010). The most comprehensive and recent density data available for cetacean species in slope and offshore waters of Oregon are from the 1991, 1993, 1996, 2001, 2005, and 2007 NMFS/SWFSC ship surveys as synthesized by Barlow and Forney (2007) and Barlow (2010). The surveys were conducted up to ~555 km offshore from June or July to November or December.

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

Oceanographic conditions, including occasional El Niño and La Niña events, influence the distribution and numbers of marine mammals present in the North Pacific Ocean, including waters off Oregon and Washington, resulting in considerable year-to-year variation in the distribution and abundance of many marine mammal species (Forney and Barlow 1998; Buchanan et al. 2001; Escorza-Treviño 2002; Ferrero et al. 2002; Philbrick et al. 2003). Thus, cetacean densities used here were derived from the pooled results of the 1991–2008 surveys (abundances and survey area given for Oregon–Washington in Barlow 2010) with the exception of the gray whale and the harbor porpoise. (Abundance and density were not estimated for gray whales or harbor porpoises in the NMFS/SWFSC surveys because their inshore habitats were inadequately covered in those studies.) Gray whale density is from DoN (2010), based on the abundance of gray whales that remain between Oregon and B.C. in summer and the area out to 43 km from shore. Harbor porpoise densities were calculated using the population estimate for the Northern Oregon/Washington Coast stock (which occupies most of the proposed survey areas) and the range for that stock given in Carretta et al. (2011a).

Table 3 gives the densities for each species of cetacean reported off Oregon and Washington. The densities from NMFS/SWFSC vessel-based surveys have been corrected for both trackline detection probability and availability bias by the authors. Trackline detection probability bias is associated with diminishing sightability with increasing lateral distance from the trackline [$f(0)$]. Availability bias refers to the fact that there is less-than-100% probability of sighting an animal that is present along the survey trackline, and it is measured by $g(0)$.

Table 3 also includes mean density information for 4 of the 5 pinniped species that occur off Oregon and Washington using the methods and calculations in DoN (2010) and population sizes that were updated based on Allen and Angliss (2011) and Carretta et al. (2011a). For the other species, the harbor seal, densities were calculated using the population estimate for the Oregon/Washington Coastal Stock and the range for that stock given in Carretta et al. (2011a).

The estimated numbers of individuals potentially exposed are based on the 160-dB re 1 μPa_{rms} criterion for all cetaceans and pinnipeds. It is assumed that marine mammals exposed to airgun sounds that strong might change their behavior sufficiently to be considered "taken by harassment".

TABLE 3. Densities of marine mammals off Oregon and Washington. Cetacean densities are from Barlow (2010) and are based on ship transect surveys conducted up to 555 km offshore in 1991, 1993, 1996, 2001, 2005, and 2007. Pinniped densities are from shore counts and calculations in DoN (2010). Cetacean densities from Barlow (2010) are corrected for *f*(0) and *g*(0). Species listed as "Endangered" under the ESA are in italics.

Species	Density (#/1000 km2)	Source[1]
Mysticetes		
North Pacific right whale	*0*	–
Gray whale	3.21	DoN (2010)
Humpback whale	*0.81*	*Barlow (2010)*
Minke whale	0.46	Barlow (2010)
Sei whale	*0.16*	*Barlow (2010)*
Fin whale	*1.29*	*Barlow (2010)*
Blue whale	*0.18*	*Barlow (2010)*
Odontocetes		
Sperm whale	*1.02*	*Barlow (2010)*
Pygmy/dwarf sperm whale	0.71	Barlow (2010)
Cuvier’s beaked whale	0.43	Barlow (2010)
Baird's beaked whale	1.18	Barlow (2010)
Mesoplodont (unidentified)[2]	1.75	Barlow (2010)
Bottlenose dolphin	0	–
Striped dolphin	0.04	Barlow (2010)
Short-beaked common dolphin	10.28	Barlow (2010)
Pacific white-sided dolphin	34.91	Barlow (2010)
Northern right-whale dolphin	12.88	Barlow (2010)
Risso’s dolphin	11.19	Barlow (2010)
False killer whale	0	–
Killer whale	1.66	Barlow (2010)
Short-finned pilot whale	0	–
Harbor porpoise	632.4	See text
Dall's porpoise	83.82	Barlow (2010)
Pinnipeds		
Northern fur seal	83.62	DoN (2010)[3]
California sea lion	0	DoN (2010)[3]
Steller sea lion	13.12	DoN (2010)[3]
Harbor seal	292.3	See text
Northern elephant seal	45.81	DoN (2010)[3]

[1] Where no source is given, the species was not included in Barlow (2010) and no takes are anticipated or requested..
[2] Includes Blainville's, Stejneger's, and Hubb's beaked whale.
[3] Population sizes in DoN (2010) were updated based on Allen and Angliss (2011) and Carretta et al. (2001)

It should be noted that the following estimates of exposures to various sound levels assume that the surveys will be fully completed; in fact, the ensonified areas calculated using the planned number of line-kilometers ***have been increased by 25%*** to accommodate turns, lines that may need to be repeated equipment testing, etc. As is typical during ship surveys, inclement weather and equipment malfunctions are likely to cause delays and may limit the number of useful line-kilometers of seismic operations that can be undertaken. Furthermore, any marine mammal sightings within or near the designated exclusion zone will result in the shut down of seismic operations as a mitigation measure. Thus, the following estimates of the numbers of marine mammals potentially exposed to 160-dB re 1 μPa_{rms} sounds are precautionary, and probably overestimate the actual numbers of marine mammals that might be involved. These estimates assume that there will be no weather, equipment, or mitigation delays, which is highly unlikely.

Furthermore, as summarized in § VII, above, and Appendix B (5) of the EA, delphinids and pinnipeds seem to be less responsive to airgun sounds than are some mysticetes. The 160-dB (rms) criterion currently applied by NMFS, on which the following estimates are based, was developed based primarily on data from gray and bowhead whales. A 170-dB re 1 μPa disturbance criterion (rather than 160 dB) is considered appropriate for delphinids (and pinnipeds), which tend to be less responsive than the more responsive cetaceans. The estimates of "takes by harassment" of delphinids and pinnipeds given below are thus considered precautionary.

Potential Number of Marine Mammals Exposed to ≥160 dB

The number of different individuals that could be exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} on one or more occasions can be estimated by considering the expected density of animals in the area along with the total marine area that would be within the 160-dB radius around the operating airgun array on at least one occasion. The number of possible exposures (including repeated exposures of the same individuals) can be estimated by considering the total marine area that would be within the 160-dB radius around the operating airguns, including areas of overlap. During the proposed survey, the transect lines are closely spaced. Thus, the area including overlap is 1.7 x the area excluding overlap, so a marine mammal that stayed in the survey area during the entire survey could be exposed ~2 times, on average. However, it is unlikely that a particular animal would stay in the area during the entire survey.

The numbers of different individuals potentially exposed to ≥160 dB re 1 μPa_{rms} were calculated by multiplying the expected species density, times the anticipated area to be ensonified to that level during airgun operations excluding overlap.

The area expected to be ensonified was determined by entering the planned survey lines (including contingency lines) into a MapInfo GIS, using the GIS to identify the relevant areas by "drawing" the applicable 160-dB buffer (see Table 1) around each seismic line, and then calculating the total area within the buffers. Areas of overlap were included only once when estimating the number of individuals exposed.

Applying the approach described above, ~18,471 km^2 (~23,089 km^2 including the 25% contingency) would be within the 160-dB isopleth during the survey. Because this approach does not allow for turnover in the mammal populations in the proposed survey area during the course of the survey, the actual number of individuals exposed could be underestimated. However, the approach assumes that no cetaceans will move away from or toward the trackline as the *Langseth* approaches in response to increasing sound levels prior to the time the levels reach 160 dB, which will result in overestimates for those species known to avoid seismic vessels (see § VII, above).

Table 4 shows estimates of the number of different individual marine mammals that potentially could be exposed to ≥160 dB re 1 μPa_{rms} during the seismic survey if no animals moved away from the survey vessel. The ***Requested Take Authorization*** is given in the far right column of Table 4. For non-listed cetacean species, the ***Requested Take Authorization*** has been increased to the mean group size off Washington and Oregon (Barlow and Forney 2007) for the particular species in cases where the calculated number of individuals exposed was between 1 and the mean group size.

TABLE 4. Estimates of the possible numbers of different individuals that could be exposed during L-DEO's proposed seismic survey in the northeastern Pacific in June–July 2012. The proposed sound source consists of an 36-airgun array with a total discharge volume of 6600 in^3. Received levels of seismic sounds are expressed in dB re 1 μPa (rms, averaged over pulse duration), consistent with NMFS' practice. Not all marine mammals will change their behavior when exposed to these sound levels, but some may alter their behavior when levels are lower (see text). Species in italics are listed under the ESA as endangered or threatened. The column of numbers in boldface shows the numbers of "takes" for which authorization is requested.

Species	Number[1]	% Regional Pop'n[2]	Requested Take Authorization
Mysticetes			
North Pacific right whale	*0*	*0*	***0***
Gray whale[3]	10	0	**10**
Humpback whale	*19*	*0.09*	***19***
Minke whale	11	0.12	**11**
Sei whale	*4*	*0.03*	***4***
Fin whale	*30*	*0.18*	***30***
Blue whale	*4*	*0.17*	***4***
Odontocetes			
Sperm whale	*24*	*0.10*	***24***
Pygmy/Dwarf sperm whale	16	NA	**16**
Cuvier's beaked whale	10	0.46	**10**
Baird's beaked whale	27	3.00	**27**
Mesoplodon spp.[4]	40	3.95	**40**
Bottlenose dolphin	0	0	**0**
Striped dolphin	1	0.01	**2**[5]
Short-beaked common dolphin	237	0.06	**238**[5]
Pacific white-sided dolphin	806	2.99	**806**
Northern right-whale dolphin	297	3.57	**297**
Risso's dolphin	258	4.12	**258**
False killer whale	0	0	**0**
Killer whale	38	1.55	**38**
Short-finned pilot whale	0	0	**0**
Harbor porpoise[3]	2153	4.12	**2153**
Dall's porpoise	1935	4.61	**1935**
Pinnipeds			
Northern fur seal	1931	0.30	**1931**
California sea lion	0	0	**0**
Steller sea lion	*303*	*0.46*	***303***
Harbor seal[3]	995	4.02	**995**
Northern elephant seal	1058	0.85	**1058**

NA – not available.
[1] Estimates are based on densities from Table 3 and an ensonified area (including 25% contingency) of 23,089 km^2.
[2] Regional population size estimates are from Table 2.
[3] Estimates based on densities from Table 3 and an ensonified area in water depths <100 m (including 25% contingency) of 3404 km^2.
[4] Includes Blainville's, Stejneger's, and Hubb's beaked whales.
[5] Requested Take Authorization increased to mean group size for cetaceans (see text).

Number of Cetaceans that could be Exposed to ≥160 dB.—The estimate of the number of individual cetaceans that could be exposed to seismic sounds with received levels ≥160 dB re 1 μPa_{rms} during the proposed survey is 5920 (Table 4). That total includes 81 cetaceans listed as ***Endangered***

under the ESA, including 30 fin whales (0.18% of the regional population), 24 sperm whales (0.10%), 19 humpback whales (0.09%), 4 blue whales (0.17%), and 4 sei whales (0.03%).

In addition, 77 beaked whales (10 Cuvier's beaked whale, 27 Baird's beaked whale, and 40 *Mesoplodon* spp.) could be exposed during the survey (Table 4). Many (36.4%) of the cetaceans potentially exposed are harbor porpoises. Most (59.7%) of the cetaceans potentially exposed are delphinids (including Dall's porpoise): Dall's porpoise, the Pacific white-sided dolphin, and the northern right whale dolphin are estimated to be the most common delphinid species in the area, with estimates of 1935 (4.61% of the regional population), 806 (2.99%), and 297 (3.57%) exposed to ≥160 dB re 1 μPa_{rms}, respectively. As noted above, a more meaningful estimate for delphinids would be for sound levels ≥170 dB.

Number of Pinnipeds that could be Exposed to ≥160 dB.— The estimate of the number of individual pinnipeds that could be exposed to seismic sounds with received levels ≥160 dB re 1 μPa_{rms} during the proposed survey is 4287 (Table 4), including 303 ***Threatened*** Steller sea lions (0.46% of the regional population). The harbor seal and northern fur seal are estimated to be the most common pinniped species in the area, with estimates of 995 (4.02% of the regional population) and 1931 (0.30%) exposed to ≥160 dB re 1 μPa_{rms}, respectively. As noted above, a more meaningful estimate for most pinnipeds would be for sound levels ≥170 dB.

Conclusions

The proposed seismic survey will involve towing an airgun array that introduces pulsed sounds into the ocean, along with simultaneous operation of an MBES and SBP. The survey will employ a 36-airgun array similar to the airgun arrays used for typical high-energy seismic surveys. The total airgun discharge volume is ~6600 in^3. Routine vessel operations, other than the proposed airgun operations, are conventionally assumed not to affect marine mammals sufficiently to constitute "taking". No "taking" of marine mammals is expected in association with echosounder operations given the considerations discussed in § I, i.e., sounds are beamed downward, the beam is narrow, and the pulses are extremely short.

Cetaceans.—Several species of mysticetes show strong avoidance reactions to seismic vessels at ranges up to 6–8 km and occasionally as far as 20–30 km from the source vessel when medium-large airgun arrays have been used. However, reactions at the longer distances appear to be atypical of most species and situations. If mysticetes are encountered, the numbers estimated to occur within the 160-dB isopleth in the survey area are expected to be relatively low.

Odontocete reactions to seismic pulses, or at least the reactions of delphinids and Dall's porpoise, are expected to extend to lesser distances than are those of mysticetes. Odontocete low-frequency hearing is less sensitive than that of mysticetes, and dolphins are often seen from seismic vessels. In fact, there are documented instances of dolphins approaching active seismic vessels. However, delphinids (along with other cetaceans) sometimes show avoidance responses and/or other changes in behavior when near operating seismic vessels.

Taking into account the mitigation measures that are planned (see § XI), effects on cetaceans are generally expected to be limited to avoidance of the area around the seismic operation and short-term changes in behavior, falling within the MMPA definition of "Level B harassment".

Estimates of the numbers of marine mammals that might be exposed to airgun sounds ≥160 dB re 1 μPa_{rms} during the proposed program have been presented with a corresponding requested "take authorization" for each species. Those figures likely overestimate the actual number of animals that will be exposed to and will react to the seismic sounds. The reasons for that conclusion are outlined above.

The relatively short-term exposures are unlikely to result in any long-term negative consequences for the individuals or their populations.

The many cases of apparent tolerance by cetaceans of seismic exploration, vessel traffic, and some other human activities show that co-existence is possible. Mitigation measures such as look outs, ramp ups, and power downs or shut downs when marine mammals are seen within defined ranges should further reduce short-term reactions, and avoid or minimize any effects on hearing sensitivity. In all cases, the effects are expected to be short-term, with no lasting biological consequence.

Pinnipeds.— Four of the five pinniped species discussed in § III are likely to occur in the proposed survey areas. The California sea lion would be at or near its rookeries in California and Baha California during the proposed surveys, which coincide with its mating season. Estimates of 1931 northern fur seals, 303 Steller sea lions, 995 harbor seals, and 1058 northern elephant seals could be exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} during the three surveys. As for cetaceans, the estimated numbers of pinnipeds that could be exposed to received levels ≥160 dB are probably overestimates of the actual numbers that will be affected significantly.

VIII. ANTICIPATED IMPACT ON SUBSISTENCE

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

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

IX. ANTICIPATED IMPACT ON HABITAT

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

The proposed seismic survey will not result in any permanent impact on habitats used by marine mammals or to the food sources they use. The main impact issue associated with the proposed activity will be temporarily elevated noise levels and the associated direct effects on marine mammals, as discussed in § VII, above. The following sections briefly review effects of airguns on fish and invertebrates, and more details are included in Appendices D and E of the EA, respectively.

Effects on Fish

One reason for the adoption of airguns as the standard energy source for marine seismic surveys is that, unlike explosives, they have not been associated with large-scale fish kills. However, existing information on the impacts of seismic surveys on marine fish populations is limited (see Appendix D of the EA). There are three types of potential effects of exposure to seismic surveys: (1) pathological, (2) physiological, and (3) behavioral. Pathological effects involve lethal and temporary or permanent sub-lethal injury. Physiological effects involve temporary and permanent primary and secondary stress responses, such as changes in levels of enzymes and proteins. Behavioral effects refer to temporary and (if they occur) permanent changes in exhibited behavior (e.g., startle and avoidance behavior). The three categories are interrelated in complex ways. For example, it is possible that certain physiological and behavioral changes could potentially lead to an ultimate pathological effect on individuals (i.e., mortality).

The specific received sound levels at which permanent adverse effects to fish potentially could occur are little studied and largely unknown. Furthermore, the available information on the impacts of seismic surveys on marine fish is from studies of individuals or portions of a population; there have been no studies at the population scale. The studies of individual fish have often been on caged fish that were exposed to airgun pulses in situations not representative of an actual seismic survey. Thus, available information provides limited insight on possible real-world effects at the ocean or population scale. This makes drawing conclusions about impacts on fish problematic because, ultimately, the most important issues concern effects on marine fish populations, their viability, and their availability to fisheries.

Hastings and Popper (2005), Popper (2009), and Popper and Hastings (2009a,b) provided recent critical reviews of the known effects of sound on fish. The following sections provide a general synopsis of the available information on the effects of exposure to seismic and other anthropogenic sound as relevant to fish. The information comprises results from scientific studies of varying degrees of rigor plus some anecdotal information. Some of the data sources may have serious shortcomings in methods, analysis, interpretation, and reproducibility that must be considered when interpreting their results (see Hastings and Popper 2005). Potential adverse effects of the program's sound sources on marine fish are then noted.

Pathological Effects

The potential for pathological damage to hearing structures in fish depends on the energy level of the received sound and the physiology and hearing capability of the species in question (see Appendix D of the EA). For a given sound to result in hearing loss, the sound must exceed, by some substantial amount, the hearing threshold of the fish for that sound (Popper 2005). The consequences of temporary or permanent hearing loss in individual fish on a fish population are unknown; however, they likely depend on the number of individuals affected and whether critical behaviors involving sound (e.g., predator avoidance, prey capture, orientation and navigation, reproduction, etc.) are adversely affected.

Little is known about the mechanisms and characteristics of damage to fish that may be inflicted by exposure to seismic survey sounds. Few data have been presented in the peer-reviewed scientific literature. As far as we know, there are only two papers with proper experimental methods, controls, and careful pathological investigation implicating sounds produced by actual seismic survey airguns in causing adverse anatomical effects. One such study indicated anatomical damage, and the second indicated TTS in fish hearing. The anatomical case is McCauley et al. (2003), who found that exposure to airgun sound caused observable anatomical damage to the auditory maculae of "pink snapper" (*Pagrus auratus*). This damage in the ears had not been repaired in fish sacrificed and examined almost two months after exposure. On the other hand, Popper et al. (2005) documented only TTS (as determined by auditory brainstem response) in two of three fish species from the Mackenzie River Delta. This study found that broad whitefish (*Coregonus nasus*) that received a sound exposure level of 177 dB re 1 $\mu Pa^2 \cdot s$ showed no hearing loss. During both studies, the repetitive exposure to sound was greater than would have occurred during a typical seismic survey. However, the substantial low-frequency energy produced by the airguns [less than ~400 Hz in the study by McCauley et al. (2003) and less than ~200 Hz in Popper et al. (2005)] likely did not propagate to the fish because the water in the study areas was very shallow (~9 m in the former case and <2 m in the latter). Water depth sets a lower limit on the lowest sound frequency that will propagate (the "cutoff frequency") at about one-quarter wavelength (Urick 1983; Rogers and Cox 1988).

Wardle et al. (2001) suggested that in water, acute injury and death of organisms exposed to seismic energy depends primarily on two features of the sound source: (1) the received peak pressure and (2) the time required for the pressure to rise and decay. Generally, as received pressure increases, the period for the pressure to rise and decay decreases, and the chance of acute pathological effects increases. According to Buchanan et al. (2004), for the types of seismic airguns and arrays involved with the proposed program, the pathological (mortality) zone for fish would be expected to be within a few meters of the seismic source. Numerous other studies provide examples of no fish mortality upon exposure to seismic sources (Falk and Lawrence 1973; Holliday et al. 1987; La Bella et al. 1996; Santulli et al. 1999; McCauley et al. 2000a,b, 2003; Bjarti 2002; Thomsen 2002; Hassel et al. 2003; Popper et al. 2005; Boeger et al. 2006).

Some studies have reported, some equivocally, that mortality of fish, fish eggs, or larvae can occur close to seismic sources (Kostyuchenko 1973; Dalen and Knutsen 1986; Booman et al. 1996; Dalen et al. 1996). Some of the reports claimed seismic effects from treatments quite different from actual seismic survey sounds or even reasonable surrogates. However, Payne et al. (2009) reported no statistical differences in mortality/morbidity between control and exposed groups of capelin eggs or monkfish larvae. Saetre and Ona (1996) applied a 'worst-case scenario' mathematical model to investigate the effects of seismic energy on fish eggs and larvae. They concluded that mortality rates caused by exposure to seismic surveys are so low, as compared to natural mortality rates, that the impact of seismic surveying on recruitment to a fish stock must be regarded as insignificant.

Physiological Effects

Physiological effects refer to cellular and/or biochemical responses of fish to acoustic stress. Such stress potentially could affect fish populations by increasing mortality or reducing reproductive success. Primary and secondary stress responses of fish after exposure to seismic survey sound appear to be temporary in all studies done to date (Sverdrup et al. 1994; Santulli et al. 1999; McCauley et al. 2000a,b). The periods necessary for the biochemical changes to return to normal are variable and depend on numerous aspects of the biology of the species and of the sound stimulus (see Appendix D of the EA).

Behavioral Effects

Behavioral effects include changes in the distribution, migration, mating, and catchability of fish populations. Studies investigating the possible effects of sound (including seismic survey sound) on fish behavior have been conducted on both uncaged and caged individuals (e.g., Chapman and Hawkins 1969; Pearson et al. 1992; Santulli et al. 1999; Wardle et al. 2001; Hassel et al. 2003). Typically, in these studies fish exhibited a sharp "startle" response at the onset of a sound followed by habituation and a return to normal behavior after the sound ceased.

There is general concern about potential adverse effects of seismic operations on fisheries, namely a potential reduction in the "catchability" of fish involved in fisheries. Although reduced catch rates have been observed in some marine fisheries during seismic testing, in a number of cases the findings are confounded by other sources of disturbance (Dalen and Raknes 1985; Dalen and Knutsen 1986; Løkkeborg 1991; Skalski et al. 1992; Engås et al. 1996). In other airgun experiments, there was no change in catch per unit effort (CPUE) of fish when airgun pulses were emitted, particularly in the immediate vicinity of the seismic survey (Pickett et al. 1994; La Bella et al. 1996). For some species, reductions in catch may have resulted from a change in behavior of the fish, e.g., a change in vertical or horizontal distribution, as reported in Slotte et al. (2004).

In general, any adverse effects on fish behavior or fisheries attributable to seismic testing may depend on the species in question and the nature of the fishery (season, duration, fishing method). They may also depend on the age of the fish, its motivational state, its size, and numerous other factors that are difficult, if not impossible, to quantify at this point, given such limited data on effects of airguns on fish, particularly under realistic at-sea conditions.

Effects on Invertebrates

The existing body of information on the impacts of seismic survey sound on marine invertebrates is very limited. However, there is some unpublished and very limited evidence of the potential for adverse effects on invertebrates, thereby justifying further discussion and analysis of this issue. The three types of potential effects of exposure to seismic surveys on marine invertebrates are pathological, physiological, and behavioral. Based on the physical structure of their sensory organs, marine invertebrates appear to be specialized to respond to particle displacement components of an impinging sound field and not to the pressure component (Popper et al. 2001; see also Appendix E of the EA).

The only information available on the impacts of seismic surveys on marine invertebrates involves studies of individuals; there have been no studies at the population scale. Thus, available information provides limited insight on possible real-world effects at the regional or ocean scale. The most important aspect of potential impacts concerns how exposure to seismic survey sound ultimately affects invertebrate populations and their viability, including availability to fisheries.

Literature reviews of the effects of seismic and other underwater sound on invertebrates were provided by Moriyasu et al. (2004) and Payne et al. (2008). The following sections provide a synopsis of available information on the effects of exposure to seismic survey sound on species of decapod crustaceans and cephalopods, the two taxonomic groups of invertebrates on which most such studies have been conducted. The available information is from studies with variable degrees of scientific soundness and from anecdotal information. A more detailed review of the literature on the effects of seismic survey sound on invertebrates is provided in Appendix E of the EA.

Pathological Effects

In water, lethal and sub-lethal injury to organisms exposed to seismic survey sound appears to depend on at least two features of the sound source: (1) the received peak pressure, and (2) the time required for the pressure to rise and decay. Generally, as received pressure increases, the period for the pressure to rise and decay decreases, and the chance of acute pathological effects increases. For the type of airgun array planned for the proposed program, the pathological (mortality) zone for crustaceans and cephalopods is expected to be within a few meters of the seismic source, at most; however, very few specific data are available on levels of seismic signals that might damage these animals. This premise is based on the peak pressure and rise/decay time characteristics of seismic airgun arrays currently in use around the world.

Some studies have suggested that seismic survey sound has a limited pathological impact on early developmental stages of crustaceans (Pearson et al. 1994; Christian et al. 2003; DFO 2004). However, the impacts appear to be either temporary or insignificant compared to what occurs under natural conditions. Controlled field experiments on adult crustaceans (Christian et al. 2003, 2004; DFO 2004) and adult cephalopods (McCauley et al. 2000a,b) exposed to seismic survey sound have not resulted in any significant pathological impacts on the animals. It has been suggested that giant squid strandings were caused by exposure to commercial seismic survey activities (Guerra et al. 2004), but there was little evidence to support the claim. André et al. (2011) exposed cephalopods, primarily cuttlefish, to continuous 50–400 Hz sinusoidal wave sweeps for two hours while captive in relatively small tanks, and reported morphological and ultrastructural evidence of massive acoustic trauma (i.e., permanent and substantial alterations of statocyst sensory hair cells). The received SPL was reported as 157±5 dB re 1µPa, with peak levels at 175 dB re 1µPa. As in the McCauley et al. (2003) paper on sensory hair cell damage in pink snapper as a result of exposure to seismic sound, the cephalopods were subjected to higher sound levels than they would be under natural conditions, and they were unable to swim away from the sound source.

Physiological Effects

Physiological effects refer mainly to biochemical responses by marine invertebrates to acoustic stress. Such stress potentially could affect invertebrate populations by increasing mortality or reducing reproductive success. Primary and secondary stress responses (i.e., changes in haemolymph levels of enzymes, proteins, etc.) of crustaceans have been noted several days or months after exposure to seismic survey sounds (Payne et al. 2007). The periods necessary for these biochemical changes to return to normal are variable and depend on numerous aspects of the biology of the species and of the sound stimulus.

Behavioral Effects

There is increasing interest in assessing the possible direct and indirect effects of seismic and other sounds on invertebrate behavior, particularly in relation to the consequences for fisheries. Changes in behavior could potentially affect such aspects as reproductive success, distribution, susceptibility to predation, and catchability by fisheries. Studies investigating the possible behavioral effects of exposure to seismic survey sound on crustaceans and cephalopods have been conducted on both uncaged and caged animals. In some cases, invertebrates exhibited startle responses (e.g., squid in McCauley et al. 2000a,b). In other cases, no behavioral impacts were noted (e.g., crustaceans in Christian et al. 2003, 2004; DFO 2004). There have been anecdotal reports of reduced catch rates of shrimp shortly after exposure to seismic surveys; however, other studies have not observed any significant changes in shrimp catch rate (Andriguetto-Filho et al. 2005). Similarly, Parry and Gason (2006) did not find any evidence that lobster catch rates were affected by seismic surveys. Any adverse effects on crustacean and cephalopod behavior or fisheries attributable to seismic survey sound depend on the species in question and the nature of the fishery (season, duration, fishing method).

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

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

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

The proposed activity is not expected to have any habitat-related effects that could cause significant or long-term consequences for individual marine mammals or their populations, because operations will be limited in duration.

XI. MITIGATION MEASURES

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

Marine mammals and sea turtles are known to occur in the proposed study area. To minimize the likelihood that impacts will occur to the species and stocks, airgun operations will be conducted in accordance with the MMPA and the ESA, including obtaining permission for incidental harassment or incidental 'take' of marine mammals and other endangered species. The proposed activities will take place in International Waters and in the EEZs of the U.S. and Canada.

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

Planning Phase

The PIs worked with L-DEO and NSF to identify potential time periods to carry out the survey taking into consideration key factors such as environmental conditions (i.e., the seasonal presence of marine mammals, sea turtles, and seabirds), weather conditions, equipment, and optimal timing for other proposed seismic surveys using the R/V *Langseth*. Most marine mammal species are expected to occur in the area year-round, so altering the timing of the proposed project likely would result in no net benefits for those species. After considering what energy source level was necessary to achieve the research goals, the PIs determined the use of the 36-airgun array with a total volume of ~6600 in^3 would be required. Given the research goals, this energy source level was viewed appropriate.

Proposed Exclusion Zones

Received sound levels have been predicted by L-DEO's model, in relation to distance and direction from the airguns, for the 36-airgun array and for a single 1900LL 40-in^3 airgun, which will be used during power downs. Results have been reported for propagation measurements of pulses from the 36-airgun array in two water depths (~1600 m and 50 m) in the Gulf of Mexico in 2007–2008 (Tolstoy et al. 2009). Results of the propagation measurements showed that radii around the airguns for various received levels varied with water depth (Tolstoy et al. 2009). As results for measurements in intermediate-depth water are still under analysis, values halfway between the deep and shallow-water measurements were used. In addition, propagation varies with array tow depth. The empirical values that resulted from Tolstoy et al. (2009) are used here to determine exclusion zones for the 36-airgun array. However, the depth of the array was different in the Gulf of Mexico calibration study (6 m) than in the proposed surveys (9, 12, and 15 m); thus, correction factors have been applied to the distances reported by Tolstoy et al. (2009). The correction factors used were the ratios of the 160-, 180-, and 190-dB distances from the modeled results for the 6600-in^3 airgun array towed at 6 m vs. 9 and 12 m, from LGL (2009): 1.285, 1.338, and 1.364, respectively for 9 m; and 1.467, 1.577, and 1.545, respectively for 12 m.

Using the corrected measurements (array) or model (single airgun), Table 1 shows the distances at which three rms sound levels are expected to be received from the 36-airgun array and a single airgun. The 180- and 190-dB re 1 μPa_{rms} distances are the safety criteria as specified by NMFS (2000) and are applicable to cetaceans and pinnipeds, respectively. The 180-dB distance will also be used as the exclusion zone for sea turtles, as required by NMFS in most other recent seismic projects (e.g., Smultea et al. 2004; Holst et al. 2005b; Holst and Beland 2008; Holst and Smultea 2008; Hauser et al. 2008; Holst 2009; Antochiw et al. n.d.). If marine mammals or sea turtles are detected within or about to enter the appropriate exclusion zone, the airguns will be powered down (or shut down if necessary) immediately (see below).

Detailed recommendations for new science-based noise exposure criteria were published in early 2008 (Southall et al. 2007). L-DEO will be prepared to revise its procedures for estimating numbers of mammals "taken", EZs, etc., as may be required by any new guidelines that result. As yet, NMFS has not specified a new procedure for determining EZs.

Mitigation During Operations

Mitigation measures that will be adopted during the proposed survey include (1) power-down procedures, (2) shut-down procedures, and (3) ramp-up procedures.

Power-down Procedures

A power down involves decreasing the number of airguns in use such that the radius of the 180-dB (or 190-dB) zone is decreased to the extent that marine mammals or turtles are no longer in or about to enter the EZ. A power down of the airgun array will also occur when the vessel is turning from one seismic line to another. During a power down, one airgun will be operated. The continued operation of one airgun is intended to alert marine mammals and turtles to the presence of the seismic vessel in the area. In contrast, a shut down occurs when all airgun activity is suspended.

If a marine mammal or turtle is detected outside the EZ but is likely to enter the EZ, the airguns will be powered down before the animal is within the EZ. Likewise, if a mammal or turtle is already within the EZ when first detected, the airguns will be powered down immediately. During a power down of the airgun array, the 40-in^3 airgun will be operated. If a marine mammal or turtle is detected within or near the smaller EZ around that single airgun (Table 1), it will be shut down (see next subsection).

Following a power down, airgun activity will not resume until the marine mammal or turtle has cleared the safety zone. The animal will be considered to have cleared the safety zone if

- it is visually observed to have left the EZ, or
- it has not been seen within the zone for 15 min in the case of small odontocetes (or pinnipeds), or
- it has not been seen within the zone for 30 min in the case of mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, and beaked whales, or
- the vessel has moved outside the EZ for turtles, e.g., if a turtle is sighted close to the vessel and the ship speed is 7.4 km/h, it would take the vessel ~8 min to leave the turtle behind.

During airgun operations following a shut down whose duration has exceeded the time limits specified above, the airgun array will be ramped up gradually. Ramp-up procedures are described below. During past R/V *Langseth* marine geophysical surveys, following an extended power-down period, the seismic source followed ramp-up procedures to return to the full seismic source level. Under a power-down scenario, however, a single mitigation airgun still would be operating to alert and warn animals of the on-going activity. Furthermore, under these circumstances, ramp-up procedures may unnecessarily extend the length of the survey time needed to collect seismic data. LDEO and NSF have discussed this mitigation practice and have concluded that a ramp-up procedure following an extended power down is not necessary and are currently consulting with NMFS on the issue. This assessment therefore does not include this practice as part of the monitoring and mitigation plan.

Shut-down Procedures

The operating airgun(s) will be shut down if a marine mammal or turtle is seen within or approaching the EZ for the single airgun. Shut downs will be implemented (1) if an animal enters the EZ of the single airgun after a power down has been initiated, or (2) if an animal is initially seen within the EZ of the single airgun when more than one airgun (typically the full array) is operating. Airgun activity will not resume until the marine mammal or turtle has cleared the safety zone, or until the PSO is confident that the animal has left the vicinity of the vessel. Criteria for judging that the animal has cleared the safety zone will be as described in the preceding subsection.

Ramp-up Procedures

A ramp-up procedure will be followed when the airgun array begins operating after a specified period without airgun operations or when a power down has exceeded that period. It is proposed that, for the present survey, this period would be ~8 min. This period is based on the 180-dB radius for the 36-airgun array (940 m) in relation to the average planned speed of the *Langseth* while shooting (7.4 km/h). Similar periods (~8–10 min) were used during previous L-DEO surveys. Ramp up will not occur if a marine mammal or sea turtle has not cleared the safety zone as described earlier.

Ramp up will begin with the smallest airgun in the array (40 in^3). Airguns will be added in a sequence such that the source level of the array will increase in steps not exceeding 6 dB per 5-min period over a total duration of ~35 min. During ramp up, the PSOs will monitor the EZ, and if marine mammals or turtles are sighted, a power down or shut down will be implemented as though the full array were operational.

If the complete EZ has not been visible for at least 30 min prior to the start of operations in either daylight or nighttime, ramp up will not commence unless at least one airgun (40 in^3 or similar) has been operating during the interruption of seismic survey operations. Given these provisions, it is likely that the airgun array will not be ramped up from a complete shut down at night or in thick fog, because the outer part of the safety zone for that array will not be visible during those conditions. If one airgun has operated during a power-down period, ramp up to full power will be permissible at night or in poor visibility, on the assumption that marine mammals and turtles will be alerted to the approaching seismic vessel by the sounds from the single airgun and could move away. Ramp up of the airguns will not be initiated if a sea turtle or marine mammal is sighted within or near the applicable EZs during the day or night.

As noted above under "Power-down Procedures", during past R/V *Langseth* marine geophysical surveys, following an extended power-down period, the seismic source followed ramp-up procedures to return to the full seismic source level. Under a power-down scenario, however, a single mitigation airgun still would be operating to alert and warn animals of the on-going activity. Furthermore, under these circumstances, ramp-up procedures may unnecessarily extend the length of the survey time needed to collect seismic data. LDEO and NSF have discussed this mitigation practice and have concluded that a ramp-up procedure following an extended power down is not necessary, and are currently consulting with NMFS on the issue. This assessment therefore does not include this practice as part of the monitoring and mitigation plan.

XII. PLAN OF COOPERATION

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

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

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

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

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

Not applicable. The proposed activity will take place in the northeast Pacific Ocean, and no activities will take place in or near a traditional Arctic subsistence hunting area.

XIII. MONITORING AND REPORTING PLAN

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

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

L-DEO's proposed Monitoring Plan is described below. L-DEO understands that this Monitoring Plan will be subject to review by NMFS, and that refinements may be required.

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

Vessel-based Visual Monitoring

PSO observations will take place during daytime airgun operations and nighttime start ups of the airguns. Airgun operations will be suspended when marine mammals or turtles are observed within, or about to enter, designated exclusion zones [see § XI above] where there is concern about potential effects on hearing or other physical effects. PSOs will also watch for marine mammals and turtles near the seismic vessel for at least 30 min prior to the planned start of airgun operations. Observations will also be made during daytime periods when the *Langseth* is underway without seismic operations, such as during transits.

During seismic operations, at least four visual PSOs will be based aboard the *Langseth*. PSOs will be appointed by L-DEO with NMFS concurrence. During the majority of seismic operations, two PSOs will monitor for marine mammals and sea turtles around the seismic vessel. Use of two simultaneous observers will increase the effectiveness of detecting animals around the source vessel. However, during meal times, only one PSO may be on duty. PSO(s) will be on duty in shifts of duration no longer than 4 h. Other crew will also be instructed to assist in detecting marine mammals and turtles and implementing mitigation requirements (if practical). Before the start of the seismic survey, the crew will be given additional instruction regarding how to do so.

The *Langseth* is a suitable platform for marine mammal and turtle observations. When stationed on the observation platform, the eye level will be ~21.5 m above sea level, and the observer will have a good view around the entire vessel. During daytime, the PSO(s) will scan the area around the vessel systematically with reticle binoculars (e.g., 7×50 Fujinon), Big-eye binoculars (25×150), and with the naked eye. During darkness, night vision devices (NVDs) will be available (ITT F500 Series Generation 3 binocular-image intensifier or equivalent), when required. Laser rangefinding binoculars (Leica LRF 1200 laser rangefinder or equivalent) will be available to assist with distance estimation. Those are useful in training observers to estimate distances visually, but are generally not useful in measuring distances to animals directly; that is done primarily with the reticles in the binoculars.

Passive Acoustic Monitoring

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

The PAM system consists of hardware (i.e., hydrophones) and software. The "wet end" of the system consists of a towed hydrophone array that is connected to the vessel by a tow cable. The tow cable is 250 m long, and the hydrophones are fitted in the last 10 m of cable. A depth gauge is attached to the free end of the cable, and the cable is typically towed at depths <20 m. The array will be deployed from a winch located on the back deck. A deck cable will connect the tow cable to the electronics unit in the main computer lab where the acoustic station, signal conditioning, and processing system will be located. The acoustic signals received by the hydrophones are amplified, digitized, and then processed by the Pamguard software. The system can detect marine mammal vocalizations at frequencies up to 250 kHz.

One acoustic PSO or PSAO (in addition to the 4 visual PSOs) will be on board. The towed hydrophones will ideally be monitored 24 h per day while at the seismic survey area during airgun operations, and during most periods when the *Langseth* is underway while the airguns are not operating. However, PAM may not be possible if damage occurs to the array or back-up systems during operations. One PSO will monitor the acoustic detection system at any one time, by listening to the signals from two channels via headphones and/or speakers and watching the real-time spectrographic display for frequency ranges produced by cetaceans. The PSAO monitoring the acoustical data will be on shift for 1–6 h at a time. All observers are expected to rotate through the PAM position, although the most experienced with acoustics will be on PAM duty more frequently.

When a vocalization is detected while visual observations are in progress, the PSAO will contact the visual PSO immediately, to alert him/her to the presence of cetaceans (if they have not already been seen), and to allow a power down or shut down to be initiated, if required. The information regarding the call will be entered into a database. The data to be entered include an acoustic encounter identification number, whether it was linked with a visual sighting, date, time when first and last heard and whenever any additional information was recorded, position and water depth when first detected, bearing if determinable, species or species group (e.g., unidentified dolphin, sperm whale), types and nature of sounds heard (e.g., clicks, continuous, sporadic, whistles, creaks, burst pulses, strength of signal, etc.), and any other notable information. The acoustic detection can also be recorded for further analysis.

PSO Data and Documentation

PSOs will record data to estimate the numbers of marine mammals and turtles exposed to various received sound levels and to document apparent disturbance reactions or lack thereof. Data will be used to estimate numbers of animals potentially 'taken' by harassment (as defined in the MMPA). They will also provide information needed to order a power down or shut down of the airguns when a marine mammal or sea turtle is within or near the EZ.

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

1. Species, group size, age/size/sex categories (if determinable), behavior when first sighted and after initial sighting, heading (if consistent), bearing and distance from seismic vessel, sighting

cue, apparent reaction to the airguns or vessel (e.g., none, avoidance, approach, paralleling, etc.), and behavioral pace.

2. Time, location, heading, speed, activity of the vessel, sea state, visibility, and sun glare.

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

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

Results from the vessel-based observations will provide

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

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

XIV. Coordinating Research to Reduce and Evaluate Incidental Take

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

L-DEO and NSF will coordinate the planned marine mammal monitoring program associated with the seismic survey with other parties that may have interest in this area. L-DEO and NSF will coordinate with applicable U.S. agencies (e.g., NMFS), and will comply with their requirements. Actions of this type that are underway include (but are not limited to) the following:

- contact Army Corps of Engineers (ACE), to confirm that no permits will be required by ACE for the proposed survey;
- consult with Olympic Coast National Marine Sanctuary; and
- coordinate with Fisheries an Oceans Canada (DFO) concerning the survey lines in Canadian waters, and will comply with their requirements

XV. LITERATURE CITED

Marine Mammals and Acoustics

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Request by Lamont-Doherty Earth Observatory for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during a Marine Geophysical Survey by the R/V *Marcus G. Langseth* off Washington and Oregon Northeast Pacific Ocean, July 2012

submitted by

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

to

National Marine Fisheries Service
Office of Protected Resources
1315 East–West Hwy, Silver Spring, MD 20910-3282

Application Prepared by

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

26 January 2012

LGL Report TA8118-3

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Request by Lamont-Doherty Earth Observatory for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during a Marine Geophysical Survey by the R/V *Marcus G. Langseth* off Washington and Oregon, Northeast Pacific Ocean, July 2012

SUMMARY

Lamont-Doherty Earth Observatory (L-DEO), with research funding from the National Science Foundation (NSF), plans to conduct a marine seismic survey in the northeastern Pacific Ocean off the coasts of Washington and Oregon in July 2012. The seismic surveys will take place in the Exclusive Economic Zone of the U.S., in water depths ~50–1000 m. The airgun array will consist of 36 airguns with a total volume of ~6600 in^3. L-DEO requests that it be issued an Incidental Harassment Authorization (IHA) allowing non-lethal takes of marine mammals incidental to the planned seismic survey. This request is submitted pursuant to Section 101 (a)(5)(D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371 (a) (5).

Numerous species of cetaceans and pinnipeds inhabit the proposed survey area in the northeast Pacific. Several of these species or stocks are listed as ***endangered*** or ***threatened*** under the U.S. ESA, including the North Pacific right, humpback, sei, fin, blue, sperm, and killer whales, and the Steller sea lion. ESA-listed sea turtle species that could occur in the survey area include the ***endangered*** leatherback turtles, and the ***threatened*** green, loggerhead, and olive ridley turtles. Listed seabirds that could be encountered in the area include the ***endangered*** short-tailed albatross and the ***threatened*** marbled murrelet and western snowy plover.

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

I. OPERATIONS TO BE CONDUCTED

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

Overview of the Activity

L-DEO plans to conduct a seismic survey in the northeast Pacific Ocean off the coasts of Washington and Oregon. ~43.5–47°N and ~124–125°W (Fig. 1). Water depths in the survey area are ~50–1000 m. The project is scheduled to occur ~5–8 July 2012. Some minor deviation from these dates is possible, depending on logistics and weather.

L-DEO plans to use conventional seismic methodology over the Cascadia thrust zone, which will provide information on complex buried structures in this region that appear to affect the frictional behavior of the plate boundary megathrust fault. A better image of the structure in this region, which coincides with apparent north-south changes in the frequency of occurrence of very large earthquakes and

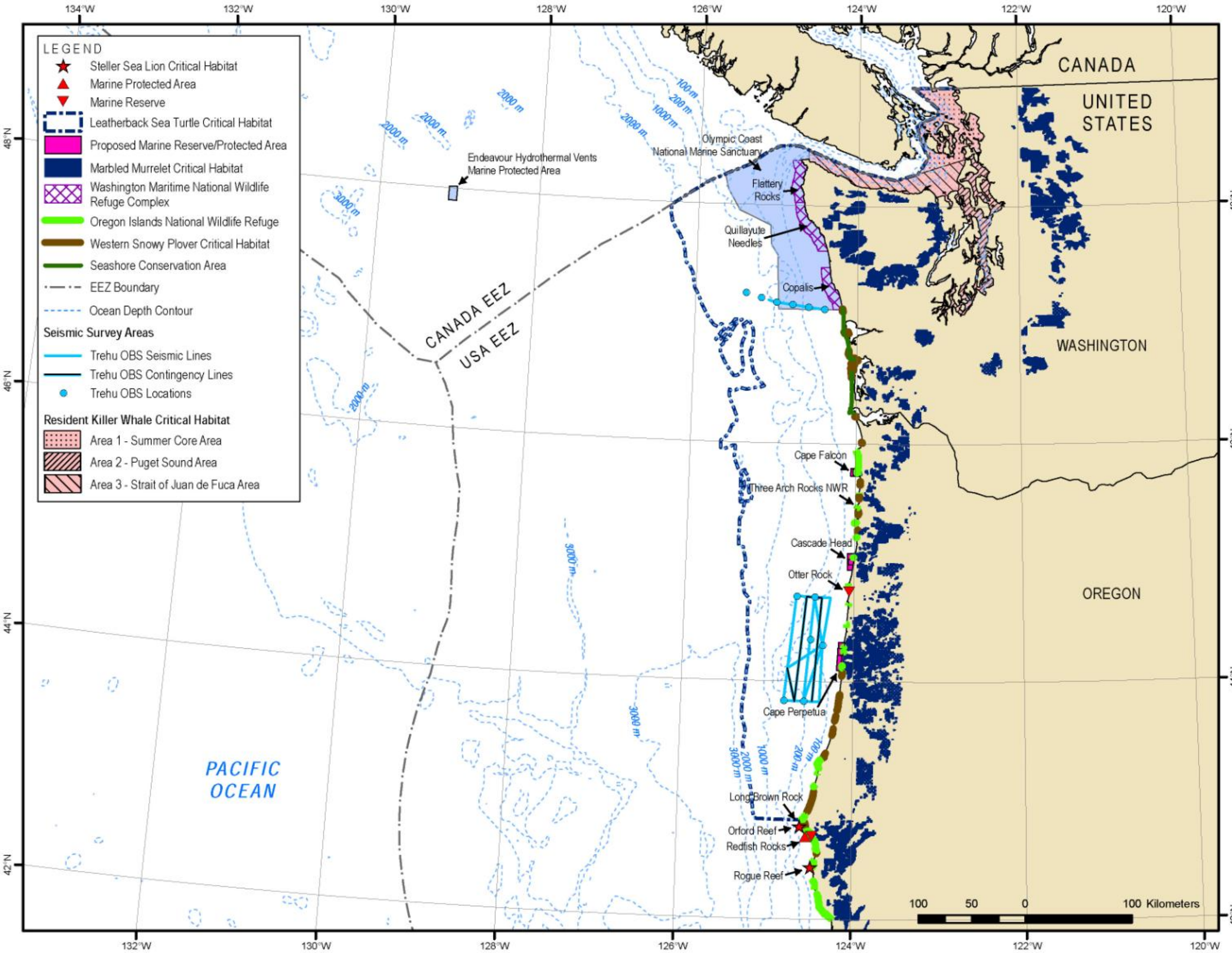

FIGURE 1. Proposed survey area for the seismic survey in the northeastern Pacific Ocean planned for 5–8 July 2012 with OBS instrument placements and seismic tracklines. EEZ = exclusive economic zone.

in contemporary patterns of strain accumulation, will provide background information for generating improved earthquake hazards analyses and a better understanding of the processes that control megathrust earthquake characteristics.

The survey will involve one source vessel, the R/V *Marcus G. Langseth*. The *Langseth* will deploy a 36-airgun array as an energy source. The receiving system will consist of ocean bottom seismometers (OBSs) and 48 onshore seismometers (33 in Oregon and 15 in Washington). As the airgun array is towed along the survey lines, the OBSs record the returning acoustic signals internally for later analysis.

The survey will take place along an onshore-offshore line off Washington and a grid of lines off Oregon (Fig. 1). Additional lines will be shot off Oregon if time permits (Fig. 1). The seismic lines are over water depths of ~50–1000 m. Total survey effort including contingency lines will consist of 5 km in depths >1000 m, 501 km in depths 100–1000 m and 287 km in water depths <100 m. The northern and southern survey areas are 15–70 and 15–50 km from shore, respectively.

In addition to the operations of the airgun array, a multibeam echosounder (MBES) and a sub-bottom profiler (SBP) will also be operated from the *Langseth* continuously throughout the cruise. All planned geophysical data acquisition activities will be conducted by L-DEO with on-board assistance by the scientists who have proposed the study. The Principal Investigators (PIs) are Drs. A.M. Trehu (Oregon State University) and G. Abers and H. Carton (L-DEO). The vessel will be self-contained, and the crew will live aboard the vessel for the entire cruise.

Source Vessel Specifications

The R/V *Marcus G. Langseth* will be used as the source vessel. The *Langseth* will tow the 36-airgun array along predetermined lines (Fig. 1). The *Langseth* has a length of 71.5 m, a beam of 17.0 m, and a maximum draft of 5.9 m. The *Langseth* was designed as a seismic research vessel, with a propulsion system designed to be as quiet as possible to avoid interference with the seismic signals. The ship is powered by two Bergen BRG-6 diesel engines, each producing 3550 hp, which drive the two propellers directly. Each propeller has four blades, and the shaft typically rotates at 600 or 750 revolutions per minute (rpm). The vessel also has an 800 hp bowthruster, which is not used during seismic acquisition. The operation speed during seismic acquisition is typically 7.4–9.3 km/h. When not towing seismic survey gear, the *Langseth* typically cruises at 18.5 km/h. The *Langseth* has a range of 25,000 km.

The *Langseth* will also serve as the platform from which vessel-based protected species observers (PSOs) will watch for marine mammals and sea turtles before and during airgun operations, as described in § XIII, below.

Other details of the *Langseth* include the following:

Owner:	National Science Foundation
Operator:	Lamont-Doherty Earth Observatory of Columbia University
Flag:	United States of America
Date Built:	1991 (Refitted in 2006)
Gross Tonnage:	3834
Accommodation Capacity:	55 including ~35 scientists

OBS Description and Deployment

For the study, 6 OBSs will be deployed along the northern line and another 6 will be deployed in the southern grid (Fig. 1). WHOI "D2" OBSs will be used. This type of OBS has a height of ~1 m and a maximum diameter of 50 cm. The anchor is made of hot-rolled steel and weighs 23 kg. The anchor dimensions are 2.5×30.5×38.1 cm.

Once an OBS is ready to be retrieved, an acoustic release transponder interrogates the instrument at a frequency of 9–11 kHz, and a response is received at a frequency of 9–13 kHz. The burn-wire release assembly is then activated, and the instrument is released from the anchor to float to the surface.

OBS deployment and retrieval will be carried out by the R/V *Oceanus*. The *Oceanus* will return to port at Astoria between deployments and retrievals. The *Oceanus* has a length of 54 m, a beam of 10 m, and a maximum draft of 5.3 m. The ship is powered by a single 3000-hp EMD diesel engine driving a single, controllable-pitch screw through a clutch and reduction gear, and an electric, 350-hp trainable bow thruster. The *Oceanus* cruises at 20.4 km/h (11 knots) and has a maximum speed of 26 km/h (14 knots). It has a normal operating range of ~13,300 km.

Other details of the *Oceanus* include the following:

Owner:	National Science Foundation
Operator:	Oregon State University (previously by Woods Hole Oceanographic Institution)
Flag:	United States of America
Date Built:	1975 (overhauled in 1994)
Gross Tonnage:	261
Accommodation Capacity:	12 crew plus 15 scientists

Airgun Description

During the survey, the airgun array to be used will consist of 36 airguns, with a total volume of ~6600 in^3. The airgun array will consist of a mixture of Bolt 1500LL and Bolt 1900LLX airguns. The airguns will be configured as four identical linear arrays or “strings” (Fig. 2). Each string will have ten airguns; the first and last airguns in the strings are spaced 16 m apart. Nine airguns in each string will be fired simultaneously, whereas the tenth is kept in reserve as a spare, to be turned on in case of failure of another airgun. The four airgun strings will be towed ~100 m behind the *Langseth* and will distributed across an area of ~24×16 m. The shot interval will be ~100 m or ~40 s. The firing pressure of the array is 1900 psi. During firing, a brief (~0.1 s) pulse of sound is emitted. The airguns will be silent during the intervening periods.

The tow depth of the array will be 12 m. Because the actual source is a distributed sound source (36 airguns) rather than a single point source, the highest sound levels measurable at any location in the water will be less than the nominal source level. In addition, the effective source level for sound propagating in near-horizontal directions will be substantially lower than the nominal source level applicable to downward propagation because of the directional nature of the sound from the airgun array.

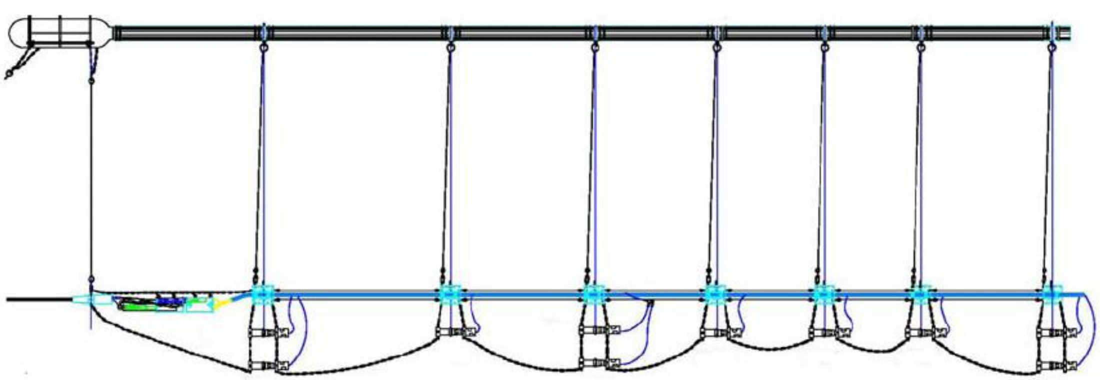

FIGURE 2. One linear airgun array or string with ten airguns, nine of which would be operating.

<u>36-Airgun Array Specifications</u>

Energy Source	Thirty-six 1900 psi Bolt airguns of 40–360 in^3, in four strings each containing nine operating airguns
Source output (downward)	0-pk is 84 bar-m (259 dB re 1 μPa · m); pk-pk is 177 bar · m (265 dB)
Air discharge volume	~6600 in^3
Dominant frequency components	2–188 Hz

Acoustic Measurements

Received sound levels have been predicted by L-DEO's model, in relation to distance and direction from the airguns, for the 36-airgun array and for a single 1900LL 40-in^3 airgun, which will be used during power downs. Results were reported for propagation measurements of pulses from the 36-airgun array in two water depths (~1600 m and 50 m) in the Gulf of Mexico in 2007–2008 (Tolstoy et al. 2009). However, measurements were not reported for a single airgun, although the sound levels in deep water have been modeled (Fig. 3). A detailed description of the modeling effort is provided in Appendix A of the Environmental Assessment (EA).

The predicted sound contours for the 40-in^3 mitigation airgun are shown in Figure 3 as sound exposure levels (SEL) in decibels (dB) re 1 $\mu Pa^2 \cdot s$. SEL is a measure of the received energy in the pulse and represents the sound pressure level (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 (see Appendix B of the EA). The advantage of working with SEL is that the SEL measure accounts for the total received energy in the pulse, and biological effects of pulsed sounds are believed to depend mainly on pulse energy (Southall et al. 2007). In contrast, SPL for a given pulse depends greatly on pulse duration. A pulse with a given SEL can be long or short depending on the extent to which propagation effects have "stretched" the pulse duration. The SPL will be low if the duration is long and higher if the duration is short, even though the pulse energy (and presumably the biological effects) are the same.

Although SEL is now believed to be a better measure than SPL when dealing with biological effects of pulsed sound, SPL is the measure that has been most commonly used in studies of marine mammal reactions to airgun sounds and in NMFS guidelines concerning levels above which "taking" might occur. SPL is often referred to as rms or "root mean square" pressure, averaged over the pulse duration. As noted above, the rms received levels that are used as impact criteria for marine mammals are not directly comparable to pulse energy (SEL). At the distances where rms levels are 160–190 dB re 1 μPa, the difference between the SEL and SPL values for the same pulse measured at the same location usually average ~10–15 dB, depending on the propagation characteristics of the location (Greene 1997; McCauley et al. 1998, 2000a; Appendix B of the EA). In this IHA Application, we assume that rms pressure levels of received seismic pulses will be 10 dB higher than the SEL values predicted by L-DEO's model. Thus, we assume that 170 dB SEL ≈ 180 dB re 1 μPa_{rms}. It should be noted that neither the SEL nor the SPL (=rms) measure is directly comparable to the peak or peak-to-peak pressure levels normally used by geophysicists to characterize source levels of airguns. Peak and peak-to-peak pressure levels for airgun pulses are always higher than the rms dB referred to in much of the biological literature (Greene 1997; McCauley et al. 1998, 2000a). For example, a measured received level of 160 dB re 1 μPa_{rms} in the far field typically would correspond to a peak measurement of ~170–172 dB re 1 μPa, and to a peak-to-peak measurement of ~176–178 dB re 1 μPa, as measured for the same pulse received at the same location (Greene 1997; McCauley et al. 1998, 2000a). (The SEL value for the same pulse would

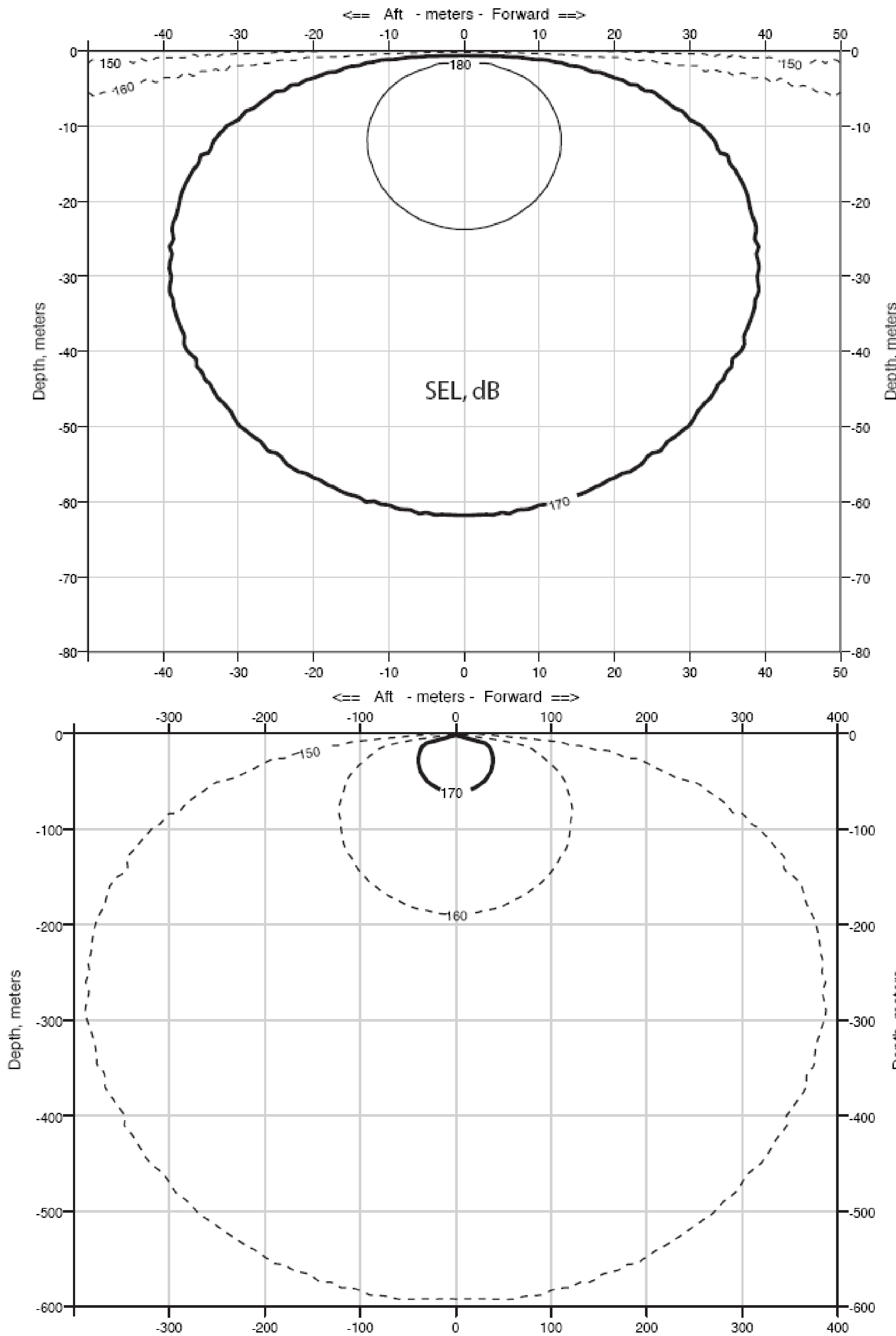

FIGURE 3. Modeled received sound levels (SELs) from a single 40-in^3 airgun operating in deep water, which is planned for use during the survey in the northeast Pacific during July 2012. Received rms levels (SPLs) are expected to be ~10 dB higher.

normally be 145–150 dB re 1 μPa$^2 \cdot$s). The precise difference between rms and peak or peak-to-peak values for a given pulse 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 and (for an airgun-type source at the ranges relevant here) higher than the SEL value.

Predicted Sound Levels

Results of the propagation measurements showed that radii around the airguns for various received levels varied with water depth (Tolstoy et al. 2009). In addition, propagation varies with array tow depth. The empirical values that resulted from Tolstoy et al. (2009) are used here to determine exclusion zones for the 36-airgun array. However, the depth of the array was different in the Gulf of Mexico calibration study (6 m) than in the proposed survey (12 m); thus, correction factors have been applied to the distances reported by Tolstoy et al. (2009). The correction factors used were the ratios of the 160-, 180-, and 190-dB distances from the modeled results for the 6600-in^3 airgun array towed at 6 m vs. 12 m, from LGL (2009): 1.467, 1.577, and 1.545, respectively.

Using the corrected empirical measurements (array) or model (single airgun), Table 1 shows the distances at which three rms sound levels are expected to be received from the 36-airgun array and a single airgun. The 180- and 190-dB re 1 μPa_{rms} distances are the safety criteria as specified by NMFS (2000) and are applicable to cetaceans and pinnipeds, respectively. The 180-dB distance will also be used as the exclusion zone for sea turtles, as required by NMFS in most other recent seismic projects (e.g., Smultea et al. 2004; Holst et al. 2005a,b; Holst and Beland 2008; Holst and Smultea 2008; Hauser et al. 2008; Holst 2009; Antochiw et al. n.d.). If marine mammals or sea turtles are detected within or about to enter the appropriate exclusion zone, the airguns will be powered down (or shut down if necessary) immediately.

Southall et al. (2007) made detailed recommendations for new science-based noise exposure criteria. L-DEO will be prepared to revise its procedures for estimating numbers of mammals "taken", exclusion zones, etc., as may be required by any new guidelines established by NMFS as a result of these recommendations. However, currently the procedures are based on best practices noted by Pierson et al. (1998) and Weir and Dolman (2007), as NMFS has not yet specified a new procedure for determining exclusion zones.

TABLE 1. Measured (array) or predicted (single airgun) distances to which sound levels ≥190, 180, and 160 dB re 1 μPa_{rms} are expected to be received during the proposed survey in the northeastern Pacific Ocean, 5–8 July 2012. Radii for the array are based on empirical data in Tolstoy at al. (2009), corrected for tow depth using model results, and predicted radii for a single airgun are based on L-DEO's model, assuming that received levels on an RMS basis are, numerically, 10 dB higher than the SEL values shown in Figure 3.

Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted RMS Radii (m)		
			190 dB	180 dB	160 dB
Single Bolt airgun 40 in^3	6–12[1]	>1000 m	12	40	385
		100–1000 m	18	60	578
		<100	150	296	1050
4 strings 36 airguns 6600 in^3	12	>1000 m	460	1100	4400
		100–1000 m	615	1810	13,935
		<100	770	2520	23,470

[1] The tow depth has minimal effect on the maximum near-field output and the shape of the frequency spectrum for the single airgun.

Description of Operations

The source vessel, the R/V *Marcus G. Langseth*, will deploy an array of 36 airguns as an energy source at a tow depth of 12 m. The receiving system will consist of ocean bottom seismometers (OBSs) and shore-based seismometers. As the airgun array is towed along the survey lines, the OBSs and shore-based seismometers record the returning acoustic signals internally for later analysis. For the study, 6 OBSs will be deployed along the northern line and another 6 will be deployed in the southern grid (Fig. 1). OBS deployment and retrieval will be carried out by the R/V *Oceanus*. The *Oceanus* will return to port at Astoria between deployments and retrievals.

The survey will take place along an onshore-offshore line off Washington and a grid of lines off Oregon (Fig. 1). Additional lines will be shot off Oregon if time permits (Fig. 1). The seismic lines are over water depths of ~50–1000 m. Total survey effort including contingency lines will consist of 5 km in depths >1000 m, 501 km in depths 100–1000 m and 287 km in water depths <100 m. There will be additional seismic operations in the survey area associated with turns, airgun testing, and repeat coverage of any areas where initial data quality is sub-standard. In our calculations (see § VI), 25% has been added for those additional operations. In addition to the operations of the airgun array, a Kongsberg EM 122 multibeam echosounder (MBES) and a Knudsen Chirp 3260 sub-bottom profiler (SBP) will also be operated from the *Langseth* continuously throughout the cruise. The *Oceanus* will operate a Knudsen Chirp 3260 SBP and/or a Knudsen 320B/R SBP while deploying and retrieving OBSs; *Oceanus* does not have an MBES.

Multibeam Echosounder and Sub-bottom Profiler

The Kongsberg EM 122 MBES operates at 10.5–13 (usually 12) kHz and is hull-mounted on the *Langseth*. The transmitting beamwidth is 1 or 2° fore–aft and 150° athwartship. The maximum source level is 242 dB re 1 μPa · m_{rms}. Each "ping" consists of eight (in water >1000 m deep) or four (<1000 m) successive fan-shaped transmissions, each ensonifying a sector that extends 1° fore–aft. Continuous-wave (CW) pulses increase from 2 to 15 ms long in water depths up to 2600 m, and FM chirp pulses up to 100 ms long are used in water >2600 m. The successive transmissions span an overall cross-track angular extent of about 150°, with 2-ms gaps between the pulses for successive sectors.

The Knudsen Chirp 3260 SBP is normally operated by the *Langseth* to provide information about the sedimentary features and the bottom topography that is being mapped simultaneously by the MBES. The SBP is capable of reaching depths of 10,000 m. The beam is transmitted as a 27º cone, which is directed downward by a 3.5-kHz transducer in the hull of the *Langseth*. The nominal power output is 10 kW, but the actual maximum radiated power is 3 kW or 222 dB re 1 μPa · m. The ping duration is up to 64 ms, and the ping interval is 1 s. A common mode of operation is to broadcast five pulses at 1-s intervals followed by a 5-s pause.

The Knudsen 320B/R SBP is a dual-frequency transceiver designed to operate at 3.5 and/or 12 kHz. The energy from the SBP is directed downward via a 3.5-kHz transducer array mounted in the hull of the R/V *Oceanus*. The maximum power output of the 320B/R is 10 kilowatts for the 3.5-kHz section and 2 kilowatts for the 12-kHz section. The pulse length for the 3.5-kHz section of the 320B/R is 0.8–24 ms, controlled by the system operator in regards to water depth and reflectivity of the bottom sediments, and will usually be 6, 12, or 24 ms at the water depths at the study sites and in transit from Astoria. The system produces one sound pulse and then waits for its return before transmitting again. Thus, the pulse interval is directly dependent upon water depth, and in this survey is 0.8–1.5 sec. Using the Sonar Equations and assuming 100% efficiency in the system (impractical in real world applications), the source level for the 320B/R is calculated to be 211 dB re 1 μPa·m. In practice, the system is rarely operated above 80% power level.

II. DATES, DURATION, AND REGION OF ACTIVITY

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

The survey will encompass the area ~43.5–47°N and ~124–125°W in the U.S. EEZ (Fig. 1). Water depths in the survey area are ~50–1000 m. The exact dates of the activities depend on logistics and weather conditions. The surveys will begin on 5 July 2012 and the *Langseth* will return to port at Astoria, OR, on 8 July 2012. Seismic operations will be carried out for an estimated 3 days.

III. SPECIES AND NUMBERS OF MARINE MAMMALS IN AREA

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

Thirty-two marine mammal species could occur in the northeast Pacific survey area. To avoid redundancy, we have included the required information about the species and (insofar as it is known) numbers of these species in § IV, below.

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

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

Sections III and IV are integrated here to minimize repetition.

Thirty-two marine mammal species could occur in the northeastern Pacific survey area, including mysticetes (baleen whales), odontocetes (toothed cetaceans, such as dolphins), pinnipeds (seals) and the sea otter (Table 2). Information on the occurrence, population size, and conservation status for each of the 32 species is presented in Table 2. The status of these species is based on the ESA, the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2011), and the Convention on International Trade in Endangered Species in Wild Fauna and Flora (CITES; UNEP-WCMC 2011). Six of the species that could occur in the proposed survey areas are listed under the ESA as ***Endangered***, including sperm, humpback, sei, fin, blue, and North Pacific right whales. Two other listed stocks could occur in the proposed survey areas: the ***Threatened*** Eastern U.S. Stock of the Steller sea lion, and the ***Endangered*** Southern Resident Stock of the killer whale.

The proposed survey areas are located ~15–70 km offshore from Washington and Oregon over water depths ~50–1000 m (Fig. 1). The sea otter is not expected in the proposed survey areas because its occurrence off Washington and Oregon is limited to very shallow (<30 m depth), coastal (<4 km from shore) waters (Laidre et al. 2009). Vagrant ringed seals, hooded seals, and ribbon seals have been sighted or stranded on the coast of California (see Mead 1981; Reeves et al. 2002) and presumably passed through Oregon waters. A vagrant beluga whale was seen off the coast of Washington (Reeves et al. 2002). Those five species are not addressed in the summaries below.

Mysticetes

North Pacific Right Whale (*Eubalaena japonica*)

The North Pacific right whale is listed as ***Endangered*** under the ESA and is considered by NMFS (1991) to be the most endangered baleen whale in the world. It is listed as ***Endangered*** on the IUCN Red List of Threatened Species (IUCN 2011) and is listed in CITES Appendix I (UNEP-WCMC 2011)

TABLE 2. The habitat, abundance, and conservation status of marine mammals that could occur in or near the proposed seismic survey areas in the northeastern Pacific Ocean off Washington and Oregon.

Species	Occurrence in survey areas	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	Common*	Coastal, shallow shelf	19,126[6]	DL	LC	I
Humpback whale	Common*	Mainly nearshore and banks	20,800[7]	EN	LC	I
Minke whale	Rare	Nearshore, offshore	9000[8]	NL	LC	I
Sei whale	Rare	Mostly pelagic	12,620[9]	EN	EN	I
Fin whale	Common	Slope, pelagic	13,620–18,680[10]	EN	EN	I
Blue whale	Rare	Pelagic and coastal	2497	EN	EN	I
Odontocetes						
Sperm whale	Common	Pelagic, steep topography	24,000[11]	EN	VU	I
Pygmy sperm whale	Rare	Deep, off shelf	N.A.	NL	DD	II
Dwarf sperm whale	Rare	Deep, shelf, slope	N.A.	NL	DD	II
Cuvier's beaked whale	Common	Pelagic	2143	NL	LC	II
Baird's beaked whale	Common	Pelagic	907	NL	DD	I
Blainville's beaked whale	Rare	Pelagic	1024[12]	NL	DD	II
Hubb's beaked whale	Rare	Slope, offshore	1024[12]	NL	DD	II
Stejneger's beaked whale	Common	Slope, offshore	1024[12]	NL	DD	II
Common bottlenose dolphin	Rare	Coastal, shelf, deep	1006[13]	NL	LC	II
Striped dolphin	Rare	Off continental shelf	10,908	NL	LC	II
Short-beaked common dolphin	Common	Shelf, pelagic, mounts	411,211	NL	LC	II
Pacific white-sided dolphin	Abundant	Offshore, slope	26,930	NL	LC	II
Northern right whale dolphin	Common	Slope, offshore waters	8,334	NL	LC	II
Risso's dolphin	Common	Shelf, slope, mounts	6,272	NL	LC	II
False killer whale	Rare	Pelagic	N.A.	NL	DD	II
Killer whale	Common	Widely distributed	2250–2700	NL/EN[13]	DD	II
Short-finned pilot whale	Rare	Pelagic, high-relief	760	NL	DD	II
Harbor porpoise	Abundant	Coastal and inland waters	55,255[14]	NL	LC	II
Dall's porpoise	Abundant	Shelf, slope, offshore	42,000	NL	LC	II
Pinnipeds						
Northern fur seal	Common	Pelagic, offshore	653,171[6]	NL	VU	NL
California sea lion	Rare	Coastal, shelf	296,750	NL	LC	NL
Steller sea lion	Common*	Coastal, shelf	58,334–72,223[6]	T	EN	NL
Harbor seal	Abundant*	Coastal	24,732[15]	NL	LC	NL
Northern elephant seal	Common	Coastal, pelagic in migration	124,000[16]	NL	LC	NL
Fissiped						
Northern sea otter	Absent	Nearshore, coastal	1125[17]	NL	EN	I

N.A. - Data not available or species status was not assessed.
* In nearshore survey areas, rare elsewhere.
[1] Abundance given for the California/Oregon/Washington or Eastern North Pacific stock (Carretta et al. 2011a,b), unless otherwise stated.
[2] Endangered Species Act: EN = Endangered, T = Threatened, DL = Delisted, NL = Not listed
[3] Codes for IUCN (2011): EN = Endangered; VU = Vulnerable; LC = Least Concern; DD = Data Deficient
[4] CITES (UNEP-WCMC 2011): Appendix I = threatened with extinction; Appendix II = not necessarily now threatened with

extinction but may become so unless trade is closely controlled, NL = Not Listed
[5] Bering Sea (Wade et al. 2010)
[6] Eastern North Pacific (Allen and Angliss 2011)
[7] North Pacific (Barlow et al. 2009)
[8] North Pacific (Wada 1976)
[9] North Pacific (Tillman 1977)
[10] North Pacific (Ohsumi and Wada 1974)
[11] Eastern Temperate North Pacific (Whitehead 2002a)
[12] All mesoplodont whales
[13] Offshore stock (Carretta et al. 2011a)
[14] The Eastern North Pacific Southern Resident Stock of killer whales is listed as Endangered under the ESA.
[15] Northern Oregon/Washington Coast and Northern California/Southern Oregon stocks
[16] Oregon/Washington Coastal Stock (Carretta et al. 2011a)
[17] California population (Carretta et al. 2011a)
[18] Minimum population estimate, WA (NMFS 2008a)

(Table 2). Although protected from commercial whaling since 1935, there has been little indication of recovery. The pre-exploitation stock could have exceeded 11,000 animals (NMFS 1991). Wada (1973) estimated a total population of 100–200 in the North Pacific based on sighting data. Based on photographic and genetic mark-recapture data, right whale abundance in the Bering Sea and Aleutian Islands was estimated at 31 and 28, respectively. The total northeastern Pacific population is unlikely to be much larger (Wade et al. 2010).

North Pacific right whales summer 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 that 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). In April 1996, a right whale was sighted off Maui, representing the first documented sighting of a right whale in Hawaiian waters since 1979 (Herman et al. 1980; Rowntree et al. 1980). The individual seen in Hawaii was one of the whales subsequently seen in the southeastern Bering Sea on several occasions, and represents the first high to low latitude North Pacific right whale match (Allen and Angliss 2011).

Whaling records indicate that right whales once ranged across the entire North Pacific north of 35ºN and occasionally occurred as far south as 20ºN. 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 on 24 May 1992, 65 km west of Cape Elizabeth, Washington, over water depths of ~1200 m; the same whale was subsequently photographically identified again ~6 hr later 48 km to the west over water depths of ~500 m. Despite many miles of systematic aerial and ship-based surveys for marine mammals off the coasts of Oregon/Washington/California over the years, only seven documented sightings of right whales were made from 1990 to 2000 (Waite et al. 2003). 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 even small numbers will be present in the proposed survey areas during the planned period of operations in June–July, and therefore no takes are anticipated or requested.

Gray Whale (*Eschrichtius robustus*)

In the North Pacific, gray whales have distinct eastern and western stocks. Although both populations were severely reduced by whaling and the western population has remained highly depleted, the eastern North Pacific population is generally considered to have recovered (Lang et al. 2010). The eastern North Pacific stock was ***Delisted*** from the ESA in 1994. The species is listed as ***Least Concern*** on the IUCN Red List of Threatened Species (IUCN 2011), and is listed in CITES Appendix I (UNEP-WCMC 2011). The population estimate for this stock is 19,126 for 2006/2007 (Allen and Angliss 2011).

The eastern North Pacific gray whale breeds and winters in Baja, California, and migrates north to summer feeding grounds in the northern Bering Sea, the Chukchi Sea, and the western Beaufort Sea (Rice and Wolman 1971; Jefferson et al. 2008); a small portion of the population also summers along the Pacific coast from Vancouver to central California (Rice and Wolman 1971; Nerini 1984; Calambokidis and Quan 1999). Whales observed foraging in these more southern locations are referred as 'resident' (Newell and Cowles 2006). In October and November, 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 (Braham 1984; Rugh et al. 2001).

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). Gray whales are known to move farther offshore between the entrance to Prince William Sound and the southern part of the Alaska Peninsula (Consiglieri et al. 1982). They migrate closest to the Washington/Oregon coastline during the spring months (April–June) when most strandings are observed (Norman et al. 2004).

Gray whales usually migrate alone, with the exception of cow/calf pairs, and groups of >6 whales are unusual (Rice and Wolman 1971; Leatherwood et al. 1982). Foraging gray whales commonly dive to depths of 50–60 m, and the maximum known dive depth is 170 m (Jones and Swartz 2009). Migrating gray whales typically dive for 3–5 min and spend 1–2.5 min on the surface between dives (Jones and Swartz 2009).

Resident gray whales have been observed foraging off the coast of Oregon from May to October (Newell and Cowles 2006). At least 28 gray whales were observed near Depoe Bay (~44.8°N) for three successive summers (Newell and Cowles 2006). 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. 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 (Ortega-Ortiz and Mate 2008). The migration paths of tracked whales seemed to follow a constant depth rather than the shoreline. Calambokidis et al. (2004a) estimated annual abundance of gray whales that remained between Oregon and B.C. in summer at 197–256 using photo-identification methods.

Humpback Whale (*Megaptera novaeangliae*)

The humpback whale is found throughout all of the oceans of the world (Clapham 2009). The species is listed as ***Endangered*** under the ESA and ***Least Concern*** on the IUCN Red List of Threatened Species (IUCN 2011), and it is listed in CITES Appendix I (UNEP-WCMC 2011) (Table 2). The world-wide population of humpback whales 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).

The entire North Pacific stock has been recently estimated at 18,302, excluding calves (Calambokidis et al. 2008). Barlow et al. (2009) provided a bias-corrected abundance estimate of 20,800. Overall, the North Pacific stock is increasing (Calambokidis et al. 2008).

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), and winter in three different breeding areas: (1) the eastern North Pacific along the coast of Mexico and Central America, and near the Revillagigedo Islands; (2) around the main Hawaiian Islands; and (3) in the western Pacific, particularly around the Ogasawara and Ryukyu islands in southern Japan and the northern Philippines (Perry et al. 1999a; Calambokidis et al. 2008). There is a low level of interchange of whales among the three main wintering areas and among feeding areas (e.g., Darling and Cerchio 1993; Salden et al. 1999; Calambokidis et al. 2001, 2008).

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). The diving behavior of humpback whales is related to time of year and whale activity. On winter breeding grounds, humpback dives have been recorded at depths >100 m (Baird et al. 2000). In summer feeding areas, humpbacks typically forage in the upper 120 m of the water column, with a maximum recorded dive depth of 500 m (Dolphin 1987; Dietz et al. 2002).

Humpback whales are often sighted singly or in small groups, and up to 20 or more while on their breeding and feeding ranges (Jefferson et al. 2008). Loose feeding aggregations of up to 35 have been sighted over the continental shelf off Oregon/Washington (Green et al. 1992). Barlow (2003) reported mean group sizes of 1.1–2.3 during surveys in 1991, 1993, 1996, and 2001 off California, Oregon, and Washington. Male humpbacks sing a characteristic song when on the wintering grounds (Winn and Reichley 1985).

The humpback whale is the most common species of large cetacean reported off the coasts of Oregon and Washington from May to November, with highest numbers reported from May to September; no humpbacks have been observed there in the winter (Green et al. 1992; Calambokidis et al. 2000, 2004b). Shifts in seasonal abundance observed off Oregon and Washington suggest north–south movement (Green et al. 1992). Off Oregon/Washington, humpbacks occur primarily over the continental shelf and slope during the summer and fall, with few reported in offshore pelagic waters (Green et al. 1992, Calambokidis et al. 2004b). 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 >200 m deep. That sighting was ~70 km west of Cape Blanco during the spring (Green et al. 1992). Encounter rates off Oregon/Washington during the summer were highest over the slope followed by shelf waters, with no sightings in offshore waters (Green et al. 1992). At least 12 humpback whale sightings were reported during the Oregon/Washington portions of the survey in summer/fall 2008 (Barlow 2010). Based on surveys conducted in 1991–2008, the estimated abundance of humpback whales off the coasts of Oregon and Washington is 260 (Barlow 2010). The abundance estimate for humpback whales off the coasts of Oregon/Washington/California is 2034 (Carretta et al. 2011a).

Minke Whale (*Balaenoptera acutorostrata*)

The minke whale has a cosmopolitan distribution that spans polar, temperate, and tropical regions (Jefferson et al. 2008). 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). Wada (1976) estimated the abundance of minke whales in the North Pacific at ~9000.

The minke whale is relatively solitary, but can occur in aggregations of up to 100 when food resources are concentrated (Jefferson et al. 2008). The small size, inconspicuous blows, and brief surfacing times of minke whales mean that they are easily overlooked in heavy sea states, although they are known to approach vessels in some circumstances (Stewart and Leatherwood 1985). Little is known about the diving behavior of minke whales, but they are not known to make prolonged deep dives (Leatherwood and Reeves 1983). One study of four minke whales equipped with speed-depth recorders off northern Norway and Svalbard reported minke whale foraging dives to 65 m (Blix and Folkow 1995).

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 resident in coastal waters off the U.S. west coast (Dorsey et al. 1990). Minke whales strandings have been reported in all seasons in Washington. Most strandings (52%) occurred in spring (March–May); 29% of strandings occurred in summer (June–August; Norman et al. 2004). Forney (2007) estimated and abundance of 957 minke whales during a 2005 ship survey off California, Oregon, and Washington, whereas the most recent survey in 2008 did not record any minke whales while on survey effort (Barlow 2010). Based on surveys conducted in 1991–2008, the estimated abundance of minke whales off the coasts of Oregon and Washington is 147 (Barlow 2010).

Sei Whale (*Balaenoptera borealis*)

The sei whale is listed as ***Endangered*** under the ESA and on the IUCN Red List of Threatened Species (IUCN 2011), and is listed in CITES Appendix I (UNEP-WCMC 2011) (Table 2). Sei whale populations were depleted by whaling, and the current status of this species is generally uncertain (Horwood 1987). The global population is thought to be ~80,000 (Horwood 2009), with up to ~12,620 in the North Pacific (Tillman 1977). The sei whale is poorly known because of confusion with Bryde's whale and unpredictable distribution patterns; it can be common in an area for several years and then seemingly disappear (Schilling et al. 1992; Jefferson et al. 2008).

The sei whale is pelagic and generally not found in coastal waters (Harwood and Wilson 2001). 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 are frequently seen in groups of 2–5 (Leatherwood et al. 1982; Jefferson et al. 2008), although larger groups sometimes form on feeding grounds (Gambell 1985a). Sei whales generally do not dive deeply, and dive durations are 15 min or longer (Gambell 1985a).

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. 2008). 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 about 20°N, and sightings have been made between southern Baja California and the Islas Revillagigedo (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 are known for California, Oregon, and Washington during extensive surveys from 1991–2008 (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. 2011a). Based on surveys conducted in 1991–2008, the estimated abundance of sei whales off the coasts of Oregon and Washington is 52 (Barlow 2010).

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° to 70° north and south of the Equator (Perry et al. 1999b). It is listed as ***Endangered*** under the ESA and on the IUCN Red List of Threatened Species (IUCN 2011), and is listed in CITES Appendix I (UNEP-WCMC 2011) (Table 2). Probably at least in part because of its initially high abundance, wide distribution, and diverse feeding habits, the fin whale does not seem to have been as badly depleted as the other large whales in the North Pacific. Northern and southern fin whale populations are distinct and are sometimes recognized as different subspecies (Aguilar 2009). Abundance estimates are 13,620–18,680 for the North Pacific (Ohsumi and Wada 1974).

Fin whales occur in coastal, shelf, and oceanic waters. Moore et al. (2002) reported that in the eastern Bering Sea, sighting rates were more than twice as high in water >100 m deep than in water 50–100 m deep; no sightings occurred in water <50 m deep. 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 can be found as individuals or groups of 2–7, but can form much larger feeding aggregations, sometimes with humpback and minke whales (e.g., Waite 2003; Jefferson et al. 2008). Barlow (2003) reported mean group sizes of 1.1–4.0 during surveys in 1991, 1993, 1996, and 2001 off California, Oregon, and Washington. Foraging fin whales have mean dive depths and times of 98 m and 6.3 min, and non-foraging fin whales have mean dive depths and times of 59 m and 4.2 min (Croll et al. 2001). Panigada et al. (1999, 2003) reported variations in dive depths coinciding with the diel migration of krill. Daytime dives were shallower (<100m) and night dives were deeper (>400m). Fin whales in southern California were reported diving 60% of their time to water depth >225 m; the other 40% of time was spent near the surface (<50 m; Goldbogen et al. 2006).

Fin whales appear to have complex seasonal movements and are likely seasonal migrants (Gambell 1985b). They mate and calve in temperate waters during the winter and migrate to feed at northern latitudes during the summer (Mackintosh 1965 *in* Gambell 1985b). The North Pacific population summers from the Chukchi Sea to California and winters from California southwards (Gambell 1985b). Recent information about the seasonal distribution of fin whales in the North Pacific has been obtained from the reception of fin whale calls by bottom-mounted, offshore hydrophone arrays along the U.S. Pacific coast, in the central North Pacific, and in the western Aleutian Islands (Moore et al. 1998, 2006;

Watkins et al. 2000a,b; Stafford et al. 2007, 2009). Fin whale calls are detected year-round in the Northern Pacific (Moore et al. 2006; Stafford et al. 2007, 2009).

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). Vocalizations from fin whales have been detected year-round off northern California, Oregon, and Washington (Moore et al. 1998). Fin whale abundance off the coasts of California/Oregon/Washington was estimated at 3044 based on summer/autumn ship surveys conducted in 2005 and 2008 (Carretta et al. 2011a). Based on survey conducted in 1991–2008, the estimated abundance of fin whales off the coasts of Oregon and Washington is 416 (Barlow 2010). At least 20 fin whale sightings were reported during the Oregon/Washington portions of the survey in 2008 (Barlow 2010).

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. 2008). It is listed as ***Endangered*** under the ESA and on the IUCN Red List of Threatened Species (IUCN 2011), and is listed in CITES Appendix I (UNEP-WCMC 2011) (Table 2). All blue whale populations have been exploited commercially, and many have been severely depleted as a result. 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 (including the California area) during summer and fall may winter in the eastern tropical Pacific (ETP) (Stafford et al. 1999, 2001). The western North Pacific stock includes whales that are found around Hawaii during winter. Blue whale abundance has been estimated at ~2497 off the U.S. west coast based on photo-identification data from 2005–2008 (Carretta et al. 2011a).

Blue whales are typically found singly or in groups of two or three (Yochem and Leatherwood 1985; Jefferson et al. 2008). Barlow (2003) reported mean group sizes of 1.0–1.9 during surveys in 1991, 1993, 1996, and 2001 off California, Oregon, and Washington. Croll et al. (2001) reported mean dive depths and times of 140 m and 7.8 min for foraging blue whales, and 68 m and 4.9 min for non-foraging individuals. Four satellite-radio-tagged blue whales in the northeast Pacific Ocean spent 94% of their time underwater; 72% of dives were <1 min long, and “true” dives (>1 min) were 4.2–7.2 min long. Shallow (<16-m) dives were most common (75%), and the average depth of deep (>16-m) dives was 105 m (Lagerquist et al. 2000). Dives of up to 300 m were recorded for tagged blue whales (Calambokidis et al. 2003).

The distribution of the species, at least during times of the year when feeding is a major activity, is in areas that provide large seasonal concentrations of euphausiids, which are the whale's main prey (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). Blue whales also have been heard off Oregon (McDonald et al. 1995; Stafford et al. 1998; Von Saunder and Barlow 1999), but sightings in the area are rare.

Barlow and Forney (2007) estimated an abundance of 603 blue whales in California, Oregon, and Washington waters, based on line-transect data collected during summer and fall 2001. Barlow (2010) estimated 442 blue whales for California, Oregon, and Washington, based on line-transect surveys conducted during summer and fall 2008. The estimate of population abundance off California, Oregon, and Washington based on mark-recapture data collected in 2004–2006 is 2842 (Calambokidis et al. 2007). Carretta et al. (2011a) noted that this represented the best estimate for the population in the area. Blue whales are considered rare off Oregon and Washington (Buchanan et al. 2001). Based on surveys conducted in 1991–2008, the estimated abundance of blue whales off the coasts of Oregon and Washington was 58 (Barlow 2010). Four blue whale sightings were reported during the Oregon/Washington portions of the survey in 2008 (Barlow 2010).

Odontocetes

Sperm Whale (*Physeter macrocephalus*)

The sperm whale is the largest of the toothed whales, with an extensive worldwide distribution (Rice 1989). The species is listed as ***Endangered*** under the U.S. ESA, but on a worldwide basis it is abundant and not biologically endangered. It is listed as ***Vulnerable*** on the IUCN Red List of Threatened Species (IUCN 2011), and is listed in CITES Appendix I (UNEP-WCMC 2011) (Table 2). There currently is no accurate estimate for the size of any sperm whale population (Whitehead 2002b). Best estimates probably are those of Whitehead (2002a), who provided a sperm whale population size of 24,000 for the eastern temperate North Pacific.

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). They spend periods of at least months on the breeding grounds, moving between mixed groups of ~20–30 animals (Whitehead 1993, 2003). Barlow (2003) reported mean group sizes of 2.0–11.8 during surveys in 1991, 1993, 1996, and 2001 off California, Oregon, and Washington. The mean group size off the coasts of Oregon and Washington in 2008 was 1.0 (Barlow 2010).

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). A recent study of tagged male sperm whales off Norway found that foraging dives extended to highly variable maximum depths, ranging from 14 to 1860 m, with a median of 175 m (Teloni et al. 2008). During a foraging dive, sperm whales typically travel ~3 km horizontally and 0.5 km vertically (Whitehead 2003). Whales in the Galápagos Islands typically dove for ~40 min and then spent 10 min at the surface (Papastavrou et al. 1989). Davis et al. (2007) reported that sperm whales in the Gulf of California foraged throughout a 24-h period, and rarely dove to the sea-floor bottom (>1000 m); dive depths (100–500 m) overlapped with depth distributions of jumbo squid.

Sperm whales are distributed widely across the North Pacific (Carretta et al. 2011a). Off Oregon, they are seen in every season except winter (Green et al. 1992). In contrast, sperm whales are found off California 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). Based on surveys conducted in 1991–2008, the estimated abundance of sperm whales off the coasts of Oregon and Washington is 329 (Barlow

2010). Three sperm whale sightings were reported in water depths >2000 m during the Oregon/ Washington portions of the survey in 2008 (Barlow 2010).

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

The pygmy sperm whale and dwarf sperm whale 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).

Pygmy sperm whales could inhabit waters beyond the continental shelf edge, whereas dwarf sperm whales are thought to inhabit the shelf edge and slope waters (Rice 1998; Wang et al. 2002; MacLeod et al. 2004). Barros et al. (1998) suggested that dwarf sperm whales could be more pelagic and dive deeper than pygmy sperm whales. Dwarf sperm whale could prefer warmer waters than pygmy sperm whales (e.g., Wade and Gerrodette 1993; Muñioz-Hincapié et al. 1998; McAlpine 2009). Pygmy sperm whales occur in small groups of up to six, and dwarf sperm whales can form groups of up to 10 (Caldwell and Caldwell 1989). Mean group size for the dwarf sperm whale was 2.3 in Hawaii (Barlow 2006) and 1.6–1.7 for the ETP (Wade and Gerrodette 1993; Jackson et al. 2008). The mean group size of the pygmy sperm whale in Hawaiian waters was 1.0 (Barlow 2006), and for the ETP was 1.3 (Jackson et al. 2008).

Pygmy sperm whales feed mainly on various species of squid in the deep zones of the continental shelf and slope (McAlpine et al. 1997). In the Gulf of California, median dive and surface times for dwarf sperm whales or unidentified *Kogia* sp. were 8.6 min and 1.2 min, and dives of up to 25 min and surface times up to 3 min were common (J. Barlow, pers. comm. *in* Willis and Baird 1998). Little is known about dive depths of *Kogia* spp. A satellite-tagged pygmy sperm whale released off Florida made longer dives (>8 min and up to ~18 min) at night and on overcast days, and shorter dives (usually 2–5 min) on clear days, probably because of the distribution of their prey, vertically-migrating squid (Scott et al. 2001).

Eight strandings of pygmy sperm whales have been recorded for Oregon and Washington, five of which occurred during autumn and winter months (Norman et al. 2004). Although there are few useful estimates of abundance for pygmy or dwarf sperm whales anywhere in their range, they are thought to be fairly common in some areas (Jefferson et al. 2008). For waters off Oregon and Washington, Barlow (2010) used data collected in 1991–2008 to estimate an abundance of 229 *Kogia* sp., which were thought to be pygmy sperm because no dwarf sperm whales had been identified on the west coast since the early 1970s.

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. 2008) and is most common in water depths >1000 m (Heyning 1989). Ferguson et al. (2006a) reported that in the ETP, the mean water depth where Cuvier's beaked whales were sighted was ~3.4 km. It is rarely observed at sea and is mostly known from strandings. It 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).

Adult males of this species usually travel alone, but these whales can be seen in groups of up to 7 (Heyning and Mead 2009), with a mean group size of 2.3 (MacLeod and D'Amico 2006). Barlow (2010) reported a mean group size of 1.3 for California/Oregon/Washington in 2008. Cuvier's beaked whale dives generally last 30–60 min, but dives of 85 min have been recorded (Tyack et al. 2006). The maximum dive depth recorded by Baird et al. (2006) was 1450 m.

It is the most common beaked whale off the U.S. west coast (Barlow 2010), and the beaked whale species that stranded most frequently on the coasts of Oregon and Washington. Most (75%) Cuvier's beaked whale strandings reported occurred in Oregon (Norman et al. 2004). The abundance estimate for the U.S. west coast, based on survey data from 2005 and 2008, is 2143 (Carretta et al. 2011a). Four beaked whale sightings were reported in water depths >2000 m during the Oregon/Washington portions of the survey in 2008 (Barlow 2010), none was seen in 1996 or 2001 (Barlow 2003), and several were recorded there from 1991 to 1995 (Barlow 1997). The abundance estimate for Oregon and Washington waters, based on data from 1991–2008, is 137 (Barlow 2010).

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). It has been suggested that Baird's beaked whales can be divided into three distinct stocks: the Sea of Japan Stock, the Okhotsk Sea Stock, and the Bering Sea/Eastern North Pacific Stock (Balcomb 1989; Reyes 1991). Any animals in the vicinity of the proposed survey areas likely would be from the Bering Sea/Eastern North Pacific stock. The mean abundance estimate for the U.S west coast based on 2005–2008 ship surveys is 907 (Carretta et al. 2011a).

Baird's beaked whales feed on deep-water and bottom-dwelling fish, cephalopods, and crustaceans (Jefferson et al. 1993), and some pelagic fish (Reyes 1991; Kasuya 2009). Typical water depths for sightings are 1000–3000 m. Baird's beaked whales can stay submerged for up to 67 min (Kasuya 2009). That makes it very difficult to sight and to visually track them. Baird's beaked whales live in pods of 5–20, although larger groups are sometimes seen. There appears to be a calving peak in March and April (Jefferson et al. 2008).

Baird's beaked whales sometimes are seen close to shore where deep water approaches the coast, but their primary habitat is over or near the continental slope and oceanic seamounts (Jefferson et al. 2008). Along the U.S. west coast, they have been sighted primarily along the continental slope from late spring to early fall (Green et al. 1992; Carretta et al. 2011a). 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.

For Oregon/Washington waters, Barlow (2010) estimated an abundance of 380 Baird's beaked whales based on survey data collected in 1991–2008. 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. Two groups were sighted during summer/fall 2008 surveys off Washington/Oregon, both in waters >2000 m deep (Barlow 2010).

Mesoplodont Beaked Whales

Three species of *Mesoplodon* can occur off the coasts of Oregon and Washington: Blainville's beaked whale (*M. densirostris*), Stejneger's beaked whale (*M. stejnegeri*), and Hubb's beaked whale (*M. carlhubbsi*). In addition, records exist for Perrin's beaked whale (*M. perrini*) and the lesser beaked whale (*M. peruvianus*) and gingko-toothed beaked whale (*M. ginkgodens*) off the coast of California and/or Baja

California (MacLeod et al. 2006). However, those species are unlikely to be seen in the proposed survey areas, and will not be discussed further.

Almost everything that is known regarding most mesoplodont species has come from stranded animals (Pitman 2009). Because of the scarcity of sightings, most are thought to be rare. The different mesoplodont species are difficult to distinguish in the field, and confirmed at-sea sightings are rare (Mead 1989; Jefferson et al. 2008; Carretta et al. 2011a).

Mesoplodonts are distributed primarily in deep waters (>2000 m) and along continental slopes at depths 200–2000 m; they are rarely found in continental shelf waters (Pitman 2009). Most mesoplodonts identified to species are known from strandings involving single individuals (Jefferson et al. 2008); thus, it is not possible to identify spatial or seasonal patterns in their distribution (Carretta et al. 2011a). Dive depths of most of these species are undocumented.

Typical group sizes range from one to six (Pitman 2009). Because of the scarcity of sightings, most are thought to be rare. However, based on stranding records, Blainville's beaked whale appears to be widespread and fairly common (Pitman 2009). In 1996, the estimated abundance of mesoplodont beaked whales was 2169 for Oregon and Washington, and in 2001, it was zero (Barlow 2003). In 2005, the estimated abundance in the area was 841, and in 2008, it was zero (Barlow 2010). The abundance of *Mesoplodon* species for Oregon and Washington waters is estimated at 565 based on data from 1991–2008 (Barlow 2010).

Blainville's beaked whale.—This species is found in tropical and temperate waters of all oceans (Jefferson et al. 2008). Blainville's beaked whale has the widest distribution throughout the world of all *Mesoplodon* species (Mead 1989). There is no evidence that Blainville's beaked whale undergoes seasonal migrations. It is most often found in singles or pairs, but also in groups of 3–7 (Jefferson et al. 2008). Barlow (2006) reported a mean group size of 2.3 for Hawaii.

Like other beaked whales, Blainville's beaked whales are generally found in waters 200–1400 m deep (Gannier 2000; Jefferson et al. 2008). Maximum dive depths have been reported as 1251 m (Tyack et al. 2006) and 1408 m (Baird et al. 2006), and dives have lasted as long as 54 min (Baird et al. 2006) to 57 min (Tyack et al. 2006). They also can occur in coastal areas and have been known to spend long periods of time at depths <50 m (Jefferson et al. 2008).

Occasional occurrences in cooler, higher-latitude waters are presumably related to warm-water incursions (Reeves et al. 2002). Strandings and sighting records in the eastern Pacific range from 37.3°N to 41.5°S (McLeod et al. 2006). None of the 36 beaked whale-stranding records in Oregon and Washington during 1930–2002 was Blainville's beaked whale (Norman et al. 2004). For California, Oregon, and Washington waters, Barlow (1997) estimated an abundance of 360 Blainville's beaked whales. It is unlikely to be present in the proposed survey areas, as its main distribution is south of there (Carretta et al. 2011a).

Stejneger's beaked whale.—This species 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). This species occurs in groups of 3 to 4, ranging to ~15 (Reeves et al. 2002). 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).

Hubb's beaked whale.—This species occurs in temperate waters of the North Pacific (Mead 1989). Most of the records are from California, but it has been sighted as far north as Prince Rupert, British

Columbia (Mead 1989). Two strandings are known from Washington/Oregon (Norman et al. 2004). The distribution of the species appears to be correlated with the deep subarctic current (Mead et al. 1982). Hubb's beaked whales are often killed in drift gillnets off California (Reeves et al. 2002).

Common Bottlenose Dolphin (*Tursiops truncatus*)

The bottlenose dolphin is distributed worldwide. It is found mainly where surface temperatures are 10–32ºC (Reeves et al. 2002). Generally, 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). As well as inhabiting different areas, these ecotypes differ in their diving abilities (Klatsky 2004) and prey types (Mead and Potter 1995). Bottlenose dolphins have been reported to dive regularly to depths >450 m for periods of >5 min, and even to depths of 600–700 m for up to 12 min (Klatsky et al. 2007). Mean group size was 8.02 for California, Oregon, and Washington in 2008 (Barlow 2010).

Bottlenose dolphins occur frequently off the coast of California, and sightings have been made as far north as 41ºN (Carretta et al. 2011a). The most recent abundance estimate of offshore bottlenose dolphins for California/Oregon/Washington is 1006 (Carretta et al. 2011a). In the proposed survey areas, it is possible that offshore bottlenose dolphins could be encountered during warm-water periods (see Carretta et al. 2002), although none have been sighted in waters off Oregon or Washington (Barlow 2010). No takes of bottlenose dolphins are anticipated or requested.

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). In the eastern North Pacific, its distribution extends as far north as Washington, although there have been few sightings (Appler et al. 2004). 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). It is fairly gregarious (groups of 20 or more are common) and active at the surface (Whitehead et al. 1998). Barlow (2010) reported a mean group size of 15.0 for California/Oregon/Washington in 2008. For the ETP, reported mean group sizes were 52–61 (Wade and Gerrodette 1993; Ferguson et al. 2006b; Jackson et al. 2008).

Off California, striped dolphins have been sighted within 185–556 km of the coast (Carretta et al. 2002). They also occur in coastal waters (Isaksen and Syvertsen 2002). There are 10 stranding records of this species in Oregon and two in Washington during 1930–2002 (Norman et al. 2004). The abundance of striped dolphins off the coasts of California/Oregon/Washington appears to be variable among years and could be affected by oceanographic conditions (Carretta et al. 2011a). The 1991–1996 average abundance estimate for was 20,235 (Barlow 1997), and the 2008 estimate was 4655 (Barlow 2010). Based on survey data from 2005 and 2008, the mean abundance estimate for California, Oregon, and Washington waters is 10,908 (Carretta et al. 2011a). However, very few sightings have been reported for Oregon or Washington, with the exception of a survey by Barlow (2003) in 1996. No striped dolphins were sighted off Washington and Oregon during the summer/fall survey in 2008 (Barlow 2010). Barlow (2010) gave an abundance estimate of 12 for waters off Oregon and Washington, based on data collected in 1991–2008.

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). There are two species of common dolphin: the short-beaked common dolphin (*D. delphis*) and the long-beaked common dolphin (*D. capensis*). The long-beaked common dolphin is less abundant, and only recently has been recognized as a separate species (Heyning and Perrin 1994). Short-beaked common dolphins have been sighted as far as 550 km from shore, and are likely present farther offshore (Barlow et al. 1997). Long-beaked common dolphins are usually found within 90 km of shore (Barlow et al. 1997), are not found north of central California (Carretta et al. 2011a). Common dolphins found in the survey area likely would be the short-beaked species.

Common dolphins often travel in large groups; schools of hundreds or even thousands are common. The groups are thought to be composed of smaller subunits of perhaps 20–30 closely related individuals (Evans 1994). Barlow (2010) reported a mean group size of 178 for the U.S. west coast in 2008. Common dolphins are easily identified from their fast swimming speed (typically 40 km/h) and their propensity for bow riding. Perrin (2009) reported foraging dives to 200 m.

The distribution of short-beaked common dolphins along the U.S. west coast is variable and likely is related to oceanographic changes (Heyning and Perrin 1994; Forney and Barlow 1998). The short-beaked common dolphin is the most abundant cetacean off California, but it is not abundant off Oregon and Washington (Carretta et al. 2011a). There were single sightings in 2001 and 2005 of common dolphins in Oregon/Washington, both off southern Oregon (Forney 2007). Only one sighting was reported off Oregon and Washington during the summer/fall survey in 2008 (Barlow 2010). Based on survey data in 2005 and 2008, the mean abundance in the area is estimated at 411,211 (Carretta et al. 2011a). The abundance estimates for waters off Oregon/Washington alone is 3312 for pooled 1991–2008 surveys (Barlow 2010).

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 marine mammal species, occurring primarily in shelf and slope waters (Green et al. 1993; Barlow 2003; Barlow 2010). It is known to occur close to shore in certain regions, including (seasonally) southern California (Brownell et al. 1999).

Pacific white-sided dolphins are very gregarious, commonly occurring in groups of 10–100, and occasionally in groups of thousands (Reeves et al. 2002). They often associate with other species, including cetaceans, pinnipeds, and seabirds. In particular, they are frequently seen in mixed-species schools with Risso's and northern right whale dolphins (Green et al. 1993). Barlow (2010) reported a mean group size of 72.4 for California/Oregon/Washington in 2008.

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; Carretta et al. 2002). During winter, this species is most abundant in California slope and offshore areas; as northern marine waters begin to warm in the spring, it appears to move north to slope and offshore waters off Oregon/Washington (Green et al. 1992, 1993; Forney 1994; Forney et al. 1995; Buchanan et al. 2001; Barlow 2003). Seasonal abundance estimates off the coast of California are an order of magnitude higher in February–April than in August–November, whereas the highest abundance estimates off Oregon and Washington are in April–May.

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). The highest encounter rates were associated with the 1992 El Niño year. Mean group sizes were significantly higher in slope (11.6) *vs*. offshore waters (6.7). 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 the second most abundant species reported during the 2008 survey (Barlow 2010). Its abundance off the coasts of California/Oregon/Washington was estimated at 26,930 based on summer/autumn ship surveys conducted in 2005 and 2008 (Carretta et al. 2011a). The abundance estimate for pooled 1991–2008 surveys off Oregon/Washington was 11,250 (Barlow 2010).

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 m to >2000 m deep (Green et al. 1993; Carretta et al. 2002; 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).

Northern right whale dolphins are gregarious, and groups of several hundred to over a thousand are not uncommon (Reeves et al. 2002). Barlow (2010) reported a mean group size of 23.7 for California, Oregon, and Washington in 2008. Northern right whale dolphins are often seen in mixed-species schools with Pacific white-sided dolphins. Calving appears to occur primarily in July and August (Reeves et al. 2002). The species presumably feeds primarily at night on small fish and squid that migrate vertically in the water column.

Recent 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; Carretta et al. 2002). 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.

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 waters 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. The abundance off the coasts of California, Oregon, and Washington was estimated at 8334 based on summer/autumn ship surveys conducted in 2005 and 2008 (Carretta et al. 2011a). The abundance estimate for pooled 1991–2008 surveys off Oregon/Washington was 4152 (Barlow 2010).

Risso's Dolphin (*Grampus griseus*)

Risso's dolphin is primarily a tropical and mid-temperate species distributed worldwide. It occurs between 60ºN and 60ºS, where surface water temperatures are at least 10ºC (Kruse et al. 1999). Water temperature appears to be an important factor affecting its distribution (Kruse et al. 1999; see also Becker

2007). 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).

Risso's dolphins are pelagic, mostly occurring on the upper continental slope shelf edge in waters 350–1000 m deep (Baumgartner 1997; Davis et al. 1998). They occur individually or in small to moderate-sized groups, normally 10–50, although groups as large as 4000 have been sighted (Baird 2009a). The majority of groups consist of <50 individuals (Kruse et al. 1999; Miyashita 1993). Mean group size was 20.3 for California/Oregon/Washington (Barlow 2010). Risso's dolphins in the Gulf of Mexico were distributed non-uniformly with respect to depth and depth gradient, occurring mainly in the steep sections of upper continental slope bounded by the 350 m and 975 m isobaths (Baumgartner 1997). Prey items collected in the stomach of stranded Risso's dolphins suggested they feed on the middle slope at depths 600–800 m (Blanco et al. 2006).

Throughout the region from California to Washington, the distribution and abundance of Risso's dolphin are highly variable, presumably in response to changing oceanographic conditions on both annual and seasonal time scales (Forney and Barlow 1998; Buchanan et al. 2001; Carretta et al. 2002). 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 that most Risso's dolphin groups sighted off Oregon were primarily at ~45–47ºN. Risso's dolphin sightings during ship surveys in summer/fall 2008 were mostly from ~30º N to ~38ºN; none were reported in Oregon/Washington (Barlow 2010). The mean abundance off the coasts of California/Oregon/Washington was estimated at 6272 based on summer/autumn ship surveys conducted in 2005 and 2008 (Carretta et al. 2011a). The abundance estimate for pooled 1991–2008 surveys off Oregon and Washington was 3607 (Barlow 2010).

False Killer Whale (*Pseudorca crassidens*)

The false killer whale is found in all tropical and warmer temperate oceans, especially in deep, off-shore waters (Odell and McClune 1999). However, it is also known to occur in nearshore areas (e.g., Stacey and Baird 1991). False killer whales travel in groups of 20–100 (Baird 2009b), although groups of several hundred are sometimes observed. Mean group sizes were 10 for Hawaii (Barlow 2006) and 11–12 for the ETP (Wade and Gerrodette 1993; Ferguson et al. 2006b; Jackson et al. 2008).

In the eastern North Pacific, the species has been reported only rarely north of Baja California (Leatherwood et al. 1982, 1987; Mangels and Gerrodette 1994). Their occurrence in Washington/Oregon is associated with warm-water incursion years (Buchanan et al. 2001). They were not seen 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). Two were reported stranded along the Washington coast during 1930–2002, both in El Niño years (Norman et al. 2004). No takes of false killer whales are anticipated or requested.

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 B.C. through parts of southeast Alaska; (3) Southern Residents, mainly in inland waters of Washington State and southern B.C.; (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. 2011a). Individuals from the Southern Resident Stock, the Offshore Stock, and the West Coast Transient Stock could be encountered in the proposed survey areas. Movements of resident groups between different geographic areas have also been documented (Leatherwood et al. 1990; Dahlheim et al. 1997; Matkin et al. 1997, 1999 *in* Angliss and Allen 2011). Most killer whale stocks in the northeast Pacific are not listed under the ESA; the Southern Resident Killer Whale Stock, occurring in inland waters of Washington and southern British Columbia, is listed as ***Endangered*** under the ESA. The northeast Pacific population is estimated at 2250–2700 (NMFS 2011).

High densities of the species occur in high latitudes, especially in areas where prey is abundant. Although resident in some parts of its range, the killer whale can also be transient. Killer whale movements generally appear to follow the distribution of their prey, which includes marine mammals, fish, and squid. Killer whales are large and conspicuous, often traveling in close-knit matrilineal groups of a few to tens of individuals (Dahlheim and Heyning 1999). Group sizes of residents are 5–50, whereas those of transients are 1–7 (Bigg et al. 1987). The mean group size off killer wales off California, Oregon, and Washington was 14.8 (Barlow 2010). The maximum depth to which seven tagged free-ranging killer whales dove off B.C. was 228 m, but only an average of 2.4 % of their time was spent deeper than 30 m (Baird et al. 2003). Diving studies on killer whales have been undertaken mainly on “resident” (fish-eating) killer whales in Puget Sound and may not be applicable across all populations of killer whales. Marine mammal-eating killer whales could display different dive patterns.

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. Barlow (1997) estimated the number of killer whales within 550 km of the coasts of California, Oregon, and Washington to be 819, of which perhaps 35% were offshore whales (Carretta et al. 2011a). Six of the 17 (35%) stranded killer whales in Washington and Oregon were confirmed as southern residents (Osborne 1999 *in* Norman et al. 2004). Two of the stranded killer whales in Oregon were confirmed as transient (Stevens et al. 1989 *in* Norman et al. 2004). Barlow (2010) reported a mean abundance estimate of 536 for pooled 1991–2008 surveys off Oregon and Washington.

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. 2008). Pilot whales are generally nomadic, but may be resident in certain locations, including California and Hawaii (Olson 2009). It is an occasional visitor as far north as the Alaska Peninsula. In the southern California Bight, the occurrence of short-finned pilot whales was associated with high-relief topography (Hui 1985).

Pilot whales are very social and are usually seen in groups of 20–90 with matrilineal associations (Olson 2009). Mean group sizes have been reported as 22.5 for Hawaii (Barlow 2006) and 18.0–18.3 for the ETP (Wade and Gerrodette 1993; Ferguson et al. 2006b; Jackson et al. 2008). Both pilot whale species (short-finned and long-finned) are known for single and mass strandings. Long-finned pilot whales outfitted with time-depth recorders dove to depths up to 828 m, although most of their time was spent above depths of 7 m (Heide-Jørgensen et al. 2002). The species’ maximum recorded dive depth is 971 m (Baird pers. comm. *in* DoN 2005).

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. 2002). 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). Only two groups of pilot whales (of 26 and 43 animals) were seen during the two most recent ship surveys conducted off California, Oregon, and Washington in 2005 and 2008 (Barlow 2010). The mean abundance off the coasts of California/Oregon/Washington was estimated at 760 based on summer/autumn ship surveys conducted in 2005 and 2008 (Carretta et al. 2011a). The abundance estimate for pooled 1991–2008 surveys off Oregon/Washington was 0 (Barlow 2010). No takes of short-finned pilot whales are anticipated or requested.

Harbor Porpoise (*Phocoena phocoena*)

The harbor porpoise inhabits temperate, subarctic, and arctic waters. In the eastern North Pacific, the harbor porpoise's usual 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) the Washington Inland Waters Stock, (2) the Northern Oregon/Washington Coast Stock, (3) the Northern California/Southern Oregon Stock, (4) the San Francisco-Russian River Stock, (5) the Monterey Bay Stock, and (6) the Morro Bay Stock (Carretta et al. 2011b). Harbor porpoises from the Northern Oregon/Washington and the Northern California/Southern Oregon stocks could occur in the proposed survey areas; the abundance estimates for those stocks are 15,674 and 39,581, respectively (Carretta et al. 2011a,b).

Harbor porpoises feed primarily near the seafloor but also in the water column, consuming schooling fish such as herring, capelin, sprat, and silver hake (Reeves et al. 2002). They also prey on squid and octopus, and their seasonal changes in abundance and distribution could be related to the movements of squid (Green et al. 1992). Harbor porpoises are normally found in small groups of up to 3 that often contain at least one mother-calf pair. Larger groups of 6–8 are not uncommon, and rarely, much larger aggregations are seen. Mean group size was 2.65 for northern California (Carretta et al. 2001). Harbor porpoises are generally not found in water deeper than 100 m, and abundance declines linearly as depth increases (Barlow 1988; Angliss and Outlaw 2011). Tagged harbor porpoises in the Bay of Fundy dove to mean depths of 14–41 m for mean durations of 44–103 s, and to a maximum depth of 226 m (Westgate et al. 1995).

The harbor porpoise inhabits shallow coastal and inland waters (Reeves et al. 2002; Carretta et al. 2011a). Based on year-round surveys spanning coastal to offshore waters of Oregon/Washington, Green et al. (1992) reported that 96% of harbor porpoise sightings occurred in coastal waters <100 m deep, with a few sightings made on the slope near the 200-m isobath. 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), south of the proposed survey areas, to California, from fall through spring. During summer, the reported encounter rates decreased notably from inner shelf to offshore waters.

Dall's Porpoise (*Phocoenoides dalli*)

Dall's porpoise is found only in temperate to cold, ice-free waters of the North Pacific and adjacent seas. It is widely distributed across the North Pacific over the continental shelf and slope waters, and over deep (>2500 m) oceanic waters (Hall 1979; Angliss and Allen 2011). 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; Jefferson et al. 2008). The most recent estimate of Dall's porpoise abundance in the eastern Pacific U.S. EEZ is 42,000, based on the mean of estimates from 2005 and 2008 summer/autumn surveys of California, Oregon, and Washington waters (Carretta et al. 2011a).

Dall's porpoises are typically seen in groups of 2–12; groups of >20–30 are uncommon, and aggregations of several thousands have been reported (Jefferson et al. 2008). In the Bering Sea, average group size was 2.7–3.7 (Moore et al. 2002). Mean group size on the U.S. west coast was 4.2 in 2008 (Barlow 2010). They are fast swimming and active porpoises, and readily approach vessels to ride the bow wave. Data from one tagged Dall's porpoise showed a mean dive depth of 33.4 m for a mean duration of 1.3 min (Hanson and Baird 1998).

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; Carretta et al. 2011a). 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).

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. 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). 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). The abundance estimate for pooled 1991–2008 surveys off Oregon/Washington was 27,010 (Barlow 2010).

Pinnipeds

Northern Fur Seal (*Callorhinus ursinus*)

The northern fur seal is endemic to the North Pacific Ocean, and it occurs from southern California to the Bering Sea, the Okhotsk Sea, and Honshu Island, Japan (Angliss and Allen 2011). Two stocks are recognized in U.S. waters: the Eastern Pacific and the San Miguel Island 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. 2011a; Angliss and Allen 2011). 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 653,171 (Angliss and Allen 2011). They were subjected to large-scale harvests on the Pribilof Islands to supply a lucrative fur trade. Abundance of the Eastern Pacific Stock has been decreasing at the Pribilof Islands since the 1940s and increasing on Bogoslof Island. The San Miguel Island stock is much smaller, estimated at 9968 (Carretta et al. 2011a).

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 British Columbia, Washington, Oregon, and California before migrating north again to the rookeries in spring (Ream et al.

2005). 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). The San Miguel Island stock is believed to remain predominantly offshore from California year round (Carretta et al. 2011a).

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, 2002a). The remainder of its life is spent on or near rookery islands or haulouts on rocky shorelines (Carretta et al. 2011a). Adult males usually occur on shore from May to August, though some may be present until November, and females are usually found ashore from June to November. 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 2002a). Kooyman and Goebel (1986) reported that the mean dive depth for tagged females was 32–207 m. The mean dive depth for tagged juvenile males was 17.5 m, with a maximum depth of 175 m. Deeper diving tended to occur on the shelf, with shallower diving off the shelf (Sterling and Ream 2004).

Bonnell et al. (1992) noted the presence of northern fur seals year-round off Oregon and 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). During the proposed survey period (July), only juveniles would be at sea.

California Sea Lion (*Zalophus californianus*)

The California sea lion is distributed along the mainland and offshore islands of the eastern North Pacific Ocean from British Columbia, Canada, to central Mexico, including the Gulf of California (Jefferson et al. 2008). The species is occasionally recorded outside of its normal range, as far as Alaska to the north (Maniscalco et al. 2004) and southern Mexico to the south (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. Five genetically distinct geographic populations have recently been identified: (1) Pacific Temperate (which includes rookeries within U.S. waters and the Coronados Islands), (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 survey areas. Based on a 2008 pup count, the California sea lion population is estimated at 296,750 (Carretta et al. 2011b).

In California and Baja California, births occur on land from mid May to late June. Females are ready to breed and actively solicit mates ~3 weeks after giving birth (Odell 1984; Trillmich 1986). Males establish territories that they defend from other males. Pups are able to swim soon after birth, and at 2–3 weeks of age, they form groups with other young pups. During August and September, after the mating season, the adult males migrate northward to feeding areas in Oregon, Washington, and B.C. (Lowry et al. 1992). They remain there until spring (March–May), when they migrate back to the breeding colonies (Lowry et al. 1992; Weise et al. 2006). The distribution of immature 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 immature seals are presumed to remain near the rookeries for most of the year (Lowry et al. 1992). Adult females remain near the rookeries throughout the year.

California sea lions are coastal animals that often haul out on shore throughout the year. 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 (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). Most dives of tagged females on San Miguel Island were <80 m deep, and less than 5% of dives were in water depths >200 m. The deepest dive recorded was estimated at 274 m (Feldkamp et al. 1989).

Off Oregon/Washington, most California sea lions occur in the fall (Bonnell et al. 1992). California sea lions are likely to be rare in the proposed survey areas during the planned July survey period, and no takes are anticipated or requested.

Steller Sea Lion (*Eumetopias jubatus*)

The Steller sea lion ranges along the North Pacific Rim from northern Japan to California (Loughlin et al. 1984). The species is listed under the ESA as ***Threatened*** in the eastern portion of its range and as ***Endangered*** in the western portion, west of 144°W. It is listed as ***Endangered*** on the IUCN Red List of Threatened Species (IUCN 2011). The major anthropogenic factors that likely contributed to a decline of the western population are by-catch in fisheries, commercial hunting of sea lions, and legal and illegal shooting of sea lions (Atkinson et al. 2008). Minimum population sizes of the U.S. Eastern Stock, including animals in Alaska, B.C., Washington, Oregon, and California, and the U.S. Western Stock are estimated at 58,334–72,223 and 42,366, respectively (Allen and Angliss 2011). The eastern stock is thought to be increasing at a rate of 3.1% annually (Pitcher et al. 2007).

In August–September 2010, the states of Oregon and Washington and the State of Alaska petitioned NMFS to delist the Eastern Designated Population Segment (DPS) of Steller sea lions. In a 90-day petition finding issued on 13 December 2010, NMFS found that the petitions' action could be warranted (NMFS 2010a). The federal agency is now in the ESA process of determining whether or not delisting is indeed warranted.

Breeding adults occupy rookeries from late May to early July (NMFS 2008b). The eastern stock of Steller sea lion rookeries are located in southeast Alaska, British Columbia, Oregon, and California (Allen and Angliss 2011). Males arrive at rookeries in May to establish their territory and are soon followed by females. Non-breeding males use haulouts or occupy sites at the periphery of rookeries during the breeding season (NRC 2003). Pupping occurs from mid May to mid July (Pitcher and Calkins 1981) and peaks in June (Pitcher et al. 2002). In Oregon, breeding occurs during the months of June and July (USFWS 2011).

Territorial males fast and remain on land during the breeding season (NMFS 2008b). 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 2008b). 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). 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, with the farthest sighting ~40 km from shore; all sightings occurred near or in waters <200 m deep.

Three rookeries and seven haul-out sites are located in Oregon; several haul-out sites are also located in Washington (NMFS 2008b). Jeffries et al. (2000) identified four haul-out sites in the Split Rock area (47.4°N); animals at these haulout locations are assumed to be immatures and non-breeding adults associated with rookeries in Oregon and British Columbia (Pitcher et al. 2007). The mean count of non-pups on Washington haul-out sites during 16 June–15 July 2001 was 516. The total number of Steller sea lions at rookeries and haul-out sites in Oregon in 2002 was estimated at 5076–5753 (NMFS 2008b).

The Steller sea lion rookery closest to the survey area is the Three Arch Rocks rookery (Fig. 1) located ~95 km from the southern survey area and ~180 km from the northern survey area. Two other rookeries, Orford Reef and Rogue Reef, are designated as Critical Habitat; they are located ~110 and ~155 km south of the southern survey area, respectively. The eastern boundary of the seismic survey lines is located ~15 km from shore, potentially within Stellar sea lion foraging range.

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. 2011a). Three separate stocks of harbor seals are recognized along the U.S. west coast: (1) Washington Inland Waters Stock, (2) Oregon and Washington Coastal Stock from Cape Flaherty (~48.4°N) to ~42°N, and (3) California Stock (Carretta et al. 2011a). The Oregon and Washington Coast Stock occurs in the proposed survey areas. The most recent estimate for the Oregon/Washington coastal stock is 24,732 (based on counts in 1999). The 1999 count of harbor seals along the outer Olympic Peninsula region alone was 7117 (Jeffries et al. 2003).

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). Juvenile harbor seals can travel significant distances (525 km) to forage or disperse, whereas adults were generally found within 190 km of their tagging location in PWS (Lowry et al. 2001). The smaller home range used by adults is suggestive of a strong site fidelity (Pitcher and Calkins 1979; Pitcher and McAllister 1981; Lowry et al. 2001). Pups tagged in the 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 PWS 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). Most diving activity occurs at night (Hastings et al. 2004). Bowen et al. (1999) found that lactating females from Sable Island, Nova Scotia, spent 45% of time on land with their pups, 55% of time at sea, and only 9% of the total time actively diving. Median depth and duration of dive are positively correlated with body mass; large adult male harbor seals in Monterey Bay generally dove deeper (mean

51.9 m) and longer than smaller adult females (mean 39.8 m). Most dives were to <100 m (Eguchi and Harvey 2005).

Female harbor seals give birth to a single pup while hauled out on shore or on glacial ice flows; pups are born from May to mid July. The mother and pup remain together until weaning occurs at 3–6 weeks (Bigg 1969). Little is known about breeding behavior in harbor seals. When molting, which occurs primarily in late August, seals spend the majority of the time hauled out on shore, glacial ice, or other substrates.

Harbor seals haul out on rocks, reefs, beaches, and offshore islands along the U.S. west coast (Carretta et al. 2011b). Jeffries et al. (2000) documented several harbor seal rookeries and haulouts along the Washington coastline. This is the only pinniped species that breeds in Washington State. 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. 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).

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 was later 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 124,000 in 2005 (Carretta et al. 2011a).

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. Females spend only ~34 days on shore. Juvenile elephant seals typically leave the rookeries in April or May and head north, traveling an average of 900–1000 km. Most elephant seals return to their natal rookeries when they start breeding (Huber et al. 1991).

When not 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). Elephant seals feed on deep-water fish and squid (Condit and Le Boeuf 1984). Davis et al. (2001) recorded an average dive depth of 186 m with range of 8–430 m for an elephant seal returning to the beach. Hindell (2009) noted that traveling likely takes place at depths >200 m.

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 British Columbia (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).

Most elephant seal sightings at sea were during June, July, and September off Washington; sightings recorded from November through May were off southern Oregon (Bonnell et al. 1992). During the survey period in July, occurrence in the survey areas could include adult females, juveniles, and pups of the year.

V. Type of Incidental Take Authorization Requested

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

L-DEO requests an IHA pursuant to Section 101 (a)(5)(D) of the Marine Mammal Protection Act (MMPA) for incidental take by harassment during its planned seismic survey in the northeastern Pacific Ocean during July 2012.

The operations outlined in § I have the potential to take marine mammals by harassment. Sounds will be generated by the airguns used during the survey, by echosounders, and by general vessel operations. "Takes" by harassment will potentially result when marine mammals near the activities are exposed to the pulsed sounds generated by the airguns or echosounders. The effects will depend on the species of marine mammal, the behavior of the animal at the time of reception of the stimulus, as well as the distance and received level of the sound (see § VII). Disturbance reactions are likely amongst some of the marine mammals near the tracklines of the source vessel. No take by serious injury is anticipated, given the nature of the planned operations and the mitigation measures that are planned (see § XI, Mitigation Measures). No lethal takes are expected.

VI. Numbers of Marine Mammals That Could be Taken

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

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

VII. Anticipated Impact on Species or Stocks

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

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

- First we summarize the potential impacts on marine mammals of airgun operations, as called for in § VII. A more comprehensive review of the relevant background information appears in Appendix B of the EA that supports this application.
- Then we discuss the potential impacts of operations by the echosounders.
- Finally, we estimate the numbers of marine mammals that could be affected by the proposed survey in the northeastern Pacific Ocean during July 2012. This section includes a description of the rationale for the estimates of the potential numbers of harassment "takes" during the planned survey, as called for in § VI.

Summary of Potential Effects of Airgun Sounds

The effects of sounds from airguns could include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and at least in theory, temporary or permanent hearing impairment, or non-auditory physical or physiological effects (Richardson et al. 1995; Gordon et al. 2004; Nowacek et al. 2007; Southall et al. 2007). Permanent hearing impairment, in the unlikely event that it occurred, would constitute injury, but temporary threshold shift (TTS) is not an injury (Southall et al. 2007). Although the possibility cannot be entirely excluded, it is unlikely that the project would result in any cases of temporary or especially permanent hearing impairment, or any significant non-auditory physical or physiological effects. Some behavioral disturbance is expected, but this would be localized and short-term.

Tolerance

Numerous studies have shown that pulsed sounds from airguns are often readily detectable in the water at distances of many kilometers. For a summary of the characteristics of airgun pulses, see Appendix B (3) of the EA. Several studies have shown that marine mammals at distances more than a few kilometers from operating seismic vessels often show no apparent response—see Appendix B (5) of the EA. That is often true even in cases when the pulsed sounds must be readily audible to the animals based on measured received levels and the hearing sensitivity of that mammal group. Although various baleen whales and toothed whales have been shown to react behaviorally to airgun pulses under some conditions, at other times mammals of both types have shown no overt reactions. The relative responsiveness of baleen and toothed whales are quite variable.

Masking

Masking effects of pulsed sounds (even from large arrays of airguns) on marine mammal calls and other natural sounds are expected to be limited, although there are very few specific data on this. Because of the intermittent nature and low duty cycle of seismic pulses, animals can emit and receive sounds in the relatively quiet intervals between pulses. However, in exceptional situations, reverberation occurs for much or all of the interval between pulses (e.g., Simard et al. 2005; Clark and Gagnon 2006) which could mask calls. Some baleen and toothed whales are known to continue calling in the presence of seismic pulses, and their calls usually can be heard between the seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999a,b; Nieukirk et al. 2004; Smultea et al. 2004; Holst et al. 2005a,b, 2006; Dunn and Hernandez 2009). However, Clark and Gagnon (2006) reported that fin whales in the northeast Pacific Ocean went silent for an extended period starting soon after the onset of a seismic survey in the area. Similarly, there has been one report that sperm whales ceased calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994). However, more recent studies found that they continued calling in the presence of seismic pulses (Madsen et al. 2002; Tyack et al. 2003; Smultea et al. 2004; Holst et al. 2006; Jochens et al. 2008). Dolphins and porpoises commonly are heard calling while airguns are operating (e.g., Gordon et al. 2004; Smultea et al. 2004; Holst et al. 2005a,b; Potter et al. 2007). The sounds important to small odontocetes are predominantly at much higher frequencies than are the dominant components of airgun sounds, thus limiting the potential for masking. In general, masking effects of seismic pulses are expected to be minor, given the normally intermittent nature of seismic pulses. Masking effects on marine mammals are discussed further in Appendix B (4) of the EA.

Disturbance Reactions

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

Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors (Richardson et al. 1995; Wartzok et al. 2004; Southall et al. 2007; Weilgart 2007). If a marine mammal does react briefly to an underwater sound by changing its behavior or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or population. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on individuals and populations could be significant (e.g., Lusseau and Bejder 2007; Weilgart 2007). Given the many uncertainties in predicting the quantity and types of impacts of noise on marine mammals, it is common practice to estimate how many mammals would be present within a particular distance of industrial activities and/or exposed to a particular level of industrial sound. In most cases, this approach likely overestimates the numbers of marine mammals that would be affected in some biologically-important manner.

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

Baleen Whales.—Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to pulses from large arrays of airguns at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, as reviewed in Appendix B (5) of the EA, baleen whales exposed to strong noise pulses from airguns often react by deviating from their normal migration route and/or interrupting their feeding and moving away. In the cases of migrating gray and bowhead whales, the observed changes in behavior appeared to be of little or no biological consequence to the animals. They simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors.

Studies of gray, bowhead, and humpback whales have shown that seismic pulses with received levels of 160–170 dB re 1 μPa_{rms} seem to cause obvious avoidance behavior in a substantial fraction of the animals exposed (Richardson et al. 1995). In many areas, seismic pulses from large arrays of airguns diminish to those levels at distances ranging from 4 to 15 km from the source. A substantial proportion of the baleen whales within those distances may show avoidance or other strong behavioral reactions to the airgun array. Subtle behavioral changes sometimes become evident at somewhat lower received levels, and studies summarized in Appendix B (5) of the EA have shown that some species of baleen whales, notably bowhead and humpback whales, at times show strong avoidance at received levels lower than 160–170 dB re 1 μPa_{rms}.

Responses of *humpback whales* to seismic surveys have been studied during migration, on summer feeding grounds, and on Angolan winter breeding grounds; there has also been discussion of effects on the Brazilian wintering grounds. McCauley et al. (1998, 2000a) studied the responses of humpback whales off Western Australia to a full-scale seismic survey with a 16-airgun, 2678-in^3 array, and to a single 20-in^3 airgun with source level 227 dB re 1 $\mu Pa \cdot m_{p-p}$. McCauley et al. (1998) documented that avoidance reactions began at 5–8 km from the array, and that those reactions kept most pods ~3–4 km from the operating seismic boat. McCauley et al. (2000a) noted localized displacement during migration of 4–5 km by traveling pods and 7–12 km by more sensitive resting pods of cow-calf pairs. Avoidance distances with respect to the single airgun were smaller but consistent with the results from the full array in terms of the received sound levels. The mean received level for initial avoidance of an approaching airgun was 140 dB re 1 µPa_{rms} for humpback pods containing females, and at the mean closest point of approach (CPA) distance the received level was 143 dB re 1 µPa_{rms}. The initial avoidance response generally occurred at distances of 5–8 km from the airgun array and 2 km from the single airgun. However, some individual humpback whales, especially males, approached within distances of 100–400 m, where the maximum received level was 179 dB re 1 µPa_{rms}.

Data collected by observers during several seismic surveys in the Northwest Atlantic showed that sighting rates of humpback whales were significantly greater during periods of no seismic compared with periods when a full array was operating (Moulton and Holst 2010). In addition, humpback whales were more likely to swim away and less likely to swim towards a vessel during seismic vs. non-seismic periods (Moulton and Holst 2010).

Humpback whales on their summer feeding grounds in southeast Alaska did not exhibit persistent avoidance when exposed to seismic pulses from a 1.64-L (100-in^3) airgun (Malme et al. 1985). Some humpbacks seemed "startled" at received levels of 150–169 dB re 1 µPa. Malme et al. (1985) concluded that there was no clear evidence of avoidance, despite the possibility of subtle effects, at received levels up to 172 re 1 µPa on an approximate rms basis. However, Moulton and Holst (2010) reported that humpback whales monitored during seismic surveys in the Northwest Atlantic had lower sighting rates and were most often seen swimming away from the vessel during seismic periods compared with periods when airguns were silent.

It has been suggested that South Atlantic humpback whales wintering off Brazil may be displaced or even strand upon exposure to seismic surveys (Engel et al. 2004). The evidence for this was circumstantial and subject to alternative explanations (IAGC 2004). Also, the evidence was not consistent with subsequent results from the same area of Brazil (Parente et al. 2006), or with direct studies of humpbacks exposed to seismic surveys in other areas and seasons. After allowance for data from subsequent years, there was "no observable direct correlation" between strandings and seismic surveys (IWC 2007:236).

There are no data on reactions of *right whales* to seismic surveys, but results from the closely-related *bowhead whale* show that their responsiveness can be quite variable depending on their activity (migrating vs. feeding). Bowhead whales migrating west across the Alaskan Beaufort Sea in autumn, in particular, are unusually responsive, with substantial avoidance occurring out to distances of 20–30 km from a medium-sized airgun source at received sound levels of around 120–130 dB re 1 µPa_{rms} [Miller et al. 1999; Richardson et al. 1999; see Appendix B (5) of the EA]. However, more recent research on bowhead whales (Miller et al. 2005; Harris et al. 2007) corroborates earlier evidence that, during the summer feeding season, bowheads are not as sensitive to seismic sources. Nonetheless, subtle but statistically significant changes in surfacing–respiration–dive cycles were evident upon statistical analysis (Richardson et al. 1986). In summer, bowheads typically begin to show avoidance reactions at received levels of about 152–178 dB re 1 µPa_{rms} (Richardson et al. 1986, 1995; Ljungblad et al. 1988; Miller et al. 2005).

Reactions of migrating and feeding (but not wintering) *gray whales* to seismic surveys have been studied. Malme et al. (1986, 1988) studied the responses of feeding eastern Pacific gray whales to pulses from a single 100-in^3 airgun off St. Lawrence Island in the northern Bering Sea. They estimated, based on small sample sizes, that 50% of feeding gray whales stopped feeding at an average received pressure level of 173 dB re 1 µPa on an (approximate) rms basis, and that 10% of feeding whales interrupted feeding at received levels of 163 dB re 1 µPa_{rms}. Those findings were generally consistent with the results of experiments conducted on larger numbers of gray whales that were migrating along the California coast (Malme et al. 1984; Malme and Miles 1985), and western Pacific gray whales feeding off Sakhalin

Island, Russia (Würsig et al. 1999; Gailey et al. 2007; Johnson et al. 2007; Yazvenko et al. 2007a,b), along with data on gray whales off British Columbia (Bain and Williams 2006).

Various species of *Balaenoptera* (blue, sei, fin, and minke whales) have occasionally been seen in areas ensonified by airgun pulses (Stone 2003; MacLean and Haley 2004; Stone and Tasker 2006), and calls from blue and fin whales have been localized in areas with airgun operations (e.g., McDonald et al. 1995; Dunn and Hernandez 2009; Castellote et al. 2010). Sightings by observers on seismic vessels off the United Kingdom from 1997 to 2000 suggest that, during times of good sightability, sighting rates for mysticetes (mainly fin and sei whales) were similar when large arrays of airguns were shooting vs. silent (Stone 2003; Stone and Tasker 2006). However, these whales tended to exhibit localized avoidance, remaining significantly further (on average) from the airgun array during seismic operations compared with non-seismic periods (Stone and Tasker 2006). Castellote et al. (2010) reported that singing fin whales in the Mediterranean moved away from an operating airgun array.

Ship-based monitoring studies of baleen whales (including blue, fin, sei, minke, and humpback whales) in the Northwest Atlantic found that overall, this group had lower sighting rates during seismic vs. non-seismic periods (Moulton and Holst 2010). Baleen whales as a group were also seen significantly farther from the vessel during seismic compared with non-seismic periods, and they were more often seen to be swimming away from the operating seismic vessel (Moulton and Holst 2010). Blue and minke whales were initially sighted significantly farther from the vessel during seismic operations compared to non-seismic periods; the same trend was observed for fin whales (Moulton and Holst 2010). Minke whales were most often observed to be swimming away from the vessel when seismic operations were underway (Moulton and Holst 2010).

Data on short-term reactions by cetaceans to impulsive noises are not necessarily indicative of long-term or biologically significant effects. It is not known whether impulsive sounds affect reproductive rate or distribution and habitat use in subsequent days or years. However, gray whales have continued to migrate annually along the west coast of North America with substantial increases in the population over recent years, despite intermittent seismic exploration (and much ship traffic) in that area for decades (Appendix A *in* Malme et al. 1984; Richardson et al. 1995; Allen and Angliss 2010). The western Pacific gray whale population did not seem affected by a seismic survey in its feeding ground during a previous year (Johnson et al. 2007). Similarly, bowhead whales have continued to travel to the eastern Beaufort Sea each summer, and their numbers have increased notably, despite seismic exploration in their summer and autumn range for many years (Richardson et al. 1987; Allen and Angliss 2010).

Toothed Whales.—Little systematic information is available about reactions of toothed whales to noise pulses. Few studies similar to the more extensive baleen whale/seismic pulse work summarized above and (in more detail) in Appendix B of the EA have been reported for toothed whales. However, there are recent systematic studies on sperm whales (e.g., Gordon et al. 2006; Madsen et al. 2006; Winsor and Mate 2006; Jochens et al. 2008; Miller et al. 2009). There is an increasing amount of information about responses of various odontocetes to seismic surveys based on monitoring studies (e.g., Stone 2003; Smultea et al. 2004; Moulton and Miller 2005; Bain and Williams 2006; Holst et al. 2006; Stone and Tasker 2006; Potter et al. 2007; Hauser et al. 2008; Holst and Smultea 2008; Weir 2008; Barkaszi et al. 2009; Richardson et al. 2009; Moulton and Holst 2010).

Seismic operators and marine mammal observers on seismic vessels regularly see dolphins and other small toothed whales near operating airgun arrays, but in general there is a tendency for most delphinids to show some avoidance of operating seismic vessels (e.g., Goold 1996a,b,c; Calambokidis and Osmek 1998; Stone 2003; Moulton and Miller 2005; Holst et al. 2006; Stone and Tasker 2006; Weir 2008; Barkaszi et al. 2009; Richardson et al. 2009; Moulton and Holst 2010). Some dolphins seem to be attracted to the seismic vessel and floats, and some ride the bow wave of the seismic vessel even when large arrays of airguns are firing (e.g., Moulton and Miller 2005). Nonetheless, small toothed whales more often tend to head away, or to maintain a somewhat greater distance from the vessel, when a large array of airguns is operating than when it is silent (e.g., Stone and Tasker 2006; Weir 2008; Barry et al. 2010; Moulton and Holst 2010). In most cases, the avoidance radii for delphinids appear to be small, on the order of 1 km less, and some individuals show no apparent avoidance. The beluga is a species that (at least at times) shows long-distance avoidance of seismic vessels. Aerial surveys conducted in the southeastern Beaufort Sea during summer found that sighting rates of beluga whales were significantly lower at distances 10–20 km compared with 20–30 km from an operating airgun array, and observers on seismic boats in that area rarely see belugas (Miller et al. 2005; Harris et al. 2007).

Captive bottlenose dolphins and beluga whales exhibited changes in behavior when exposed to strong pulsed sounds similar in duration to those typically used in seismic surveys (Finneran et al. 2000, 2002, 2005). However, the animals tolerated high received levels of sound before exhibiting aversive behaviors.

Results for porpoises depend on species. The limited available data suggest that harbor porpoises show stronger avoidance of seismic operations than do Dall's porpoises (Stone 2003; MacLean and Koski 2005; Bain and Williams 2006; Stone and Tasker 2006). Dall's porpoises seem relatively tolerant of airgun operations (MacLean and Koski 2005; Bain and Williams 2006), although they too have been observed to avoid large arrays of operating airguns (Calambokidis and Osmek 1998; Bain and Williams 2006). This apparent difference in responsiveness of these two porpoise species is consistent with their relative responsiveness to boat traffic and some other acoustic sources (Richardson et al. 1995; Southall et al. 2007).

Most studies of sperm whales exposed to airgun sounds indicate that the sperm whale shows considerable tolerance of airgun pulses (e.g., Stone 2003; Stone and Tasker 2006; Weir 2008; Moulton and Holst 2010). In most cases, the whales do not show strong avoidance, and they continue to call (see Appendix B of the EA for review). However, controlled exposure experiments in the Gulf of Mexico indicate that foraging behavior was altered upon exposure to airgun sound (Jochens et al. 2008; Miller et al. 2009; Tyack 2009).

There are almost no specific data on the behavioral reactions of beaked whales to seismic surveys. However, some northern bottlenose whales remained in the general area and continued to produce high-frequency clicks when exposed to sound pulses from distant seismic surveys (Gosselin and Lawson 2004; Laurinolli and Cochrane 2005; Simard et al. 2005). Most beaked whales tend to avoid approaching vessels of other types (e.g., Würsig et al. 1998). They may also dive for an extended period when approached by a vessel (e.g., Kasuya 1986), although it is uncertain how much longer such dives may be as compared to dives by undisturbed beaked whales, which also are often quite long (Baird et al. 2006; Tyack et al. 2006). Based on a single observation, Aguilar-Soto et al. (2006) suggested that foraging efficiency of Cuvier's beaked whales may be reduced by close approach of vessels. In any event, it is likely that most beaked whales would also show strong avoidance of an approaching seismic vessel, although this has not been documented explicitly. In fact, Moulton and Holst (2010) reported 15 sightings of beaked whales during seismic studies in the Northwest Atlantic; seven of those sightings were made at times when at least one airgun was operating. There was little evidence to indicate that beaked whale behavior was affected by airgun operations; sighting rates and distances were similar during seismic and non-seismic periods (Moulton and Holst 2010).

There are increasing indications that some beaked whales tend to strand when naval exercises involving mid-frequency sonar operation are ongoing nearby (e.g., Simmonds and Lopez-Jurado 1991; Frantzis 1998; NOAA and USN 2001; Jepson et al. 2003; Hildebrand 2005; Barlow and Gisiner 2006; see also the "Strandings and Mortality" subsection, later). These strandings are apparently at least in part a disturbance response, although auditory or other injuries or other physiological effects may also be involved. Whether beaked whales would ever react similarly to seismic surveys is unknown (see "Strandings and Mortality", below). Seismic survey sounds are quite different from those of the sonars in operation during the above-cited incidents.

Odontocete reactions to large arrays of airguns are variable and, at least for delphinids and Dall's porpoises, seem to be confined to a smaller radius than has been observed for the more responsive of the mysticetes, belugas, and harbor porpoises (Appendix B of the EA). A ≥170 dB re 1 µPa disturbance criterion (rather than ≥160 dB) is considered appropriate for delphinids, Dall's porpoise, and pinnipeds, which tend to be less responsive than the more responsive cetaceans.

Pinnipeds.—Pinnipeds are not likely to show a strong avoidance reaction to the airgun array. Visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds, and only slight (if any) changes in behavior—see Appendix B (5) of the EA. In the Beaufort Sea, some ringed seals avoided an area of 100 m to (at most) a few hundred meters around seismic vessels, but many seals remained within 100–200 m of the trackline as the operating airgun array passed by (e.g., Harris et al. 2001; Moulton and Lawson 2002; Miller et al. 2005). Ringed seal sightings averaged somewhat farther away from the seismic vessel when the airguns were operating than when they were not, but the difference was small (Moulton and Lawson 2002). Similarly, in Puget Sound, sighting distances for harbor seals and California sea lions tended to be larger when airguns were operating (Calambokidis and Osmek 1998). Previous telemetry work suggests that avoidance and other behavioral reactions may be stronger than evident to date from visual studies (Thompson et al. 1998).

Additional details on the behavioral reactions (or the lack thereof) by all types of marine mammals to seismic vessels can be found in Appendix B (5) of the EA.

Hearing Impairment and Other Physical Effects

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds. TTS has been demonstrated and studied in certain captive odontocetes and pinnipeds exposed to strong sounds (reviewed in Southall et al. 2007). However, there has been no specific documentation of TTS let alone permanent hearing damage, i.e., permanent threshold shift (PTS), in free-ranging marine mammals exposed to sequences of airgun pulses during realistic field conditions. Current NMFS policy regarding exposure of marine mammals to high-level sounds is that cetaceans should not be exposed to impulsive sounds with received levels ≥180 dB re 1 μPa_{rms} (NMFS 2000). This criterion has been used in establishing the exclusion (=shut-down) zones planned for the proposed seismic survey. However, this criterion was established before there was any information about minimum received levels of sounds necessary to cause auditory impairment in marine mammals. As discussed in Appendix B (6) of the EA and summarized here,

- the 180-dB criterion for cetaceans is probably quite precautionary, i.e., lower than necessary to avoid temporary auditory impairment let alone permanent auditory injury, at least for delphinids.
- TTS is not injury and does not constitute "Level A harassment" in U.S. MMPA terminology.
- the minimum sound level necessary to cause permanent hearing impairment ("Level A harassment") is higher, by a variable and generally unknown amount, than the level that induces barely-detectable TTS.
- the level associated with the onset of TTS is often considered to be a level below which there is no danger of permanent damage. The actual PTS threshold is likely to be well above the level causing onset of TTS (Southall et al. 2007).

Recommendations for new science-based noise exposure criteria for marine mammals, frequency-weighting procedures, and related matters have been published (Southall et al. 2007). Those recommendations have not, as of mid 2011, been formally adopted by NMFS for use in regulatory processes and during mitigation programs associated with seismic surveys. However, some aspects of the recommendations have been taken into account in certain environmental impact statements and small-take authorizations. NMFS has indicated that it may issue new noise exposure criteria for marine mammals that account for the now-available scientific data on TTS, the expected offset between the TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive (e.g., M-weighting or generalized frequency weightings for various groups of marine mammals, allowing for their functional bandwidths), and other relevant factors. Preliminary information about possible changes in the regulatory and mitigation requirements, and about the possible structure of new criteria, was given by Wieting (2004) and NMFS (2005).

Several aspects of the planned monitoring and mitigation measures for this project are designed to detect marine mammals occurring near the airgun array, and to avoid exposing them to sound pulses that might, at least in theory, cause hearing impairment (see § XI and § XIII). In addition, many cetaceans and (to a limited degree) sea turtles show some avoidance of the area where received levels of airgun sound are high enough such that hearing impairment could potentially occur. In those cases, the avoidance responses of the animals themselves will reduce or (most likely) avoid any possibility of hearing impairment.

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might (in theory) occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, and other types of organ or tissue damage. It is possible that some marine mammal species (i.e., beaked whales) may be especially susceptible to injury and/or stranding when exposed to strong transient sounds. However, as discussed below, there is no definitive evidence that any of these effects occur even for marine mammals in close proximity to large arrays of airguns. It is unlikely that any effects of these types would occur during the present project given the brief duration of exposure of any given mammal, and the planned monitoring and mitigation measures (see below). The following subsections discuss in somewhat more detail the possibilities of TTS, PTS, and non-auditory physical effects.

Temporary Threshold Shift.—TTS is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter 1985). While experiencing TTS, the hearing threshold rises and a sound must be stronger in order to be heard. At least in terrestrial mammals, TTS can last from minutes or hours to (in cases of strong TTS) days. For sound exposures at or somewhat above the TTS threshold, hearing sensitivity in both terrestrial and marine mammals recovers rapidly after exposure to the noise ends. Few data on sound levels and durations necessary to elicit mild TTS have been obtained for marine mammals, and none of the published data concern TTS elicited by exposure to multiple pulses of sound. Available data on TTS in marine mammals are summarized in Southall et al. (2007).

For toothed whales exposed to single short pulses, the TTS threshold appears to be, to a first approximation, a function of the energy content of the pulse (Finneran et al. 2002, 2005). Based on these data, the received energy level of a single seismic pulse (with no frequency weighting) might need to be ~186 dB re 1 $\mu Pa^2 \cdot s$ (i.e., 186 dB SEL or ~196–201 dB re 1 μPa_{rms}) in order to produce brief, mild TTS[1]. Exposure to several strong seismic pulses that each have received levels near 190 dB re 1 μPa_{rms} might

[1] If the low frequency components of the watergun sound used in the experiments of Finneran et al. (2002) are downweighted as recommended by Miller et al. (2005) and Southall et al. (2007) using their M_{mf}-weighting curve, the effective exposure level for onset of mild TTS was 183 dB re 1 $\mu Pa^2 \cdot s$ (Southall et al. 2007).

result in cumulative exposure of ~186 dB SEL and thus slight TTS in a small odontocete assuming the TTS threshold is (to a first approximation) a function of the total received pulse energy; however, this 'equal-energy' concept is an oversimplification. The distances from the *Langseth*'s airguns at which the received energy level (per pulse, flat-weighted) would be expected to be ≥190 dB re 1 μPa_{rms} are estimated in Table 1. Levels ≥190 dB re 1 μPa_{rms} are expected to be restricted to radii no more than 770 m (Table 1). For an odontocete closer to the surface, the maximum radius with ≥190 dB re 1 μPa_{rms} would be smaller.

The above TTS information for odontocetes is derived from studies on the bottlenose dolphin and beluga. For the one harbor porpoise tested, the received level of airgun sound that elicited onset of TTS was lower (Lucke et al. 2009). If these results from a single animal are representative, it is inappropriate to assume that onset of TTS occurs at similar received levels in all odontocetes (*cf.* Southall et al. 2007). Some cetaceans apparently can incur TTS at considerably lower sound exposures than are necessary to elicit TTS in the beluga or bottlenose dolphin.

For baleen whales, there are no data, direct or indirect, on levels or properties of sound that are required to induce TTS. The frequencies to which baleen whales are most sensitive are assumed to be lower than those to which odontocetes are most sensitive, and natural background noise levels at those low frequencies tend to be higher. As a result, auditory thresholds of baleen whales within their frequency band of best hearing are believed to be higher (less sensitive) than are those of odontocetes at their best frequencies (Clark and Ellison 2004). From this, it is suspected that received levels causing TTS onset may also be higher in baleen whales (Southall et al. 2007). In any event, no cases of TTS are expected given three considerations: (1) the low abundance of baleen whales in the planned study area at the time of the survey; (2) the strong likelihood that baleen whales would avoid the approaching airguns (or vessel) before being exposed to levels high enough for TTS to occur; and (3) the mitigation measures that are planned.

In pinnipeds, TTS thresholds associated with exposure to brief pulses (single or multiple) of underwater sound have not been measured. Initial evidence from more prolonged (non-pulse) exposures suggested that some pinnipeds (harbor seals in particular) incur TTS at somewhat lower received levels than do small odontocetes exposed for similar durations (Kastak et al. 1999, 2005; Ketten et al. 2001). The TTS threshold for pulsed sounds has been indirectly estimated as being an SEL of ~171 dB re 1 $\mu Pa^2 \cdot s$ (Southall et al. 2007), which would be equivalent to a single pulse with received level ~181–186 dB re 1 $\mu Pa_{rms,}$ or a series of pulses for which the highest rms values are a few dB lower. Corresponding values for California sea lions and northern elephant seals are likely to be higher (Kastak et al. 2005).

NMFS (1995, 2000) concluded that cetaceans and pinnipeds should not be exposed to pulsed under-water noise at received levels exceeding, respectively, 180 and 190 dB re 1 μPa_{rms}. Those sound levels are ***not*** considered to be the levels above which TTS might occur. Rather, they were the received levels above which, in the view of a panel of bioacoustics specialists convened by NMFS before TTS measurements for marine mammals started to become available, one could not be certain that there would be no injurious effects, auditory or otherwise, to marine mammals. As summarized above and in Southall et al. (2007), data that are now available imply that TTS is unlikely to occur in most odontocetes (and probably mysticetes as well) unless they are exposed to a sequence of several airgun pulses stronger than 190 dB re 1 μPa_{rms}. For the harbor seal and any species with similarly low TTS thresholds, TTS may occur upon exposure to one or more airgun pulses whose received level equals the NMFS "do not exceed" value of 190 dB re 1 μPa_{rms}. That criterion corresponds to a single-pulse SEL of 175–180 dB re 1 $\mu Pa^2 \cdot s$ in typical conditions, whereas TTS is suspected to be possible (in harbor seals) with a cumulative SEL of ~171 dB re 1 $\mu Pa^2 \cdot s$.

Permanent Threshold Shift.—When PTS occurs, there is physical damage to the sound receptors in the ear. In severe cases, there can be total or partial deafness, whereas in other cases, the animal has an impaired ability to hear sounds in specific frequency ranges (Kryter 1985).

There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal, even with large arrays of airguns. However, given the possibility that mammals close to an airgun array might incur at least mild TTS, there has been further speculation about the possibility that some individuals occurring very close to airguns might incur PTS (e.g., Richardson et al. 1995, p. 372*ff*; Gedamke et al. 2008). Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage, but repeated or (in some cases) single exposures to a level well above that causing TTS onset might elicit PTS.

Relationships between TTS and PTS thresholds have not been studied in marine mammals, but are assumed to be similar to those in humans and other terrestrial mammals. PTS might occur at a received sound level at least several decibels above that inducing mild TTS if the animal were exposed to strong sound pulses with rapid rise time—see Appendix B (6) of the EA. Based on data from terrestrial mammals, a precautionary assumption is that the PTS threshold for impulse sounds (such as airgun pulses as received close to the source) is *at least* 6 dB higher than the TTS threshold on a peak-pressure basis, and probably >6 dB (Southall et al. 2007). On an SEL basis, Southall et al. (2007:441-4) estimated that received levels would need to exceed the TTS threshold by at least 15 dB for there to be risk of PTS. Thus, for cetaceans they estimate that the PTS threshold might be an M-weighted SEL (for the sequence of received pulses) of ~198 dB re 1 $\mu Pa^2 \cdot s$ (15 dB higher than the M_{mf}-weighted TTS threshold, in a beluga, for a watergun impulse), where the SEL value is cumulated over the sequence of pulses. Additional assumptions had to be made to derive a corresponding estimate for pinnipeds, as the only available data on TTS-thresholds in pinnipeds pertain to non-impulse sound. Southall et al. (2007) estimate that the PTS threshold could be a cumulative M_{pw}-weighted SEL of ~186 dB re 1 $\mu Pa^2 \cdot s$ in the harbor seal exposed to impulse sound. The PTS threshold for the California sea lion and northern elephant seal would probably be higher, given the higher TTS thresholds in those species.

Southall et al. (2007) also note that, regardless of the SEL, there is concern about the possibility of PTS if a cetacean received one or more pulses with peak pressure exceeding 230 or 218 dB re 1 μPa (peak), respectively. Thus, PTS might be expected upon exposure of cetaceans to *either* SEL ≥198 dB re 1 $\mu Pa^2 \cdot s$ *or* peak pressure ≥ 230 dB re 1 μPa. Corresponding proposed dual criteria for pinnipeds (at least harbor seals) are ≥ 186 dB SEL and ≥ 218 dB peak pressure (Southall et al. 2007). These estimates are all first approximations, given the limited underlying data, assumptions, species differences, and evidence that the "equal energy" model may not be entirely correct. A peak pressure of 230 dB re 1 μPa (3.2 bar · m, 0-pk) would only be found within a few meters of the largest (360-in^3) airguns in the planned airgun array (e.g., Caldwell and Dragoset 2000). A peak pressure of 218 dB re 1 μPa could be received somewhat farther away; to estimate that specific distance, one would need to apply a model that accurately calculates peak pressures in the near-field around an array of airguns.

Given the higher level of sound necessary to cause PTS as compared with TTS, it is considerably less likely that PTS would occur. Baleen whales generally avoid the immediate area around operating seismic vessels, as do some other marine mammals and sea turtles. The planned monitoring and mitigation measures, including visual monitoring, passive acoustic monitoring (PAM) to complement visual observations (if practicable), power downs, and shut downs of the airguns when mammals are seen within or approaching the "exclusion zones", will further reduce the probability of exposure of marine mammals to sounds strong enough to induce PTS.

Stranding and Mortality.— Marine mammals close to underwater detonations of high explosives can be killed or severely injured, and the auditory organs are especially susceptible to injury (Ketten et al. 1993; Ketten 1995). However, explosives are no longer used for marine waters for commercial seismic surveys or (with rare exceptions) for seismic research; they have been replaced entirely by airguns or related non-explosive pulse generators. Airgun pulses are less energetic and have slower rise times, and there is no specific evidence that they can cause serious injury, death, or stranding even in the case of large airgun arrays. However, the association of strandings of beaked whales with naval exercises and, in one case, an L-DEO seismic survey (Malakoff 2002; Cox et al. 2006), has raised the possibility that beaked whales exposed to strong "pulsed" sounds may be especially susceptible to injury and/or behavioral reactions that can lead to stranding (e.g., Hildebrand 2005; Southall et al. 2007). Appendix B (6) of the EA provides additional details.

Specific sound-related processes that lead to strandings and mortality are not well documented, but may include (1) swimming in avoidance of a sound into shallow water; (2) a change in behavior (such as a change in diving behavior) that might contribute to tissue damage, gas bubble formation, hypoxia, cardiac arrhythmia, hypertensive hemorrhage or other forms of trauma; (3) a physiological change such as a vestibular response leading to a behavioral change or stress-induced hemorrhagic diathesis, leading in turn to tissue damage; and (4) tissue damage directly from sound exposure, such as through acoustically mediated bubble formation and growth or acoustic resonance of tissues. Some of these mechanisms are unlikely to apply in the case of impulse sounds. However, there are increasing indications that gas-bubble disease (analogous to "the bends"), induced in supersaturated tissue by a behavioral response to acoustic exposure, could be a pathologic mechanism for the strandings and mortality of some deep-diving cetaceans exposed to sonar. However, the evidence for this remains circumstantial and associated with exposure to naval mid-frequency sonar, not seismic surveys (Cox et al. 2006; Southall et al. 2007).

Seismic pulses and mid-frequency sonar signals are quite different, and some mechanisms by which sonar sounds have been hypothesized to affect beaked whales are unlikely to apply to airgun pulses. Sounds produced by airgun arrays are broadband impulses with most of the energy below 1 kHz. Typical military mid-frequency sonars emit non-impulse sounds at frequencies of 2–10 kHz, generally with a relatively narrow bandwidth at any one time. A further difference between seismic surveys and naval exercises is that naval exercises can involve sound sources on more than one vessel. Thus, it is not appropriate to assume that there is a direct connection between the effects of military sonar and seismic surveys on marine mammals. However, evidence that sonar signals can, in special circumstances, lead (at least indirectly) to physical damage and mortality (e.g., Balcomb and Claridge 2001; NOAA and USN 2001; Jepson et al. 2003; Fernández et al. 2004, 2005; Hildebrand 2005; Cox et al. 2006) suggests that caution is warranted when dealing with exposure of marine mammals to any high-intensity pulsed sound.

There is no conclusive evidence of cetacean strandings or deaths at sea as a result of exposure to seismic surveys, but a few cases of strandings in the general area where a seismic survey was ongoing have led to speculation concerning a possible link between seismic surveys and strandings. Suggestions that there was a link between seismic surveys and strandings of humpback whales in Brazil (Engel et al. 2004) were not well founded (IAGC 2004; IWC 2007). In September 2002, there was a stranding of two Cuvier's beaked whales in the Gulf of California, Mexico, when the L-DEO vessel R/V *Maurice Ewing* was operating a 20-airgun, 8490-in^3 airgun array in the general area. The link between the stranding and the seismic surveys was inconclusive and not based on any physical evidence (Hogarth 2002; Yoder 2002). Nonetheless, the Gulf of California incident plus the beaked whale strandings near naval exercises involving use of mid-frequency sonar suggests a need for caution in conducting seismic surveys in areas occupied by beaked whales until more is known about effects of seismic surveys on those species (Hildebrand 2005). No injuries of beaked whales are anticipated during the proposed study because of (1) the high likelihood that any beaked whales nearby would avoid the approaching vessel before being exposed to high sound levels, (2) the proposed monitoring and mitigation measures, and (3) differences between the sound sources operated by L-DEO and those involved in the naval exercises associated with strandings.

Non-auditory Physiological Effects.—Non-auditory physiological effects or injuries that theoretically might occur in marine mammals exposed to strong underwater sound include stress, neurological effects, bubble formation, resonance, and other types of organ or tissue damage (Cox et al. 2006; Southall et al. 2007). Studies examining such effects are limited. However, resonance effects (Gentry 2002) and direct noise-induced bubble formation (Crum et al. 2005) are implausible in the case of exposure to an impulsive broadband source like an airgun array. If seismic surveys disrupt diving patterns of deep-diving species, this might perhaps result in bubble formation and a form of "the bends", as speculated to occur in beaked whales exposed to sonar. However, there is no specific evidence of this upon exposure to airgun pulses.

In general, very little is known about the potential for seismic survey sounds (or other types of strong underwater sounds) to cause non-auditory physical effects in marine mammals. Such effects, if they occur at all, would presumably be limited to short distances and to activities that extend over a prolonged period. The available data do not allow identification of a specific exposure level above which non-auditory effects can be expected (Southall et al. 2007), or any meaningful quantitative predictions of the numbers (if any) of marine mammals that might be affected in those ways. Marine mammals that show behavioral avoidance of seismic vessels, including most baleen whales, some odontocetes, and some pinnipeds are especially unlikely to incur non-auditory physical effects. Also, the planned mitigation measures (§ XI), including shut downs of the airguns, will reduce any such effects that might otherwise occur.

Possible Effects of Multibeam Echosounder Signals

The Kongsberg EM 122 MBES will be operated from the source vessel during the planned study. Information about this equipment was provided in § II. Sounds from the MBES are very short pulses, occurring for 2–15 ms once every 5–20 s, depending on water depth. Most of the energy in the sound emitted by this MBES is at frequencies near 12 kHz, and the maximum source level is 242 dB re 1 $\mu Pa_{rms} \cdot m$. The beam is narrow (1–2º) in fore-aft extent and wide (150º) in the cross-track extent. Each ping consists of eight (in water >1000 m deep) or four (<1000 m deep) successive fan-shaped transmissions (segments) at different cross-track angles. Any given mammal at depth near the trackline would be in the main beam for only one or two of the segments. Also, marine mammals that encounter the Kongsberg EM 122 are unlikely to be subjected to repeated pulses because of the narrow fore–aft width of the beam and will receive only limited amounts of pulse energy because of the short pulses. Animals close to the ship (where the beam is narrowest) are especially unlikely to be ensonified for more than one 2–15 ms pulse (or two pulses if in the overlap area). Similarly, Kremser et al. (2005) noted that the probability of a cetacean swimming through the area of exposure when an MBES emits a pulse is small. The animal would have to pass the transducer at close range and be swimming at speeds similar to the vessel in order to receive the multiple pulses that might result in sufficient exposure to cause TTS.

Navy sonars that have been linked to avoidance reactions and stranding of cetaceans (1) generally have a longer pulse duration than the Kongsberg EM 122, and (2) are often directed close to horizontally vs. more downward for the MBES. The area of possible influence of the MBES is much smaller—a narrow band below the source vessel. The duration of exposure for a given marine mammal can be much longer for a naval sonar. During L-DEO's operations, the individual pulses will be very short, and a given mammal would not receive many of the downward-directed pulses as the vessel passes by. Possible effects of an MBES on marine mammals are outlined below.

Masking

Marine mammal communications will not be masked appreciably by the MBES signals given the low duty cycle of the echosounder and the brief period when an individual mammal is likely to be within its beam. Furthermore, in the case of baleen whales, the MBES signals (12 kHz) do not overlap with the predominant frequencies in the calls, which would avoid any significant masking.

Behavioral Responses

Behavioral reactions of free-ranging marine mammals to sonars, echosounders, and other sound sources appear to vary by species and circumstance. Observed reactions have included silencing and dispersal by sperm whales (Watkins et al. 1985), increased vocalizations and no dispersal by pilot whales (Rendell and Gordon 1999), and the previously-mentioned beachings by beaked whales. During exposure to a 21–25 kHz "whale-finding" sonar with a source level of 215 dB re 1 μPa · m, gray whales reacted by orienting slightly away from the source and being deflected from their course by ~200 m (Frankel 2005). When a 38-kHz echosounder and a 150-kHz acoustic Doppler current profiler were transmitting during studies in the ETP, baleen whales showed no significant responses, whereas spotted and spinner dolphins were detected slightly more often and beaked whales less often during visual surveys (Gerrodette and Pettis 2005).

Captive bottlenose dolphins and a white whale exhibited changes in behavior when exposed to 1-s tonal signals at frequencies similar to those that will be emitted by the MBES used by L-DEO, and to shorter broadband pulsed signals. Behavioral changes typically involved what appeared to be deliberate attempts to avoid the sound exposure (Schlundt et al. 2000; Finneran et al. 2002; Finneran and Schlundt 2004). The relevance of those data to free-ranging odontocetes is uncertain, and in any case, the test sounds were quite different in duration as compared with those from an MBES.

Very few data are available on the reactions of pinnipeds to echosounder sounds at frequencies similar to those used during seismic operations. Hastie and Janik (2007) conducted a series of behavioral response tests on two captive gray seals to determine their reactions to underwater operation of a 375-kHz multibeam imaging echosounder that included significant signal components down to 6 kHz. Results indicated that the two seals reacted to the signal by significantly increasing their dive durations. Because of the likely brevity of exposure to the MBES sounds, pinniped reactions are expected to be limited to startle or otherwise brief responses of no lasting consequence to the animals.

Hearing Impairment and Other Physical Effects

Given recent stranding events that have been associated with the operation of naval sonar, there is concern that mid-frequency sonar sounds can cause serious impacts to marine mammals (see above). However, the MBES proposed for use by L-DEO is quite different than sonars used for navy operations. Pulse duration of the MBES is very short relative to the naval sonars. Also, at any given location, an individual marine mammal would be in the beam of the MBES for much less time given the generally downward orientation of the beam and its narrow fore-aft beamwidth; navy sonars often use near-horizontally-directed sound. Those factors would all reduce the sound energy received from the MBES rather drastically relative to that from the sonars used by the navy.

Given the maximum source level of 242 dB re 1 $\mu Pa \cdot m_{rms}$ (see § I), the received level for an animal within the MBES beam 100 m below the ship would be ~202 dB re 1 μPa_{rms}, assuming 40 dB of spreading loss over 100 m (circular spreading). Given the narrow beam, only one pulse is likely to be received by a given animal as the ship passes overhead. The received energy level from a single pulse of duration 15 ms would be about 184 dB re 1 $\mu Pa^2 \cdot s$, i.e., 202 dB + 10 log (0.015 s). That is below the TTS threshold for a cetacean receiving a single non-impulse sound (195 dB re 1 $\mu Pa^2 \cdot s$) and even further below the anticipated PTS threshold (215 dB re 1 $\mu Pa^2 \cdot s$) (Southall et al. 2007). In contrast, an animal that was only 10 m below the MBES when a ping is emitted would be expected to receive a level ~20 dB higher, i.e., 204 dB re 1 $\mu Pa^2 \cdot s$ in the case of the EM 122. That animal might incur some TTS (which would be fully recoverable), but the exposure would still be below the anticipated PTS threshold for cetaceans. As noted by Burkhardt et al. (2007, 2008), cetaceans are very unlikely to incur PTS from operation of scientific sonars on a ship that is underway.

In the harbor seal, the TTS threshold for non-impulse sounds is about 183 dB re 1 $\mu Pa^2 \cdot s$, as compared with ~195 dB re 1 $\mu Pa^2 \cdot s$ in odontocetes (Kastak et al. 2005; Southall et al. 2007). TTS onset occurs at higher received energy levels in the California sea lion and northern elephant seal than in the harbor seal. A harbor seal as much as 100 m below the *Langseth* could receive a single MBES ping with received energy level of ≥184 dB re 1 $\mu Pa^2 \cdot s$ (as calculated in the toothed whale subsection above) and thus could incur slight TTS. Species of pinnipeds with higher TTS thresholds would not incur TTS unless they were closer to the transducers when a ping was emitted. However, the SEL criterion for PTS in pinnipeds (203 dB re 1 $\mu Pa^2 \cdot s$) might be exceeded for a ping received within a few meters of the transducers, although the risk of PTS is higher for certain species (e.g., harbor seal). Given the intermittent nature of the signals and the narrow MBES beam, only a small fraction of the pinnipeds below (and close to) the ship would receive a ping as the ship passed overhead.

Possible Effects of the Sub-bottom Profiler Signals

An SBP will also be operated from the source vessel during the planned study and two SBPs will be operated from the vessel that deploys and retrieves the OBSs. Details about this equipment were provided in § I. Sounds from the SBPs are very short pulses, occurring for up to 64 ms once every second. Most of the energy in the sound pulses emitted by the SBPs is at 3.5 kHz, and the beam is directed downward. The sub-bottom profiler on the *Langseth* has a maximum source level of 222 dB re 1 μPa·m and the SBPs on the *Oceanus* have maximum source level of 211 and 222 dB re 1 μPa·m (see § I). Kremser et al. (2005) noted that the probability of a cetacean swimming through the area of exposure when a bottom profiler emits a pulse is small—even for an SBP more powerful than that on the *Langseth*—if the animal was in the area, it would have to pass the transducer at close range and in order to be subjected to sound levels that could cause TTS.

Masking

Marine mammal communications will not be masked appreciably by the SBP signals given the directionality of the signal and the brief period when an individual mammal is likely to be within its beam. Furthermore, in the case of most baleen whales, the SBP signals do not overlap with the predominant frequencies in the calls, which would avoid significant masking.

Behavioral Responses

Marine mammal behavioral reactions to other pulsed sound sources are discussed above, and responses to the SBP are likely to be similar to those for other pulsed sources if received at the same levels. However, the pulsed signals from the SBP are considerably weaker than those from the MBES. Therefore, behavioral responses are not expected unless marine mammals are very close to the source.

Hearing Impairment and Other Physical Effects

It is unlikely that the SBP produces pulse levels strong enough to cause hearing impairment or other physical injuries even in an animal that is (briefly) in a position near the source. The SBP is usually operated simultaneously with other higher-power acoustic sources. Many marine mammals will move away in response to the approaching higher-power sources or the vessel itself before the mammals would be close enough for there to be any possibility of effects from the less intense sounds from the SBP. In the case of mammals that do not avoid the approaching vessel and its various sound sources, mitigation measures that would be applied to minimize effects of other sources (see § XI) would further reduce or eliminate any minor effects of the SBP.

Possible Effects of Acoustic Release Signals

The acoustic release transponder used to communicate with the OBSs uses frequencies of 9–13 kHz. These signals will be used very intermittently. It is unlikely that the acoustic release signals would have a significant effect on marine mammals or sea turtles through masking, disturbance, or hearing impairment. Any effects likely would be negligible given the brief exposure at presumable low levels.

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

All anticipated takes would be "takes by harassment", involving temporary changes in behavior. The mitigation measures to be applied will minimize the possibility of injurious takes. (However, as noted earlier, there is no specific information demonstrating that injurious "takes" would occur even in the absence of the planned mitigation measures.) In the sections below, we describe methods to estimate the number of potential exposures to various received sound levels and present estimates of the numbers of marine mammals that could be affected during the proposed seismic program. The estimates are based on a consideration of the number of marine mammals that could be disturbed appreciably by operations with the 36-airgun array to be used during ~800 km of seismic surveys in the northeast Pacific Ocean. The sources of distributional and numerical data used in deriving the estimates are described in the next subsection.

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

Basis for Estimating "Take by Harassment"

Extensive systematic aircraft- and ship-based surveys have been conducted for marine mammals offshore from Oregon and Washington (e.g., Bonnell et al. 1992; Green et al. 1992, 1993; Barlow 1997, 2003; Barlow and Taylor 2001; Calambokidis and Barlow 2004; Barlow and Forney 2007; Barlow 2010). The most comprehensive and recent density data available for cetacean species in slope and offshore waters of Oregon are from the 1991, 1993, 1996, 2001, 2005, and 2007 NMFS/SWFSC ship surveys as synthesized by Barlow and Forney (2007) and Barlow (2010). The surveys were conducted up to ~555 km offshore from June or July to November or December.

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

Oceanographic conditions, including occasional El Niño and La Niña events, influence the distribution and numbers of marine mammals present in the North Pacific Ocean, including waters off Oregon and Washington, resulting in considerable year-to-year variation in the distribution and abundance of many marine mammal species (Forney and Barlow 1998; Buchanan et al. 2001; Escorza-Treviño 2002; Ferrero et al. 2002; Philbrick et al. 2003). Thus, cetacean densities used here were derived from the pooled results of the 1991–2008 surveys (abundances and survey area given for Oregon–Washington in Barlow 2010) with the exception of the gray whale and the harbor porpoise. (Abundance and density were not estimated for gray whales or harbor porpoises in the NMFS/SWFSC surveys because their inshore habitats were inadequately covered in those studies.) Gray whale density is from DoN (2010), based on the abundance of gray whales that remain between Oregon and B.C. in summer and the area out to 43 km from shore. Harbor porpoise densities were calculated using the population estimate for the Northern Oregon/Washington Coast stock (which occupies most of the proposed survey areas) and the range for that stock given in Carretta et al. (2011a).

Table 3 gives the densities for each species of cetacean reported off Oregon and Washington. The densities from NMFS/SWFSC vessel-based surveys have been corrected for both trackline detection probability and availability bias by the authors. Trackline detection probability bias is associated with diminishing sightability with increasing lateral distance from the trackline [*f*(0)]. Availability bias refers to the fact that there is less-than-100% probability of sighting an animal that is present along the survey trackline, and it is measured by *g*(0).

TABLE 3. Densities of marine mammals off Oregon and Washington. Cetacean densities are from Barlow (2010) and are based on ship transect surveys conducted up to 555 km offshore in 1991, 1993, 1996, 2001, 2005, and 2007. Pinniped densities are from shore counts and calculations in DoN (2010). Cetacean densities from Barlow (2010) are corrected for *f*(0) and *g*(0). Species listed as "Endangered" under the ESA are in italics.

Species	Density (#/1000 km2)	Source[1]
Mysticetes		
North Pacific right whale	*0*	–
Gray whale	3.21	DoN (2010)
Humpback whale	*0.81*	*Barlow (2010)*
Minke whale	0.46	Barlow (2010)
Sei whale	*0.16*	*Barlow (2010)*
Fin whale	*1.29*	*Barlow (2010)*
Blue whale	*0.18*	*Barlow (2010)*
Odontocetes		
Sperm whale	*1.02*	*Barlow (2010)*
Pygmy/dwarf sperm whale	0.71	Barlow (2010)
Cuvier's beaked whale	0.43	Barlow (2010)
Baird's beaked whale	1.18	Barlow (2010)
Mesoplodont (unidentified)[2]	1.75	Barlow (2010)
Bottlenose dolphin	0	–
Striped dolphin	0.04	Barlow (2010)
Short-beaked common dolphin	10.28	Barlow (2010)
Pacific white-sided dolphin	34.91	Barlow (2010)
Northern right-whale dolphin	12.88	Barlow (2010)
Risso's dolphin	11.19	Barlow (2010)
False killer whale	0	–
Killer whale	1.66	Barlow (2010)
Short-finned pilot whale	0	–
Harbor porpoise	632.4	See text
Dall's porpoise	83.82	Barlow (2010)
Pinnipeds		
Northern fur seal	83.62	DoN (2010)[3]
California sea lion	0	DoN (2010)[3]
Steller sea lion	13.12	DoN (2010)[3]

Harbor seal	292.3	See text
Northern elephant seal	45.81	DoN (2010)[3]

[1] Where no source is given, the species was not included in Barlow (2010) and no takes are anticipated or requested..
[2] Includes Blainville's, Stejneger's, and Hubb's beaked whale.
[3] Population sizes in DoN (2010) were updated based on Allen and Angliss (2011) and Carretta et al. (2001)

Table 3 also includes mean density information for 4 of the 5 pinniped species that occur off Oregon and Washington using the methods and calculations in DoN (2010) and population sizes that were updated based on Allen and Angliss (2011) and Carretta et al. (2011a). For the other species, the harbor seal, densities were calculated using the population estimate for the Oregon/Washington Coastal Stock and the range for that stock given in Carretta et al. (2011a).

The estimated numbers of individuals potentially exposed are based on the 160-dB re 1 μPa_{rms} criterion for all cetaceans and pinnipeds. It is assumed that marine mammals exposed to airgun sounds that strong might change their behavior sufficiently to be considered "taken by harassment".

It should be noted that the following estimates of exposures to various sound levels assume that the surveys will be fully completed; in fact, the ensonified areas calculated using the planned number of line-kilometers ***have been increased by 25%*** to accommodate turns, lines that may need to be repeated equipment testing, etc. As is typical during ship surveys, inclement weather and equipment malfunctions are likely to cause delays and may limit the number of useful line-kilometers of seismic operations that can be undertaken. Furthermore, any marine mammal sightings within or near the designated exclusion zone will result in the shut down of seismic operations as a mitigation measure. Thus, the following estimates of the numbers of marine mammals potentially exposed to 160-dB re 1 μPa_{rms} sounds are precautionary, and probably overestimate the actual numbers of marine mammals that might be involved. These estimates assume that there will be no weather, equipment, or mitigation delays, which is highly unlikely.

Furthermore, as summarized in § VII, above, and Appendix B (5) of the EA, delphinids and pinnipeds seem to be less responsive to airgun sounds than are some mysticetes. The 160-dB (rms) criterion currently applied by NMFS, on which the following estimates are based, was developed based primarily on data from gray and bowhead whales. A 170-dB re 1 μPa disturbance criterion (rather than 160 dB) is considered appropriate for delphinids (and pinnipeds), which tend to be less responsive than the more responsive cetaceans. The estimates of "takes by harassment" of delphinids and pinnipeds given below are thus considered precautionary.

Potential Number of Marine Mammals Exposed to ≥160 dB

The number of different individuals that could be exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} on one or more occasions can be estimated by considering the expected density of animals in the area along with the total marine area that would be within the 160-dB radius around the operating airgun array on at least one occasion. The number of possible exposures (including repeated exposures of the same individuals) can be estimated by considering the total marine area that would be within the 160-dB radius around the operating airguns, including areas of overlap. During the proposed survey, the transect lines are closely spaced. Thus, the area including overlap is 2.8 x the area excluding overlap, so a marine mammal that stayed in the survey area during the entire survey could be exposed ~3 times, on average. However, it is unlikely that a particular animal would stay in the area during the entire survey.

The numbers of different individuals potentially exposed to ≥160 dB re 1 μPa_{rms} were calculated by multiplying the expected species density, times the anticipated area to be ensonified to that level during airgun operations excluding overlap.

The area expected to be ensonified was determined by entering the planned survey lines (including contingency lines) into a MapInfo GIS, using the GIS to identify the relevant areas by "drawing" the applicable 160-dB buffer (see Table 1) around each seismic line, and then calculating the total area within the buffers. Areas of overlap were included only once when estimating the number of individuals exposed.

Applying the approach described above, ~11,448 km^2 (~14,310 km^2 including the 25% contingency) would be within the 160-dB isopleth during the survey. Because this approach does not allow for turnover in the mammal populations in the proposed survey area during the course of the survey, the actual number of individuals exposed could be underestimated. However, the approach assumes that no cetaceans will move away from or toward the trackline as the *Langseth* approaches in response to increasing sound levels prior to the time the levels reach 160 dB, which will result in overestimates for those species known to avoid seismic vessels (see § VII, above).

Table 4 shows estimates of the number of different individual marine mammals that potentially could be exposed to ≥160 dB re 1 μPa_{rms} during the seismic survey if no animals moved away from the survey vessel. The ***Requested Take Authorization*** is given in the far right column of Table 4. For non-listed cetacean species, the ***Requested Take Authorization*** has been increased to the mean group size off Washington and Oregon (Barlow and Forney 2007) for the particular species in cases where the calculated number of individuals exposed was between 1 and the mean group size.

Number of Cetaceans that could be Exposed to ≥160 dB.—The estimate of the number of individual cetaceans that could be exposed to seismic sounds with received levels ≥160 dB re 1 μPa_{rms} during the proposed survey is 9679 (Table 4). That total includes 50 cetaceans listed as ***Endangered*** under the ESA, including 18 fin whales (0.11% of the regional population), 15 sperm whales (0.06%), 12 humpback whales (0.06%), 3 blue whales (0.10%), and 2 sei whales (0.02%).

In addition, 48 beaked whales (6 Cuvier's beaked whale, 17 Baird's beaked whale, and 25 *Mesoplodon* spp.) could be exposed during the survey (Table 4). Most (75.6%) of the cetaceans potentially exposed are harbor porpoises. Another 22.6% are delphinids (including Dall's porpoise): Dall's porpoises, the Pacific white-sided dolphin, and the northern right whale dolphin are estimated to be the most common delphinid species in the area, with estimates of 1199 (2.86% of the regional population), 500 (1.86%), and 184 (2.21%) exposed to ≥160 dB re 1 μPa_{rms}, respectively. As noted above, a more meaningful estimate for delphinids would be for sound levels ≥170 dB.

Number of Pinnipeds that could be Exposed to ≥160 dB.—The estimate of the number of individual pinnipeds that could be exposed to seismic sounds with received levels ≥160 dB re 1 μPa_{rms} during the proposed survey is 5421 (Table 4), including 188 ***Threatened*** Steller sea lions (0.29% of the regional population). The harbor seal and the northern fur seal are estimated to be the most common pinniped species in the area, with estimates of 3380 (13.67% of the regional population) and 1197 (0.18%) exposed to ≥160 dB re 1 μPa_{rms}, respectively. As noted above, a more meaningful estimate for most pinnipeds would be for sound levels ≥170 dB.

Conclusions

The proposed seismic survey will involve towing an airgun array that introduces pulsed sounds into the ocean, along with simultaneous operation of an MBES and SBP. The survey will employ a 36-airgun array similar to the airgun arrays used for typical high-energy seismic surveys. The total airgun discharge volume is ~6600 in^3. Routine vessel operations, other than the proposed airgun operations, are conventionally assumed not to affect marine mammals sufficiently to constitute "taking". No "taking" of marine mammals is expected in association with echosounder operations given the considerations discussed in § I, i.e., sounds are beamed downward, the beam is narrow, and the pulses are extremely short.

Cetaceans.—Several species of mysticetes show strong avoidance reactions to seismic vessels at ranges up to 6–8 km and occasionally as far as 20–30 km from the source vessel when medium-large airgun arrays have been used. However, reactions at the longer distances appear to be atypical of most species and situations. If mysticetes are encountered, the numbers estimated to occur within the 160-dB isopleth in the survey area are expected to be relatively low.

Odontocete reactions to seismic pulses, or at least the reactions of delphinids and Dall's porpoise, are expected to extend to lesser distances than are those of mysticetes. Odontocete low-frequency hearing is less sensitive than that of mysticetes, and dolphins are often seen from seismic vessels. In fact, there are documented instances of dolphins approaching active seismic vessels. However, delphinids (along with other cetaceans) sometimes show avoidance responses and/or other changes in behavior when near operating seismic vessels.

TABLE 4. Estimates of the possible numbers of different individuals that could be exposed during L-DEO's proposed seismic survey in the northeastern Pacific during 5–8 July 2012. The proposed sound source consists of an 36-airgun array with a total discharge volume of 6600 in^3. Received levels of seismic sounds are expressed in dB re 1 μPa (rms, averaged over pulse duration), consistent with NMFS' practice. Not all marine mammals will change their behavior when exposed to these sound levels, but some may alter their behavior when levels are lower (see text). Species in italics are listed under the ESA as endangered or threatened. The column of numbers in boldface shows the numbers of "takes" for which authorization is requested.

Species	Number[1]	% Regional Pop'n[2]	Requested Take Authorization
Mysticetes			
North Pacific right whale	*0*	*0*	***0***
Gray whale[3]	35	0.18	**35**
Humpback whale	*12*	*0.06*	***12***
Minke whale	7	0.07	**7**
Sei whale	*2*	*0.02*	***2***
Fin whale	*18*	*0.11*	***18***
Blue whale	*3*	*0.10*	***3***
Odontocetes			
Sperm whale	*15*	*0.06*	***15***
Pygmy/Dwarf sperm whale	10	NA	**10**
Cuvier's beaked whale	6	0.28	**6**
Baird's beaked whale	17	1.86	**17**
Mesoplodon spp.[4]	25	2.45	**25**
Bottlenose dolphin	0	0	**0**
Striped dolphin	1	<0.01	**2**[5]
Short-beaked common dolphin	147	0.04	**238**[5]
Pacific white-sided dolphin	500	1.86	**500**
Northern right-whale dolphin	184	2.21	**184**
Risso's dolphin	160	2.55	**160**
False killer whale	0	0	**0**
Killer whale	24	0.96	**24**
Short-finned pilot whale	0	0	**0**
Harbor porpoise[3]	7314	14.00	**7314**
Dall's porpoise	1199	2.86	**1199**

Pinnipeds			
Northern fur seal	1197	0.18	**1197**
California sea lion	0	0	**0**
Steller sea lion	*188*	*0.29*	***188***
Harbor seal[3]	3380	13.67	**3380**
Northern elephant seal	656	0.53	**656**

NA – not available.
[1] Estimates are based on densities from Table 3 and an ensonified area (including 25% contingency) of 14,310 km^2.
[2] Regional population size estimates are from Table 2.
[3] Estimates based on densities from Table 3 and an ensonified area in water depths <100 m (including 25% contingency) of 11.565 km^2
[4] Includes Blainville's, Stejneger's, and Hubb's beaked whales.
[5] Requested Take Authorization increased to mean group size for cetaceans (see text).

Taking into account the mitigation measures that are planned (see § XI), effects on cetaceans are generally expected to be limited to avoidance of the area around the seismic operation and short-term changes in behavior, falling within the MMPA definition of "Level B harassment".

Estimates of the numbers of marine mammals that might be exposed to airgun sounds ≥160 dB re 1 μPa_{rms} during the proposed program have been presented with a corresponding requested "take authorization" for each species. Those figures likely overestimate the actual number of animals that will be exposed to and will react to the seismic sounds. The reasons for that conclusion are outlined above. The relatively short-term exposures are unlikely to result in any long-term negative consequences for the individuals or their populations.

The many cases of apparent tolerance by cetaceans of seismic exploration, vessel traffic, and some other human activities show that co-existence is possible. Mitigation measures such as look outs, ramp ups, and power downs or shut downs when marine mammals are seen within defined ranges should further reduce short-term reactions, and avoid or minimize any effects on hearing sensitivity. In all cases, the effects are expected to be short-term, with no lasting biological consequence.

Pinnipeds.— Four of the five pinniped species discussed in § III are likely to occur in the proposed survey areas. The California sea lion would be at or near its rookeries in California and Baha California during the proposed surveys, which coincide with its mating season. Estimates of 1197 northern fur seals, 188 Steller sea lions, 3380 harbor seals, and 656 northern elephant seals could be exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} during the survey. As for cetaceans, the estimated numbers of pinnipeds that could be exposed to received levels ≥160 dB are probably overestimates of the actual numbers that will be affected significantly.

VIII. ANTICIPATED IMPACT ON SUBSISTENCE

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

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

IX. ANTICIPATED IMPACT ON HABITAT

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

The proposed seismic survey will not result in any permanent impact on habitats used by marine mammals or to the food sources they use. The main impact issue associated with the proposed activity will be temporarily elevated noise levels and the associated direct effects on marine mammals, as discussed in § VII, above. The following sections briefly review effects of airguns on fish and invertebrates, and more details are included in Appendices D and E of the EA, respectively.

Effects on Fish

One reason for the adoption of airguns as the standard energy source for marine seismic surveys is that, unlike explosives, they have not been associated with large-scale fish kills. However, existing information on the impacts of seismic surveys on marine fish populations is limited (see Appendix D of the EA). There are three types of potential effects of exposure to seismic surveys: (1) pathological, (2) physiological, and (3) behavioral. Pathological effects involve lethal and temporary or permanent sub-lethal injury. Physiological effects involve temporary and permanent primary and secondary stress responses, such as changes in levels of enzymes and proteins. Behavioral effects refer to temporary and (if they occur) permanent changes in exhibited behavior (e.g., startle and avoidance behavior). The three categories are interrelated in complex ways. For example, it is possible that certain physiological and behavioral changes could potentially lead to an ultimate pathological effect on individuals (i.e., mortality).

The specific received sound levels at which permanent adverse effects to fish potentially could occur are little studied and largely unknown. Furthermore, the available information on the impacts of seismic surveys on marine fish is from studies of individuals or portions of a population; there have been no studies at the population scale. The studies of individual fish have often been on caged fish that were exposed to airgun pulses in situations not representative of an actual seismic survey. Thus, available information provides limited insight on possible real-world effects at the ocean or population scale. This makes drawing conclusions about impacts on fish problematic because, ultimately, the most important issues concern effects on marine fish populations, their viability, and their availability to fisheries.

Hastings and Popper (2005), Popper (2009), and Popper and Hastings (2009a,b) provided recent critical reviews of the known effects of sound on fish. The following sections provide a general synopsis of the available information on the effects of exposure to seismic and other anthropogenic sound as relevant to fish. The information comprises results from scientific studies of varying degrees of rigor plus some anecdotal information. Some of the data sources may have serious shortcomings in methods, analysis, interpretation, and reproducibility that must be considered when interpreting their results (see Hastings and Popper 2005). Potential adverse effects of the program's sound sources on marine fish are then noted.

Pathological Effects

The potential for pathological damage to hearing structures in fish depends on the energy level of the received sound and the physiology and hearing capability of the species in question (see Appendix D of the EA). For a given sound to result in hearing loss, the sound must exceed, by some substantial amount, the hearing threshold of the fish for that sound (Popper 2005). The consequences of temporary or permanent hearing loss in individual fish on a fish population are unknown; however, they likely depend on the number of individuals affected and whether critical behaviors involving sound (e.g., predator avoidance, prey capture, orientation and navigation, reproduction, etc.) are adversely affected.

Little is known about the mechanisms and characteristics of damage to fish that may be inflicted by exposure to seismic survey sounds. Few data have been presented in the peer-reviewed scientific literature. As far as we know, there are only two papers with proper experimental methods, controls, and careful pathological investigation implicating sounds produced by actual seismic survey airguns in causing adverse anatomical effects. One such study indicated anatomical damage, and the second indicated TTS in fish hearing. The anatomical case is McCauley et al. (2003), who found that exposure to airgun sound caused observable anatomical damage to the auditory maculae of "pink snapper" (*Pagrus auratus*). This damage in the ears had not been repaired in fish sacrificed and examined almost two months after exposure. On the other hand, Popper et al. (2005) documented only TTS (as determined by auditory brainstem response) in two of three fish species from the Mackenzie River Delta. This study found that broad whitefish (*Coregonus nasus*) that received a sound exposure level of 177 dB re 1 $\mu Pa^2 \cdot s$ showed no hearing loss. During both studies, the repetitive exposure to sound was greater than would have occurred during a typical seismic survey. However, the substantial low-frequency energy produced by the airguns [less than ~400 Hz in the study by McCauley et al. (2003) and less than ~200 Hz in Popper et al. (2005)] likely did not propagate to the fish because the water in the study areas was very shallow (~9 m in the former case and <2 m in the latter). Water depth sets a lower limit on the lowest sound frequency that will propagate (the "cutoff frequency") at about one-quarter wavelength (Urick 1983; Rogers and Cox 1988).

Wardle et al. (2001) suggested that in water, acute injury and death of organisms exposed to seismic energy depends primarily on two features of the sound source: (1) the received peak pressure and (2) the time required for the pressure to rise and decay. Generally, as received pressure increases, the period for the pressure to rise and decay decreases, and the chance of acute pathological effects increases. According to Buchanan et al. (2004), for the types of seismic airguns and arrays involved with the proposed program, the pathological (mortality) zone for fish would be expected to be within a few meters of the seismic source. Numerous other studies provide examples of no fish mortality upon exposure to seismic sources (Falk and Lawrence 1973; Holliday et al. 1987; La Bella et al. 1996; Santulli et al. 1999; McCauley et al. 2000a,b, 2003; Bjarti 2002; Thomsen 2002; Hassel et al. 2003; Popper et al. 2005; Boeger et al. 2006).

Some studies have reported, some equivocally, that mortality of fish, fish eggs, or larvae can occur close to seismic sources (Kostyuchenko 1973; Dalen and Knutsen 1986; Booman et al. 1996; Dalen et al. 1996). Some of the reports claimed seismic effects from treatments quite different from actual seismic survey sounds or even reasonable surrogates. However, Payne et al. (2009) reported no statistical differences in mortality/morbidity between control and exposed groups of capelin eggs or monkfish larvae. Saetre and Ona (1996) applied a 'worst-case scenario' mathematical model to investigate the effects of seismic energy on fish eggs and larvae. They concluded that mortality rates caused by exposure to seismic surveys are so low, as compared to natural mortality rates, that the impact of seismic surveying on recruitment to a fish stock must be regarded as insignificant.

Physiological Effects

Physiological effects refer to cellular and/or biochemical responses of fish to acoustic stress. Such stress potentially could affect fish populations by increasing mortality or reducing reproductive success. Primary and secondary stress responses of fish after exposure to seismic survey sound appear to be temporary in all studies done to date (Sverdrup et al. 1994; Santulli et al. 1999; McCauley et al. 2000a,b). The periods necessary for the biochemical changes to return to normal are variable and depend on numerous aspects of the biology of the species and of the sound stimulus (see Appendix D of the EA).

Behavioral Effects

Behavioral effects include changes in the distribution, migration, mating, and catchability of fish populations. Studies investigating the possible effects of sound (including seismic survey sound) on fish behavior have been conducted on both uncaged and caged individuals (e.g., Chapman and Hawkins 1969; Pearson et al. 1992; Santulli et al. 1999; Wardle et al. 2001; Hassel et al. 2003). Typically, in these studies fish exhibited a sharp "startle" response at the onset of a sound followed by habituation and a return to normal behavior after the sound ceased.

There is general concern about potential adverse effects of seismic operations on fisheries, namely a potential reduction in the "catchability" of fish involved in fisheries. Although reduced catch rates have been observed in some marine fisheries during seismic testing, in a number of cases the findings are confounded by other sources of disturbance (Dalen and Raknes 1985; Dalen and Knutsen 1986; Løkkeborg 1991; Skalski et al. 1992; Engås et al. 1996). In other airgun experiments, there was no change in catch per unit effort (CPUE) of fish when airgun pulses were emitted, particularly in the immediate vicinity of the seismic survey (Pickett et al. 1994; La Bella et al. 1996). For some species, reductions in catch may have resulted from a change in behavior of the fish, e.g., a change in vertical or horizontal distribution, as reported in Slotte et al. (2004).

In general, any adverse effects on fish behavior or fisheries attributable to seismic testing may depend on the species in question and the nature of the fishery (season, duration, fishing method). They may also depend on the age of the fish, its motivational state, its size, and numerous other factors that are difficult, if not impossible, to quantify at this point, given such limited data on effects of airguns on fish, particularly under realistic at-sea conditions.

Effects on Invertebrates

The existing body of information on the impacts of seismic survey sound on marine invertebrates is very limited. However, there is some unpublished and very limited evidence of the potential for adverse effects on invertebrates, thereby justifying further discussion and analysis of this issue. The three types of potential effects of exposure to seismic surveys on marine invertebrates are pathological, physiological, and behavioral. Based on the physical structure of their sensory organs, marine invertebrates appear to be specialized to respond to particle displacement components of an impinging sound field and not to the pressure component (Popper et al. 2001; see also Appendix E of the EA).

The only information available on the impacts of seismic surveys on marine invertebrates involves studies of individuals; there have been no studies at the population scale. Thus, available information provides limited insight on possible real-world effects at the regional or ocean scale. The most important aspect of potential impacts concerns how exposure to seismic survey sound ultimately affects invertebrate populations and their viability, including availability to fisheries.

Literature reviews of the effects of seismic and other underwater sound on invertebrates were provided by Moriyasu et al. (2004) and Payne et al. (2008). The following sections provide a synopsis of available information on the effects of exposure to seismic survey sound on species of decapod crustaceans and cephalopods, the two taxonomic groups of invertebrates on which most such studies have been conducted. The available information is from studies with variable degrees of scientific soundness and from anecdotal information. A more detailed review of the literature on the effects of seismic survey sound on invertebrates is provided in Appendix E of the EA.

Pathological Effects

In water, lethal and sub-lethal injury to organisms exposed to seismic survey sound appears to depend on at least two features of the sound source: (1) the received peak pressure, and (2) the time required for the pressure to rise and decay. Generally, as received pressure increases, the period for the pressure to rise and decay decreases, and the chance of acute pathological effects increases. For the type of airgun array planned for the proposed program, the pathological (mortality) zone for crustaceans and cephalopods is expected to be within a few meters of the seismic source, at most; however, very few specific data are available on levels of seismic signals that might damage these animals. This premise is based on the peak pressure and rise/decay time characteristics of seismic airgun arrays currently in use around the world.

Some studies have suggested that seismic survey sound has a limited pathological impact on early developmental stages of crustaceans (Pearson et al. 1994; Christian et al. 2003; DFO 2004). However, the impacts appear to be either temporary or insignificant compared to what occurs under natural conditions. Controlled field experiments on adult crustaceans (Christian et al. 2003, 2004; DFO 2004) and adult cephalopods (McCauley et al. 2000a,b) exposed to seismic survey sound have not resulted in any significant pathological impacts on the animals. It has been suggested that giant squid strandings were caused by exposure to commercial seismic survey activities (Guerra et al. 2004), but there was little evidence to support the claim. André et al. (2011) exposed cephalopods, primarily cuttlefish, to continuous 50–400 Hz sinusoidal wave sweeps for two hours while captive in relatively small tanks, and reported morphological and ultrastructural evidence of massive acoustic trauma (i.e., permanent and substantial alterations of statocyst sensory hair cells). The received SPL was reported as 157±5 dB re 1µPa, with peak levels at 175 dB re 1µPa. As in the McCauley et al. (2003) paper on sensory hair cell damage in pink snapper as a result of exposure to seismic sound, the cephalopods were subjected to higher sound levels than they would be under natural conditions, and they were unable to swim away from the sound source.

Physiological Effects

Physiological effects refer mainly to biochemical responses by marine invertebrates to acoustic stress. Such stress potentially could affect invertebrate populations by increasing mortality or reducing reproductive success. Primary and secondary stress responses (i.e., changes in haemolymph levels of enzymes, proteins, etc.) of crustaceans have been noted several days or months after exposure to seismic survey sounds (Payne et al. 2007). The periods necessary for these biochemical changes to return to normal are variable and depend on numerous aspects of the biology of the species and of the sound stimulus.

Behavioral Effects

There is increasing interest in assessing the possible direct and indirect effects of seismic and other sounds on invertebrate behavior, particularly in relation to the consequences for fisheries. Changes in behavior could potentially affect such aspects as reproductive success, distribution, susceptibility to predation, and catchability by fisheries. Studies investigating the possible behavioral effects of exposure to seismic survey sound on crustaceans and cephalopods have been conducted on both uncaged and caged animals. In some cases, invertebrates exhibited startle responses (e.g., squid in McCauley et al. 2000a,b). In other cases, no behavioral impacts were noted (e.g., crustaceans in Christian et al. 2003, 2004; DFO 2004). There have been anecdotal reports of reduced catch rates of shrimp shortly after exposure to seismic surveys; however, other studies have not observed any significant changes in shrimp catch rate (Andriguetto-Filho et al. 2005). Similarly, Parry and Gason (2006) did not find any evidence that lobster catch rates were affected by seismic surveys. Any adverse effects on crustacean and cephalopod behavior or fisheries attributable to seismic survey sound depend on the species in question and the nature of the fishery (season, duration, fishing method).

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

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

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

The proposed activity is not expected to have any habitat-related effects that could cause significant or long-term consequences for individual marine mammals or their populations, because operations will be limited in duration.

XI. Mitigation Measures

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

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

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

Planning Phase

The PIs worked with L-DEO and NSF to identify potential time periods to carry out the survey taking into consideration key factors such as environmental conditions (i.e., the seasonal presence of marine mammals, sea turtles, and seabirds), weather conditions, equipment, and optimal timing for other proposed seismic surveys using the R/V *Langseth*. Most marine mammal species are expected to occur in the area year-round, so altering the timing of the proposed project likely would result in no net benefits for those species. After considering what energy source level was necessary to achieve the research goals, the PIs determined the use of the 36-airgun array with a total volume of ~6600 in^3 would be required. Given the research goals, this energy source level was viewed appropriate.

Proposed Exclusion Zones

Received sound levels have been predicted by L-DEO's model, in relation to distance and direction from the airguns, for the 36-airgun array and for a single 1900LL 40-in^3 airgun, which will be used during power downs. Results have been reported for propagation measurements of pulses from the 36-airgun array in two water depths (~1600 m and 50 m) in the Gulf of Mexico in 2007–2008 (Tolstoy et al. 2009). Results of the propagation measurements showed that radii around the airguns for various received levels varied with water depth (Tolstoy et al. 2009). As results for measurements in intermediate-depth water are still under analysis, values halfway between the deep and shallow-water measurements were used. In addition, propagation varies with array tow depth. The empirical values that resulted from Tolstoy et al. (2009) are used here to determine exclusion zones for the 36-airgun array. However, the depth of the array was different in the Gulf of Mexico calibration study (6 m) than in the proposed surveys (9, 12, and 15 m); thus, correction factors have been applied to the distances reported by Tolstoy et al. (2009). The correction factors used were the ratios of the 160-, 180-, and 190-dB distances from the modeled results for the 6600-

in^3 airgun array towed at 6 m vs. 9 and 12 m, from LGL (2009): 1.285, 1.338, and 1.364, respectively for 9 m; and 1.467, 1.577, and 1.545, respectively for 12 m.

Using the corrected measurements (array) or model (single airgun), Table 1 shows the distances at which three rms sound levels are expected to be received from the 36-airgun array and a single airgun. The 180- and 190-dB re 1 μPa_{rms} distances are the safety criteria as specified by NMFS (2000) and are applicable to cetaceans and pinnipeds, respectively. The 180-dB distance will also be used as the exclusion zone for sea turtles, as required by NMFS in most other recent seismic projects (e.g., Smultea et al. 2004; Holst et al. 2005b; Holst and Beland 2008; Holst and Smultea 2008; Hauser et al. 2008; Holst 2009; Antochiw et al. n.d.). If marine mammals or sea turtles are detected within or about to enter the appropriate exclusion zone, the airguns will be powered down (or shut down if necessary) immediately (see below).

Detailed recommendations for new science-based noise exposure criteria were published in early 2008 (Southall et al. 2007). L-DEO will be prepared to revise its procedures for estimating numbers of mammals "taken", EZs, etc., as may be required by any new guidelines that result. As yet, NMFS has not specified a new procedure for determining EZs.

Mitigation During Operations

Mitigation measures that will be adopted during the proposed survey include (1) power-down procedures, (2) shut-down procedures, and (3) ramp-up procedures.

Power-down Procedures

A power down involves decreasing the number of airguns in use such that the radius of the 180-dB (or 190-dB) zone is decreased to the extent that marine mammals or turtles are no longer in or about to enter the EZ. A power down of the airgun array will also occur when the vessel is turning from one seismic line to another. During a power down, one airgun will be operated. The continued operation of one airgun is intended to alert marine mammals and turtles to the presence of the seismic vessel in the area. In contrast, a shut down occurs when all airgun activity is suspended.

If a marine mammal or turtle is detected outside the EZ but is likely to enter the EZ, the airguns will be powered down before the animal is within the EZ. Likewise, if a mammal or turtle is already within the EZ when first detected, the airguns will be powered down immediately. During a power down of the airgun array, the 40-in^3 airgun will be operated. If a marine mammal or turtle is detected within or near the smaller EZ around that single airgun (Table 1), it will be shut down (see next subsection).

Following a power down, airgun activity will not resume until the marine mammal or turtle has cleared the safety zone. The animal will be considered to have cleared the safety zone if

- it is visually observed to have left the EZ, or
- it has not been seen within the zone for 15 min in the case of small odontocetes (or pinnipeds), or
- it has not been seen within the zone for 30 min in the case of mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, and beaked whales, or
- the vessel has moved outside the EZ for turtles, e.g., if a turtle is sighted close to the vessel and the ship speed is 7.4 km/h, it would take the vessel ~8 min to leave the turtle behind.

During airgun operations following a shut down whose duration has exceeded the time limits specified above, the airgun array will be ramped up gradually. Ramp-up procedures are described below. During past R/V *Langseth* marine geophysical surveys, following an extended power-down period, the seismic source followed ramp-up procedures to return to the full seismic source level. Under a power-down scenario, however, a single mitigation airgun still would be operating to alert and warn animals of the on-going activity. Furthermore, under these circumstances, ramp-up procedures may unnecessarily extend the length of the survey time needed to collect seismic data. LDEO and NSF have discussed this mitigation practice and have concluded that a ramp-up procedure following an extended power down is not necessary, and are currently consulting with NMFS on the issue. This assessment therefore does not include this practice as part of the monitoring and mitigation plan.

Shut-down Procedures

The operating airgun(s) will be shut down if a marine mammal or turtle is seen within or approaching the EZ for the single airgun. Shut downs will be implemented (1) if an animal enters the EZ of the single airgun after a power down has been initiated, or (2) if an animal is initially seen within the EZ of the single airgun when more than one airgun (typically the full array) is operating. Airgun activity will not resume until the marine mammal or turtle has cleared the safety zone, or until the PSO is confident that the animal has left the vicinity of the vessel. Criteria for judging that the animal has cleared the safety zone will be as described in the preceding subsection.

Ramp-up Procedures

A ramp-up procedure will be followed when the airgun array begins operating after a specified period without airgun operations or when a power down has exceeded that period. It is proposed that, for the present survey, this period would be ~8 min. This period is based on the 180-dB radius for the 36-airgun array (940 m) in relation to the average planned speed of the *Langseth* while shooting (7.4 km/h). Similar periods (~8–10 min) were used during previous L-DEO surveys. Ramp up will not occur if a marine mammal or sea turtle has not cleared the safety zone as described earlier.

Ramp up will begin with the smallest airgun in the array (40 in^3). Airguns will be added in a sequence such that the source level of the array will increase in steps not exceeding 6 dB per 5-min period over a total duration of ~35 min. During ramp up, the PSOs will monitor the EZ, and if marine mammals or turtles are sighted, a power down or shut down will be implemented as though the full array were operational.

If the complete EZ has not been visible for at least 30 min prior to the start of operations in either daylight or nighttime, ramp up will not commence unless at least one airgun (40 in^3 or similar) has been operating during the interruption of seismic survey operations. Given these provisions, it is likely that the airgun array will not be ramped up from a complete shut down at night or in thick fog, because the outer part of the safety zone for that array will not be visible during those conditions. If one airgun has operated during a power-down period, ramp up to full power will be permissible at night or in poor visibility, on the assumption that marine mammals and turtles will be alerted to the approaching seismic vessel by the sounds from the single airgun and could move away. Ramp up of the airguns will not be initiated if a sea turtle or marine mammal is sighted within or near the applicable EZs during the day or night.

As noted above under "Power-down Procedures", during past R/V *Langseth* marine geophysical surveys, following an extended power-down period, the seismic source followed ramp-up procedures to return to the full seismic source level. Under a power-down scenario, however, a single mitigation airgun still would be operating to alert and warn animals of the on-going activity. Furthermore, under these circumstances, ramp-up procedures may unnecessarily extend the length of the survey time needed to collect seismic data. LDEO and NSF have discussed this mitigation practice and have concluded that a ramp-up procedure following an extended power down is not necessary, and are currently consulting with NMFS on the issue. This assessment therefore does not include this practice as part of the monitoring and mitigation plan.

XII. PLAN OF COOPERATION

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

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

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

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

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

Not applicable. The proposed activity will take place in the northeast Pacific Ocean, and no activities will take place in or near a traditional Arctic subsistence hunting area.

XIII. MONITORING AND REPORTING PLAN

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

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

L-DEO's proposed Monitoring Plan is described below. L-DEO understands that this Monitoring Plan will be subject to review by NMFS, and that refinements may be required.

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

Vessel-based Visual Monitoring

PSO observations will take place during daytime airgun operations and nighttime start ups of the airguns. Airgun operations will be suspended when marine mammals or turtles are observed within, or about to enter, designated exclusion zones [see § XI above] where there is concern about potential effects on hearing or other physical effects. PSOs will also watch for marine mammals and turtles near the seismic vessel for at least 30 min prior to the planned start of airgun operations. Observations will also be made during daytime periods when the *Langseth* is underway without seismic operations, such as during transits.

During seismic operations, at least four visual PSOs will be based aboard the *Langseth*. PSOs will be appointed by L-DEO with NMFS concurrence. During the majority of seismic operations, two PSOs will monitor for marine mammals and sea turtles around the seismic vessel. Use of two simultaneous observers will increase the effectiveness of detecting animals around the source vessel. However, during meal times, only one PSO may be on duty. PSO(s) will be on duty in shifts of duration no longer than 4 h. Other crew will also be instructed to assist in detecting marine mammals and turtles and implementing mitigation requirements (if practical). Before the start of the seismic survey, the crew will be given additional instruction regarding how to do so.

The *Langseth* is a suitable platform for marine mammal and turtle observations. When stationed on the observation platform, the eye level will be ~21.5 m above sea level, and the observer will have a good view around the entire vessel. During daytime, the PSO(s) will scan the area around the vessel systematically with reticle binoculars (e.g., 7×50 Fujinon), Big-eye binoculars (25×150), and with the naked eye. During darkness, night vision devices (NVDs) will be available (ITT F500 Series Generation 3 binocular-image intensifier or equivalent), when required. Laser rangefinding binoculars (Leica LRF 1200 laser rangefinder or equivalent) will be available to assist with distance estimation. Those are useful in training observers to estimate distances visually, but are generally not useful in measuring distances to animals directly; that is done primarily with the reticles in the binoculars.

Passive Acoustic Monitoring

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

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

One acoustic PSO or PSAO (in addition to the 4 visual PSOs) will be on board. The towed hydrophones will ideally be monitored 24 h per day while at the seismic survey area during airgun operations, and during most periods when the *Langseth* is underway while the airguns are not operating. However, PAM may not be possible if damage occurs to the array or back-up systems during operations. One PSO will monitor the acoustic detection system at any one time, by listening to the signals from two channels via headphones and/or speakers and watching the real-time spectrographic display for frequency ranges produced by cetaceans. The PSAO monitoring the acoustical data will be on shift for 1–6 h at a time. All observers are expected to rotate through the PAM position, although the most experienced with acoustics will be on PAM duty more frequently.

When a vocalization is detected while visual observations are in progress, the PSAO will contact the visual PSO immediately, to alert him/her to the presence of cetaceans (if they have not already been seen), and to allow a power down or shut down to be initiated, if required. The information regarding the call will be entered into a database. The data to be entered include an acoustic encounter identification number, whether it was linked with a visual sighting, date, time when first and last heard and whenever any additional information was recorded, position and water depth when first detected, bearing if determinable, species or species group (e.g., unidentified dolphin, sperm whale), types and nature of sounds heard (e.g., clicks, continuous, sporadic, whistles, creaks, burst pulses, strength of signal, etc.), and any other notable information. The acoustic detection can also be recorded for further analysis.

PSO Data and Documentation

PSOs will record data to estimate the numbers of marine mammals and turtles exposed to various received sound levels and to document apparent disturbance reactions or lack thereof. Data will be used to estimate numbers of animals potentially 'taken' by harassment (as defined in the MMPA). They will also provide information needed to order a power down or shut down of the airguns when a marine mammal or sea turtle is within or near the EZ.

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

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

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

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

Results from the vessel-based observations will provide

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

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

XIV. Coordinating Research to Reduce and Evaluate Incidental Take

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

L-DEO and NSF will coordinate the planned marine mammal monitoring program associated with the seismic survey with other parties that may have interest in this area. L-DEO and NSF will coordinate with applicable U.S. agencies (e.g., NMFS), and will comply with their requirements. Actions of this type that are underway include (but are not limited to) the following:

- contact Army Corps of Engineers (ACE), to confirm that no permits will be required by ACE for the proposed survey; and
- consult with Olympic Coast National Marine Sanctuary.

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Request by Lamont-Doherty Earth Observatory for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during a Marine Geophysical Survey by the R/V *Marcus G. Langseth* off Washington, Northeast Pacific Ocean, July 2012

submitted by

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

to

National Marine Fisheries Service
Office of Protected Resources
1315 East–West Hwy, Silver Spring, MD 20910-3282

Application Prepared by

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

26 January 2012

LGL Report TA8118-4

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Request by Lamont-Doherty Earth Observatory for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during a Marine Geophysical Survey by the R/V *Marcus G. Langseth* off Washington, Northeast Pacific Ocean, July 2012

SUMMARY

Lamont-Doherty Earth Observatory (L-DEO), with research funding from the National Science Foundation (NSF), plans to conduct a marine seismic survey in the northeastern Pacific Ocean off the coast of Washington in July 2012. The seismic surveys will take place in the Exclusive Economic Zone of the U.S., in water depths ~95–2650 m. The airgun array will consist of 36 airguns with a total volume of ~6600 in^3. L-DEO requests that it be issued an Incidental Harassment Authorization (IHA) allowing non-lethal takes of marine mammals incidental to the planned seismic survey. This request is submitted pursuant to Section 101 (a)(5)(D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371 (a)(5).

Numerous species of cetaceans and pinnipeds inhabit the proposed survey area in the northeast Pacific. Several of these species or stocks are listed as ***endangered*** or ***threatened*** under the U.S. ESA, including the North Pacific right, humpback, sei, fin, blue, sperm, and killer whales, and the Steller sea lion. ESA-listed sea turtle species that could occur in the survey area include the ***endangered*** leatherback turtles, and the ***threatened*** green, loggerhead, and olive ridley turtles. Listed seabirds that could be encountered in the area include the ***endangered*** short-tailed albatross and the ***threatened*** marbled murrelet and western snowy plover.

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

I. OPERATIONS TO BE CONDUCTED

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

Overview of the Activity

L-DEO plans to conduct a seismic survey in the northeast Pacific Ocean off the coast of Washington at ~46.5–47.5°N and ~124.5–126°W (Fig. 1). Water depths in the survey area are ~95–2650 m. The project is scheduled to occur ~12–23 July 2012. Some minor deviation from these dates is possible, depending on logistics and weather.

L-DEO plans to use conventional seismic methodology over the Cascadia subduction margin off Grays Harbor, WA, to address key scientific issues regarding the location, physical state, fluid budget, and associated methane systems of the subducting plate boundary and overlying crust. This system

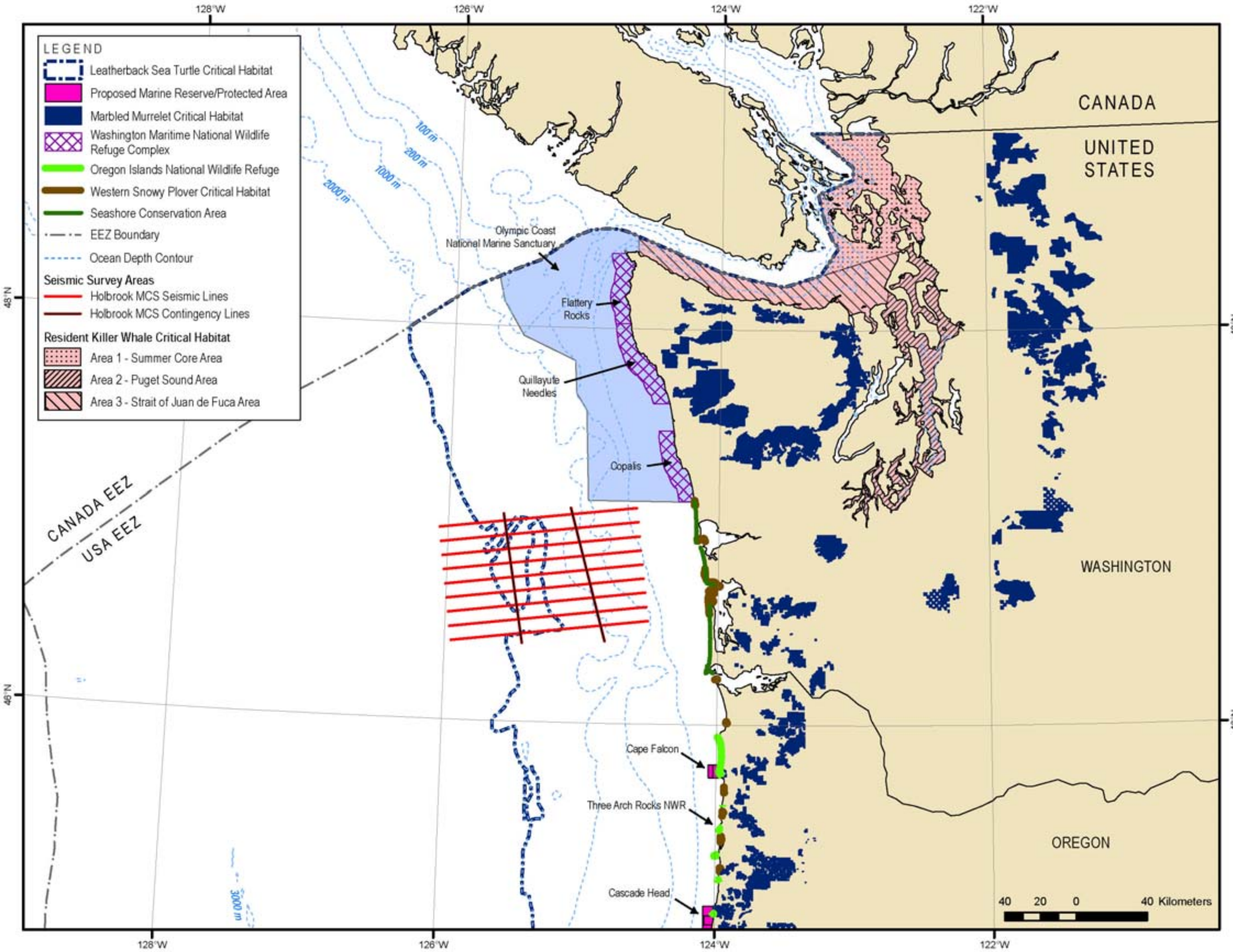

FIGURE 1. Proposed survey area for the seismic survey in the northeastern Pacific Ocean planned for 12–23 July 2012 with seismic tracklines. EEZ = exclusive economic zone.

is of great scientific and societal interest, as it is capable of very large (~9 M_W) earthquakes, creates volcanic hazards in the Cascades, and hosts periodic episodic tremor and slip episodes.

The survey will involve one source vessel, the R/V *Marcus G. Langseth*. The *Langseth* will deploy a 36-airgun array as an energy source. The receiving system will consist of an 8-km streamer. As the airgun array is towed along the survey lines, the hydrophone streamer will receive the returning acoustic signals and transfer the data to the on-board processing system.

This survey will take place along 9 parallel lines 8 km apart and, if time permits, along an additional two lines perpendicular to the parallel lines (Fig. 1). The seismic lines are over water depths of ~95–2650 m. The total survey effort including contingency lines will consist of ~785 km of transect lines in depths >1000 m, 350 km in depths 100–1000 m, and 12 km in depths <100 m. The survey area is 32–150 km from shore.

In addition to the operations of the airgun array, a multibeam echosounder (MBES) and a sub-bottom profiler (SBP) will also be operated from the *Langseth* continuously throughout the cruise. All planned geophysical data acquisition activities will be conducted by L-DEO with on-board assistance by the scientists who have proposed the study. The Principal Investigators (PIs) are Drs. W.S. Holbrook (University of Wyoming), A.M. Trehu (Oregon State University), H.P. Johnson (University of Washington), G.M. Kent (University of Nevada), and K. Keranen (University of Oklahoma). The vessel will be self-contained, and the crew will live aboard the vessel for the entire cruise.

Source Vessel Specifications

The R/V *Marcus G. Langseth* will be used as the source vessel. The *Langseth* will tow the 36-airgun array and streamer along predetermined lines (Fig. 1). When the *Langseth* is towing the airgun array as well as the hydrophone streamer, the turning rate of the vessel while the gear is deployed is limited to five degrees per minute. Thus, the maneuverability of the vessel is limited during operations with the streamer.

The *Langseth* has a length of 71.5 m, a beam of 17.0 m, and a maximum draft of 5.9 m. The *Langseth* was designed as a seismic research vessel, with a propulsion system designed to be as quiet as possible to avoid interference with the seismic signals. The ship is powered by two Bergen BRG-6 diesel engines, each producing 3550 hp, which drive the two propellers directly. Each propeller has four blades, and the shaft typically rotates at 600 or 750 revolutions per minute (rpm). The vessel also has an 800 hp bowthruster, which is not used during seismic acquisition. The operation speed during seismic acquisition is typically 7.4–9.3 km/h. When not towing seismic survey gear, the *Langseth* typically cruises at 18.5 km/h. The *Langseth* has a range of 25,000 km.

The *Langseth* will also serve as the platform from which vessel-based protected species observers (PSOs) will watch for marine mammals and sea turtles before and during airgun operations, as described in § XIII, below.

Other details of the *Langseth* include the following:

Owner:	National Science Foundation
Operator:	Lamont-Doherty Earth Observatory of Columbia University
Flag:	United States of America
Date Built:	1991 (Refitted in 2006)
Gross Tonnage:	3834
Accommodation Capacity:	55 including ~35 scientists

Airgun Description

During the survey, the airgun array to be used will consist of 36 airguns, with a total volume of ~6600 in^3. The airgun array will consist of a mixture of Bolt 1500LL and Bolt 1900LLX airguns. The airguns will be configured as four identical linear arrays or "strings" (Fig. 2). Each string will have ten airguns; the first and last airguns in the strings are spaced 16 m apart. Nine airguns in each string will be fired simultaneously, whereas the tenth is kept in reserve as a spare, to be turned on in case of failure of another airgun. The four airgun strings will be towed ~100 m behind the *Langseth* and will distributed across an area of ~24×16 m. The shot interval will be ~50 m (20 s). The firing pressure of the array is 1900 psi. During firing, a brief (~0.1 s) pulse of sound is emitted. The airguns will be silent during the intervening periods.

The tow depth of the array will be 15 m. Because the actual source is a distributed sound source (36 airguns) rather than a single point source, the highest sound levels measurable at any location in the water will be less than the nominal source level. In addition, the effective source level for sound propagating in near-horizontal directions will be substantially lower than the nominal source level applicable to downward propagation because of the directional nature of the sound from the airgun array.

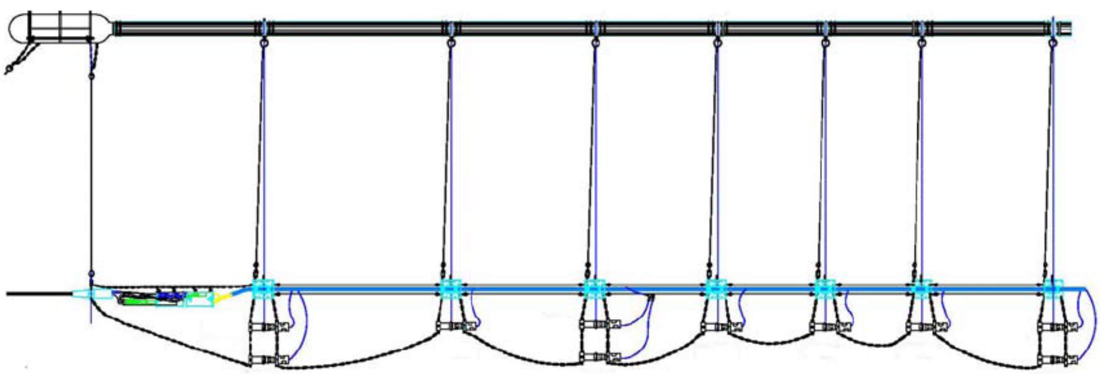

FIGURE 2. One linear airgun array or string with ten airguns, nine of which would be operating.

36-Airgun Array Specifications

Energy Source	Thirty-six 1900 psi Bolt airguns of 40–360 in^3, in four strings each containing nine operating airguns
Source output (downward)	0-pk is 84 bar-m (259 dB re 1 μPa·m); pk-pk is 177 bar·m (265 dB)
Air discharge volume	~6600 in^3
Dominant frequency components	2–188 Hz

Acoustic Measurements

Received sound levels have been predicted by L-DEO's model, in relation to distance and direction from the airguns, for the 36-airgun array and for a single 1900LL 40-in^3 airgun, which will be used during power downs. Results were reported for propagation measurements of pulses from the 36-airgun array in two water depths (~1600 m and 50 m) in the Gulf of Mexico in 2007–2008 (Tolstoy et al. 2009). However, measurements were not reported for a single airgun, although the sound levels in deep water have been modeled (Fig. 3). A detailed description of the modeling effort is provided in Appendix A of the Environmental Assessment (EA).

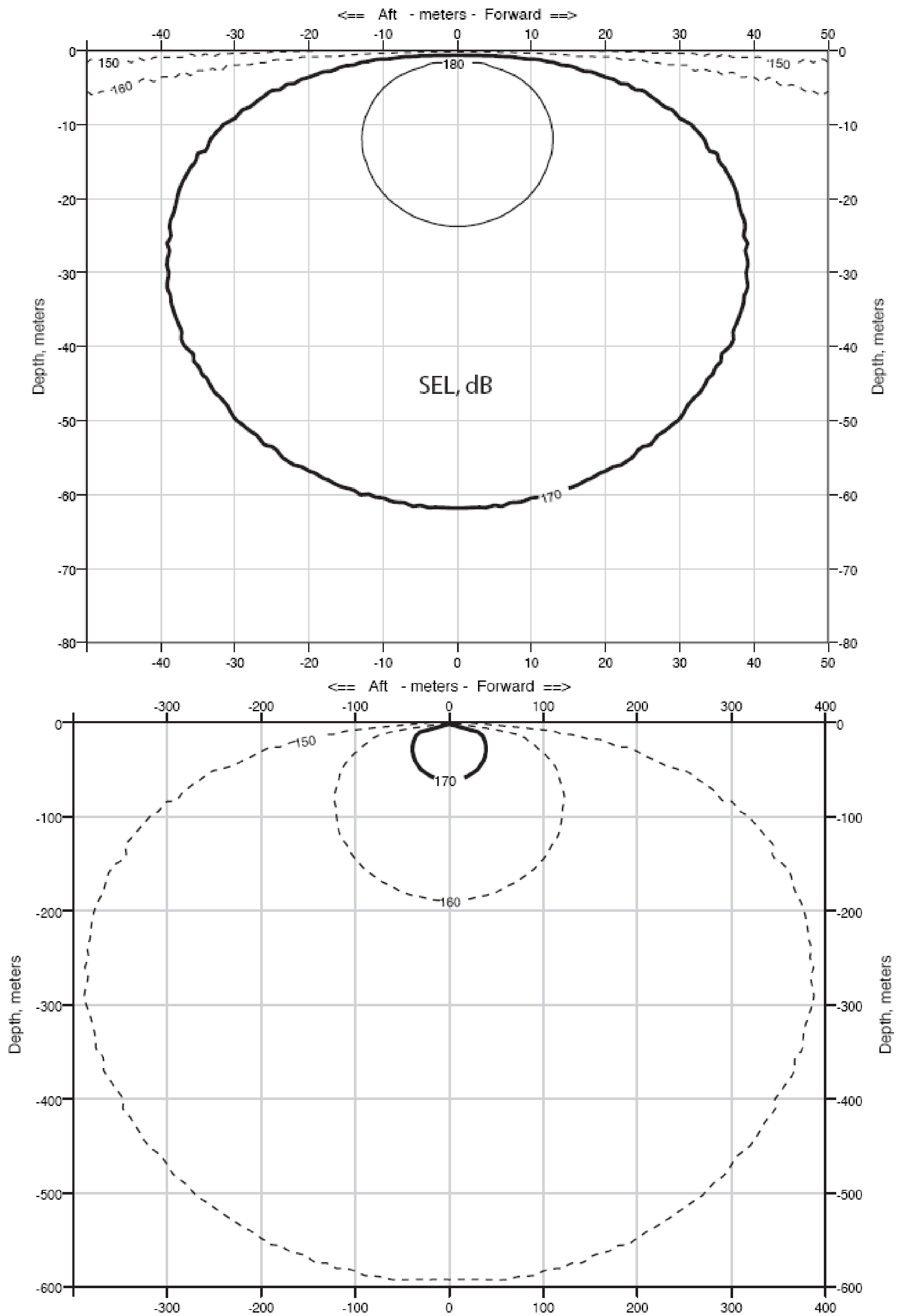

FIGURE 3. Modeled received sound levels (SELs) from a single 40-in^3 airgun operating in deep water, which is planned for use during the survey in the northeast Pacific during July 2012. Received rms levels (SPLs) are expected to be ~10 dB higher.

The predicted sound contours for the 40-in^3 mitigation airgun are shown in Figure 3 as sound exposure levels (SEL) in decibels (dB) re 1 μPa$^2 \cdot$ s. SEL is a measure of the received energy in the pulse and represents the sound pressure level (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 (see Appendix B of the EA). The advantage of working with SEL is that the SEL measure accounts for the total received energy in the pulse, and biological effects of pulsed sounds are believed to depend mainly on pulse energy (Southall et al. 2007). In contrast, SPL for a given pulse depends greatly on pulse duration. A pulse with a given SEL can be long or short depending on the extent to which propagation effects have "stretched" the pulse duration. The SPL will be low if the duration is long and higher if the duration is short, even though the pulse energy (and presumably the biological effects) are the same.

Although SEL is now believed to be a better measure than SPL when dealing with biological effects of pulsed sound, SPL is the measure that has been most commonly used in studies of marine mammal reactions to airgun sounds and in NMFS guidelines concerning levels above which "taking" might occur. SPL is often referred to as rms or "root mean square" pressure, averaged over the pulse duration. As noted above, the rms received levels that are used as impact criteria for marine mammals are not directly comparable to pulse energy (SEL). At the distances where rms levels are 160–190 dB re 1 μPa, the difference between the SEL and SPL values for the same pulse measured at the same location usually average ~10–15 dB, depending on the propagation characteristics of the location (Greene 1997; McCauley et al. 1998, 2000a; Appendix B of the EA). In this IHA Application, we assume that rms pressure levels of received seismic pulses will be 10 dB higher than the SEL values predicted by L-DEO's model. Thus, we assume that 170 dB SEL ≈ 180 dB re 1 μPa_{rms}. It should be noted that neither the SEL nor the SPL (=rms) measure is directly comparable to the peak or peak-to-peak pressure levels normally used by geophysicists to characterize source levels of airguns. Peak and peak-to-peak pressure levels for airgun pulses are always higher than the rms dB referred to in much of the biological literature (Greene 1997; McCauley et al. 1998, 2000a). For example, a measured received level of 160 dB re 1 μPa_{rms} in the far field typically would correspond to a peak measurement of ~170–172 dB re 1 μPa, and to a peak-to-peak measurement of ~176–178 dB re 1 μPa, as measured for the same pulse received at the same location (Greene 1997; McCauley et al. 1998, 2000a). (The SEL value for the same pulse would normally be 145–150 dB re 1 μPa$^2 \cdot$s). The precise difference between rms and peak or peak-to-peak values for a given pulse 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 and (for an airgun-type source at the ranges relevant here) higher than the SEL value.

Predicted Sound Levels

Results of the propagation measurements showed that radii around the airguns for various received levels varied with water depth (Tolstoy et al. 2009). In addition, propagation varies with array tow depth. The empirical values that resulted from Tolstoy et al. (2009) are used here to determine exclusion zones for the 36-airgun array. However, the depth of the array was different in the Gulf of Mexico calibration study (6 m) than in the proposed survey (15 m); thus, correction factors have been applied to the distances reported by Tolstoy et al. (2009). The correction factors used were the ratios of the 160-, 180-, and 190-dB distances from the modeled results for the 6600-in^3 airgun array towed at 6 m vs. 15 m, from LGL (2009): 1.647, 1.718, and 1.727, respectively.

Using the corrected empirical measurements (array) or model (single airgun), Table 1 shows the distances at which three rms sound levels are expected to be received from the 36-airgun array and a

TABLE 1. Measured (array) or predicted (single airgun) distances to which sound levels ≥190, 180, and 160 dB re 1 μPa_{rms} are expected to be received during the proposed survey in the northeastern Pacific Ocean, 12–23 July 2012. Radii for the array are based on empirical data in Tolstoy at al. (2009), corrected for tow depth using model results, and predicted radii for a single airgun are based on L-DEO's model, assuming that received levels on an RMS basis are, numerically, 10 dB higher than the SEL values shown in Figure 3.

Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted RMS Radii (m)		
			190 dB	**180 dB**	**160 dB**
Single Bolt airgun 40 in^3	6–15[1]	>1000 m	12	40	385
		100–1000 m	18	60	578
		<100	150	296	1050
4 strings 36 airguns 6600 in^3	15	>1000 m	520	1200	4940
		100–1000 m	690	1975	15,650
		<100	865	2750	26,350

[1] The tow depth has minimal effect on the maximum near-field output and the shape of the frequency spectrum for the single airgun.

single airgun. The 180- and 190-dB re 1 μPa_{rms} distances are the safety criteria as specified by NMFS (2000) and are applicable to cetaceans and pinnipeds, respectively. The 180-dB distance will also be used as the exclusion zone for sea turtles, as required by NMFS in most other recent seismic projects (e.g., Smultea et al. 2004; Holst et al. 2005a,b; Holst and Beland 2008; Holst and Smultea 2008; Hauser et al. 2008; Holst 2009; Antochiw et al. n.d.). If marine mammals or sea turtles are detected within or about to enter the appropriate exclusion zone, the airguns will be powered down (or shut down if necessary) immediately.

Southall et al. (2007) made detailed recommendations for new science-based noise exposure criteria. L-DEO will be prepared to revise its procedures for estimating numbers of mammals "taken", exclusion zones, etc., as may be required by any new guidelines established by NMFS as a result of these recommendations. However, currently the procedures are based on best practices noted by Pierson et al. (1998) and Weir and Dolman (2007), as NMFS has not yet specified a new procedure for determining exclusion zones.

Description of Operations

The source vessel, the R/V *Marcus G. Langseth*, will deploy an array of 36 airguns as an energy source at a tow depth of 15 m. The receiving system will consist of one 8-km long hydrophone streamer. As the airgun array is towed along the survey lines, the hydrophone streamer will receive the returning acoustic signals and transfer the data to the on-board processing system.

This survey will take place along 9 parallel lines 8 km apart and, if time permits, along an additional two lines perpendicular to the parallel lines (Fig. 1). The seismic lines are over water depths of ~95–2650 m. The total survey effort including contingency lines will consist of ~785 km of transect lines in depths >1000 m, 350 km in depths 100–1000 m, and 12 km in water depths <100 m. There will be additional seismic operations in the survey area associated with turns, airgun testing, and repeat coverage of any areas where initial data quality is sub-standard. In our calculations (see § VI), 25% has been added for those additional operations. In addition to the operations of the airgun array, a Kongsberg EM 122 multibeam echosounder (MBES) and a Knudsen Chirp 3260 sub-bottom profiler (SBP) will also be operated from the *Langseth* continuously throughout the cruise.

Multibeam Echosounder and Sub-bottom Profiler

The Kongsberg EM 122 MBES operates at 10.5–13 (usually 12) kHz and is hull-mounted on the *Langseth*. The transmitting beamwidth is 1 or 2° fore–aft and 150° athwartship. The maximum source level is 242 dB re 1 μPa · m_{rms}. Each "ping" consists of eight (in water >1000 m deep) or four (<1000 m) successive fan-shaped transmissions, each ensonifying a sector that extends 1° fore–aft. Continuous-wave (CW) pulses increase from 2 to 15 ms long in water depths up to 2600 m, and FM chirp pulses up to 100 ms long are used in water >2600 m. The successive transmissions span an overall cross-track angular extent of about 150°, with 2-ms gaps between the pulses for successive sectors.

The Knudsen Chirp 3260 SBP is normally operated by the *Langseth* to provide information about the sedimentary features and the bottom topography that is being mapped simultaneously by the MBES. The SBP is capable of reaching depths of 10,000 m. The beam is transmitted as a 27º cone, which is directed downward by a 3.5-kHz transducer in the hull of the *Langseth*. The nominal power output is 10 kW, but the actual maximum radiated power is 3 kW or 222 dB re 1 μPa · m. The ping duration is up to 64 ms, and the ping interval is 1 s. A common mode of operation is to broadcast five pulses at 1-s intervals followed by a 5-s pause.

II. DATES, DURATION, AND REGION OF ACTIVITY

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

The survey will encompass the area ~~46.5–47.5°N and ~124.5–126°W in the U.S. EEZ (Fig. 1). Water depths in the survey area are ~95–2650 m. The exact dates of the activities depend on logistics and weather conditions. The *Langseth* will depart again from Astoria, OR, on 12 July 2012 and return there on 23 July. Seismic operations will be carried out for an estimated 10 days.

III. SPECIES AND NUMBERS OF MARINE MAMMALS IN AREA

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

Thirty-two marine mammal species could occur in the northeast Pacific survey area. To avoid redundancy, we have included the required information about the species and (insofar as it is known) numbers of these species in § IV, below.

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

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

Sections III and IV are integrated here to minimize repetition.

Thirty-two marine mammal species could occur in the northeastern Pacific survey area, including mysticetes (baleen whales), odontocetes (toothed cetaceans, such as dolphins), pinnipeds (seals) and the sea otter (Table 2). Information on the occurrence, population size, and conservation status for each of the 32 species is presented in Table 2. The status of these species is based on the ESA, the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2011), and the Convention on International Trade in Endangered Species in Wild Fauna and Flora (CITES; UNEP-WCMC 2011). Six of the species that could occur in the proposed survey areas are listed under the ESA as ***Endangered***, including sperm, humpback, sei, fin, blue, and North Pacific right whales. Two other

TABLE 2. The habitat, abundance, and conservation status of marine mammals that could occur in or near the proposed seismic survey areas in the northeastern Pacific Ocean off Washington and Oregon.

Species	Occurrence in survey areas	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	Common*	Coastal, shallow shelf	19,126[6]	DL	LC	I
Humpback whale	Common*	Mainly nearshore and banks	20,800[7]	EN	LC	I
Minke whale	Rare	Nearshore, offshore	9000[8]	NL	LC	I
Sei whale	Rare	Mostly pelagic	12,620[9]	EN	EN	I
Fin whale	Common	Slope, pelagic	13,620–18,680[10]	EN	EN	I
Blue whale	Rare	Pelagic and coastal	2497	EN	EN	I
Odontocetes						
Sperm whale	Common	Pelagic, steep topography	24,000[11]	EN	VU	I
Pygmy sperm whale	Rare	Deep, off shelf	N.A.	NL	DD	II
Dwarf sperm whale	Rare	Deep, shelf, slope	N.A.	NL	DD	II
Cuvier's beaked whale	Common	Pelagic	2143	NL	LC	II
Baird's beaked whale	Common	Pelagic	907	NL	DD	I
Blainville's beaked whale	Rare	Pelagic	1024[12]	NL	DD	II
Hubb's beaked whale	Rare	Slope, offshore	1024[12]	NL	DD	II
Stejneger's beaked whale	Common	Slope, offshore	1024[12]	NL	DD	II
Common bottlenose dolphin	Rare	Coastal, shelf, deep	1006[13]	NL	LC	II
Striped dolphin	Rare	Off continental shelf	10,908	NL	LC	II
Short-beaked common dolphin	Common	Shelf, pelagic, mounts	411,211	NL	LC	II
Pacific white-sided dolphin	Abundant	Offshore, slope	26,930	NL	LC	II
Northern right whale dolphin	Common	Slope, offshore waters	8,334	NL	LC	II
Risso's dolphin	Common	Shelf, slope, mounts	6,272	NL	LC	II
False killer whale	Rare	Pelagic	N.A.	NL	DD	II
Killer whale	Common	Widely distributed	2250–2700	NL/EN[13]	DD	II
Short-finned pilot whale	Rare	Pelagic, high-relief	760	NL	DD	II
Harbor porpoise	Abundant	Coastal and inland waters	55,255[14]	NL	LC	II
Dall's porpoise	Abundant	Shelf, slope, offshore	42,000	NL	LC	II
Pinnipeds						
Northern fur seal	Common	Pelagic, offshore	653,171[6]	NL	VU	NL
California sea lion	Rare	Coastal, shelf	296,750	NL	LC	NL
Steller sea lion	Common*	Coastal, shelf	58,334–72,223[6]	T	EN	NL
Harbor seal	Abundant*	Coastal	24,732[15]	NL	LC	NL
Northern elephant seal	Common	Coastal, pelagic in migration	124,000[16]	NL	LC	NL
Fissiped						
Northern sea otter	Absent	Nearshore, coastal	1125[17]	NL	EN	I

N.A. - Data not available or species status was not assessed.
* In nearshore survey areas, rare elsewhere.
[1] Abundance given for the California/Oregon/Washington or Eastern North Pacific stock (Carretta et al. 2011a,b), unless otherwise stated.
[2] Endangered Species Act: EN = Endangered, T = Threatened, DL = Delisted, NL = Not listed
[3] Codes for IUCN (2011): EN = Endangered; VU = Vulnerable; LC = Least Concern; DD = Data Deficient
[4] CITES (UNEP-WCMC 2011): Appendix I = threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled, NL = Not Listed
[5] Bering Sea (Wade et al. 2010)
[6] Eastern North Pacific (Allen and Angliss 2011)
[7] North Pacific (Barlow et al. 2009)
[8] North Pacific (Wada 1976)
[9] North Pacific (Tillman 1977)
[10] North Pacific (Ohsumi and Wada 1974)
[11] Eastern Temperate North Pacific (Whitehead 2002a)
[12] All mesoplodont whales
[13] Offshore stock (Carretta et al. 2011a)

[14] The Eastern North Pacific Southern Resident Stock of killer whales is listed as Endangered under the ESA.
[15] Northern Oregon/Washington Coast and Northern California/Southern Oregon stocks
[16] Oregon/Washington Coastal Stock (Carretta et al. 2011a)
[17] California population (Carretta et al. 2011a)
[18] Minimum population estimate, WA (NMFS 2008a)

listed stocks could occur in the proposed survey areas: the ***Threatened*** Eastern U.S. Stock of the Steller sea lion, and the ***Endangered*** Southern Resident Stock of the killer whale.

The proposed survey areas are located ~32–150 km offshore from Washington over water depths ~95–2650 m (Fig. 1). The sea otter is not expected in the proposed survey areas because its occurrence off Washington and Oregon is limited to very shallow (<30 m depth), coastal (<4 km from shore) waters (Laidre et al. 2009). Vagrant ringed seals, hooded seals, and ribbon seals have been sighted or stranded on the coast of California (see Mead 1981; Reeves et al. 2002) and presumably passed through Oregon waters. A vagrant beluga whale was seen off the coast of Washington (Reeves et al. 2002). Those five species are not addressed in the summaries below.

Mysticetes

North Pacific Right Whale (*Eubalaena japonica*)

The North Pacific right whale is listed as ***Endangered*** under the ESA and is considered by NMFS (1991) to be the most endangered baleen whale in the world. It is listed as ***Endangered*** on the IUCN Red List of Threatened Species (IUCN 2011) and is listed in CITES Appendix I (UNEP-WCMC 2011) (Table 2). Although protected from commercial whaling since 1935, there has been little indication of recovery. The pre-exploitation stock could have exceeded 11,000 animals (NMFS 1991). Wada (1973) estimated a total population of 100–200 in the North Pacific based on sighting data. Based on photographic and genetic mark-recapture data, right whale abundance in the Bering Sea and Aleutian Islands was estimated at 31 and 28, respectively. The total northeastern Pacific population is unlikely to be much larger (Wade et al. 2010).

North Pacific right whales summer 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 that 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). In April 1996, a right whale was sighted off Maui, representing the first documented sighting of a right whale in Hawaiian waters since 1979 (Herman et al. 1980; Rowntree et al. 1980). The individual seen in Hawaii was one of the whales subsequently seen in the southeastern Bering Sea on several occasions, and represents the first high to low latitude North Pacific right whale match (Allen and Angliss 2011).

Whaling records indicate that right whales once ranged across the entire North Pacific north of 35ºN and occasionally occurred as far south as 20ºN. 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 on 24 May 1992, 65 km west of Cape Elizabeth, Washington, over water depths of

~1200 m; the same whale was subsequently photographically identified again ~6 hr later 48 km to the west over water depths of ~500 m. Despite many miles of systematic aerial and ship-based surveys for marine mammals off the coasts of Oregon/Washington/California over the years, only seven documented sightings of right whales were made from 1990 to 2000 (Waite et al. 2003). 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 even small numbers will be present in the proposed survey areas during the planned period of operations in June–July, and therefore no takes are anticipated or requested.

Gray Whale (*Eschrichtius robustus*)

In the North Pacific, gray whales have distinct eastern and western stocks. Although both populations were severely reduced by whaling and the western population has remained highly depleted, the eastern North Pacific population is generally considered to have recovered (Lang et al. 2010). The eastern North Pacific stock was ***Delisted*** from the ESA in 1994. The species is listed as ***Least Concern*** on the IUCN Red List of Threatened Species (IUCN 2011), and is listed in CITES Appendix I (UNEP-WCMC 2011). The population estimate for this stock is 19,126 for 2006/2007 (Allen and Angliss 2011).

The eastern North Pacific gray whale breeds and winters in Baja, California, and migrates north to summer feeding grounds in the northern Bering Sea, the Chukchi Sea, and the western Beaufort Sea (Rice and Wolman 1971; Jefferson et al. 2008); a small portion of the population also summers along the Pacific coast from Vancouver to central California (Rice and Wolman 1971; Nerini 1984; Calambokidis and Quan 1999). Whales observed foraging in these more southern locations are referred as 'resident' (Newell and Cowles 2006). In October and November, 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 (Braham 1984; Rugh et al. 2001).

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). Gray whales are known to move farther offshore between the entrance to Prince William Sound and the southern part of the Alaska Peninsula (Consiglieri et al. 1982). They migrate closest to the Washington/Oregon coastline during the spring months (April–June) when most strandings are observed (Norman et al. 2004).

Gray whales usually migrate alone, with the exception of cow/calf pairs, and groups of >6 whales are unusual (Rice and Wolman 1971; Leatherwood et al. 1982). Foraging gray whales commonly dive to depths of 50–60 m, and the maximum known dive depth is 170 m (Jones and Swartz 2009). Migrating gray whales typically dive for 3–5 min and spend 1–2.5 min on the surface between dives (Jones and Swartz 2009).

Resident gray whales have been observed foraging off the coast of Oregon from May to October (Newell and Cowles 2006). At least 28 gray whales were observed near Depoe Bay (~44.8°N) for three successive summers (Newell and Cowles 2006). 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. 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 (Ortega-Ortiz and Mate 2008). The migration paths of tracked whales seemed to follow a constant depth rather than the shoreline. Calambokidis et al. (2004a) estimated annual abundance of gray whales that remained between Oregon and B.C. in summer at 197–256 using photo-identification methods.

Humpback Whale (*Megaptera novaeangliae*)

The humpback whale is found throughout all of the oceans of the world (Clapham 2009). The species is listed as ***Endangered*** under the ESA and ***Least Concern*** on the IUCN Red List of Threatened Species (IUCN 2011), and it is listed in CITES Appendix I (UNEP-WCMC 2011) (Table 2). The world-wide population of humpback whales 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).

The entire North Pacific stock has been recently estimated at 18,302, excluding calves (Calambokidis et al. 2008). Barlow et al. (2009) provided a bias-corrected abundance estimate of 20,800. Overall, the North Pacific stock is increasing (Calambokidis et al. 2008).

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), and winter in three different breeding areas: (1) the eastern North Pacific along the coast of Mexico and Central America, and near the Revillagigedo Islands; (2) around the main Hawaiian Islands; and (3) in the western Pacific, particularly around the Ogasawara and Ryukyu islands in southern Japan and the northern Philippines (Perry et al. 1999a; Calambokidis et al. 2008). There is a low level of interchange of whales among the three main wintering areas and among feeding areas (e.g., Darling and Cerchio 1993; Salden et al. 1999; Calambokidis et al. 2001, 2008).

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). The diving behavior of humpback whales is related to time of year and whale activity. On winter breeding grounds, humpback dives have been recorded at depths >100 m (Baird et al. 2000). In summer feeding areas, humpbacks typically forage in the upper 120 m of the water column, with a maximum recorded dive depth of 500 m (Dolphin 1987; Dietz et al. 2002).

Humpback whales are often sighted singly or in small groups, and up to 20 or more while on their breeding and feeding ranges (Jefferson et al. 2008). Loose feeding aggregations of up to 35 have been sighted over the continental shelf off Oregon/Washington (Green et al. 1992). Barlow (2003) reported mean group sizes of 1.1–2.3 during surveys in 1991, 1993, 1996, and 2001 off California, Oregon, and Washington. Male humpbacks sing a characteristic song when on the wintering grounds (Winn and Reichley 1985).

The humpback whale is the most common species of large cetacean reported off the coasts of Oregon and Washington from May to November, with highest numbers reported from May to September; no humpbacks have been observed there in the winter (Green et al. 1992; Calambokidis et al. 2000, 2004b). Shifts in seasonal abundance observed off Oregon and Washington suggest north–south movement (Green et al. 1992). Off Oregon/Washington, humpbacks occur primarily over the continental shelf and slope during the summer and fall, with few reported in offshore pelagic waters (Green et al. 1992, Calambokidis et al. 2004b). 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 >200 m deep. That sighting was ~70 km west of Cape Blanco during the spring (Green et al. 1992). Encounter rates off Oregon/Washington during the summer were highest over the slope followed by shelf waters, with no sightings in offshore waters (Green et al. 1992). At least 12 humpback whale sightings were reported during the Oregon/Washington portions of the survey in summer/fall 2008 (Barlow 2010). Based on surveys conducted in 1991–2008, the estimated abundance of humpback whales off the coasts of Oregon and Washington is 260 (Barlow 2010). The abundance estimate for humpback whales off the coasts of Oregon/Washington/California is 2034 (Carretta et al. 2011a).

Minke Whale (*Balaenoptera acutorostrata*)

The minke whale has a cosmopolitan distribution that spans polar, temperate, and tropical regions (Jefferson et al. 2008). 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). Wada (1976) estimated the abundance of minke whales in the North Pacific at ~9000.

The minke whale is relatively solitary, but can occur in aggregations of up to 100 when food resources are concentrated (Jefferson et al. 2008). The small size, inconspicuous blows, and brief surfacing times of minke whales mean that they are easily overlooked in heavy sea states, although they are known to approach vessels in some circumstances (Stewart and Leatherwood 1985). Little is known about the diving behavior of minke whales, but they are not known to make prolonged deep dives (Leatherwood and Reeves 1983). One study of four minke whales equipped with speed-depth recorders off northern Norway and Svalbard reported minke whale foraging dives to 65 m (Blix and Folkow 1995).

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 resident in coastal waters off the U.S. west coast (Dorsey et al. 1990). Minke whales strandings have been reported in all seasons in Washington. Most strandings (52%) occurred in spring (March–May); 29% of strandings occurred in summer (June–August; Norman et al. 2004). Forney (2007) estimated and abundance of 957 minke whales during a 2005 ship survey off California, Oregon, and Washington, whereas the most recent survey in 2008 did not record any minke whales while on survey effort (Barlow 2010). Based on surveys conducted in 1991–2008, the estimated abundance of minke whales off the coasts of Oregon and Washington is 147 (Barlow 2010).

Sei Whale (*Balaenoptera borealis*)

The sei whale is listed as ***Endangered*** under the ESA and on the IUCN Red List of Threatened Species (IUCN 2011), and is listed in CITES Appendix I (UNEP-WCMC 2011) (Table 2). Sei whale populations were depleted by whaling, and the current status of this species is generally uncertain (Horwood 1987). The global population is thought to be ~80,000 (Horwood 2009), with up to ~12,620 in the North Pacific (Tillman 1977). The sei whale is poorly known because of confusion with Bryde's whale and unpredictable distribution patterns; it can be common in an area for several years and then seemingly disappear (Schilling et al. 1992; Jefferson et al. 2008).

The sei whale is pelagic and generally not found in coastal waters (Harwood and Wilson 2001). 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 are frequently seen in groups of 2–5 (Leatherwood et al. 1982; Jefferson et al. 2008), although larger groups sometimes form on feeding grounds (Gambell 1985a). Sei whales generally do not dive deeply, and dive durations are 15 min or longer (Gambell 1985a).

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. 2008). 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 about 20°N, and sightings have been made between southern Baja California and the Islas Revillagigedo (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 are known for California, Oregon, and Washington during extensive surveys from 1991–2008 (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. 2011a). Based on surveys conducted in 1991–2008, the estimated abundance of sei whales off the coasts of Oregon and Washington is 52 (Barlow 2010).

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° to 70° north and south of the Equator (Perry et al. 1999b). It is listed as ***Endangered*** under the ESA and on the IUCN Red List of Threatened Species (IUCN 2011), and is listed in CITES Appendix I (UNEP-WCMC 2011) (Table 2). Probably at least in part because of its initially high abundance, wide distribution, and diverse feeding habits, the fin whale does not seem to have been as badly depleted as the other large whales in the North Pacific. Northern and southern fin whale populations are distinct and are sometimes recognized as different subspecies (Aguilar 2009). Abundance estimates are 13,620–18,680 for the North Pacific (Ohsumi and Wada 1974).

Fin whales occur in coastal, shelf, and oceanic waters. Moore et al. (2002) reported that in the eastern Bering Sea, sighting rates were more than twice as high in water >100 m deep than in water 50–100 m deep; no sightings occurred in water <50 m deep. 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 can be found as individuals or groups of 2–7, but can form much larger feeding aggregations, sometimes with humpback and minke whales (e.g., Waite 2003; Jefferson et al. 2008). Barlow (2003) reported mean group sizes of 1.1–4.0 during surveys in 1991, 1993, 1996, and 2001 off California, Oregon, and Washington. Foraging fin whales have mean dive depths and times of 98 m and 6.3 min, and non-foraging fin whales have mean dive depths and times of 59 m and 4.2 min (Croll et al. 2001). Panigada et al. (1999, 2003) reported variations in dive depths coinciding with the diel migration of krill. Daytime dives were shallower (<100m) and night dives were deeper (>400m). Fin whales in southern California were reported diving 60% of their time to water depth >225 m; the other 40% of time was spent near the surface (<50 m; Goldbogen et al. 2006).

Fin whales appear to have complex seasonal movements and are likely seasonal migrants (Gambell 1985b). They mate and calve in temperate waters during the winter and migrate to feed at northern latitudes during the summer (Mackintosh 1965 *in* Gambell 1985b). The North Pacific population summers from the Chukchi Sea to California and winters from California southwards (Gambell 1985b). Recent information about the seasonal distribution of fin whales in the North Pacific has been obtained from the reception of fin whale calls by bottom-mounted, offshore hydrophone arrays along the U.S. Pacific coast, in the central North Pacific, and in the western Aleutian Islands (Moore et al. 1998, 2006; Watkins et al. 2000a,b; Stafford et al. 2007, 2009). Fin whale calls are detected year-round in the Northern Pacific (Moore et al. 2006; Stafford et al. 2007, 2009).

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). Vocalizations from fin whales have been detected year-round off northern California, Oregon, and Washington (Moore et al. 1998). Fin whale abundance off the coasts of California/Oregon/Washington was estimated at 3044 based on summer/autumn ship surveys conducted in 2005 and 2008 (Carretta et al. 2011a). Based on survey conducted in 1991–2008, the estimated abundance of fin whales off the coasts of Oregon and Washington is 416 (Barlow 2010). At least 20 fin whale sightings were reported during the Oregon/Washington portions of the survey in 2008 (Barlow 2010).

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. 2008). It is listed as ***Endangered*** under the ESA and on the IUCN Red List of Threatened Species (IUCN 2011), and is listed in CITES Appendix I (UNEP-WCMC 2011) (Table 2). All blue whale populations have been exploited commercially, and many have been severely depleted as a result. 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 (including the California area) during summer and fall may winter in the eastern tropical Pacific (ETP) (Stafford et al. 1999, 2001). The western North Pacific stock includes whales that are found around Hawaii during winter. Blue whale abundance has been estimated at ~2497 off the U.S. west coast based on photo-identification data from 2005–2008 (Carretta et al. 2011a).

Blue whales are typically found singly or in groups of two or three (Yochem and Leatherwood 1985; Jefferson et al. 2008). Barlow (2003) reported mean group sizes of 1.0–1.9 during surveys in 1991, 1993, 1996, and 2001 off California, Oregon, and Washington. Croll et al. (2001) reported mean dive depths and times of 140 m and 7.8 min for foraging blue whales, and 68 m and 4.9 min for non-foraging individuals. Four satellite-radio-tagged blue whales in the northeast Pacific Ocean spent 94% of their time underwater; 72% of dives were <1 min long, and "true" dives (>1 min) were 4.2–7.2 min long. Shallow (<16-m) dives were most common (75%), and the average depth of deep (>16-m) dives was 105 m (Lagerquist et al. 2000). Dives of up to 300 m were recorded for tagged blue whales (Calambokidis et al. 2003).

The distribution of the species, at least during times of the year when feeding is a major activity, is in areas that provide large seasonal concentrations of euphausiids, which are the whale's main prey (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). Blue whales also have been heard off Oregon (McDonald et al. 1995; Stafford et al. 1998; Von Saunder and Barlow 1999), but sightings in the area are rare.

Barlow and Forney (2007) estimated an abundance of 603 blue whales in California, Oregon, and Washington waters, based on line-transect data collected during summer and fall 2001. Barlow (2010) estimated 442 blue whales for California, Oregon, and Washington, based on line-transect surveys conducted during summer and fall 2008. The estimate of population abundance off California, Oregon, and Washington based on mark-recapture data collected in 2004–2006 is 2842 (Calambokidis et al. 2007). Carretta et al. (2011a) noted that this represented the best estimate for the population in the area. Blue whales are considered rare off Oregon and Washington (Buchanan et al. 2001). Based on surveys conducted in 1991–2008, the estimated abundance of blue whales off the coasts of Oregon and Washington was 58 (Barlow 2010). Four blue whale sightings were reported during the Oregon/Washington portions of the survey in 2008 (Barlow 2010).

Odontocetes

Sperm Whale (*Physeter macrocephalus*)

The sperm whale is the largest of the toothed whales, with an extensive worldwide distribution (Rice 1989). The species is listed as ***Endangered*** under the U.S. ESA, but on a worldwide basis it is abundant and not biologically endangered. It is listed as ***Vulnerable*** on the IUCN Red List of Threatened Species (IUCN 2011), and is listed in CITES Appendix I (UNEP-WCMC 2011) (Table 2). There currently is no accurate estimate for the size of any sperm whale population (Whitehead 2002b). Best estimates probably are those of Whitehead (2002a), who provided a sperm whale population size of 24,000 for the eastern temperate North Pacific.

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). They spend periods of at least months on the breeding grounds, moving between mixed groups of ~20–30 animals (Whitehead 1993, 2003). Barlow (2003) reported mean group sizes of 2.0–11.8 during surveys in 1991, 1993, 1996, and 2001 off California, Oregon, and Washington. The mean group size off the coasts of Oregon and Washington in 2008 was 1.0 (Barlow 2010).

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). A recent study of tagged male sperm whales off Norway found that foraging dives extended to highly variable maximum depths, ranging from 14 to 1860 m, with a median of 175 m (Teloni et al. 2008). During a foraging dive, sperm whales typically travel ~3 km horizontally and 0.5 km vertically (Whitehead 2003). Whales in the Galápagos Islands typically dove for ~40 min and then spent 10 min at the surface (Papastavrou et al. 1989). Davis et al. (2007) reported that sperm whales in the Gulf of California foraged throughout a 24-h period, and rarely dove to the sea-floor bottom (>1000 m); dive depths (100–500 m) overlapped with depth distributions of jumbo squid.

Sperm whales are distributed widely across the North Pacific (Carretta et al. 2011a). Off Oregon, they are seen in every season except winter (Green et al. 1992). In contrast, sperm whales are found off California 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). Based on surveys conducted in 1991–2008, the estimated abundance of sperm whales off the coasts of Oregon and Washington is 329 (Barlow 2010). Three sperm whale sightings were reported in water depths >2000 m during the Oregon/ Washington portions of the survey in 2008 (Barlow 2010).

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

The pygmy sperm whale and dwarf sperm whale 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).

Pygmy sperm whales could inhabit waters beyond the continental shelf edge, whereas dwarf sperm whales are thought to inhabit the shelf edge and slope waters (Rice 1998; Wang et al. 2002; MacLeod et al. 2004). Barros et al. (1998) suggested that dwarf sperm whales could be more pelagic and dive deeper than pygmy sperm whales. Dwarf sperm whale could prefer warmer waters than pygmy sperm whales (e.g., Wade and Gerrodette 1993; Muñioz-Hincapié et al. 1998; McAlpine 2009). Pygmy sperm whales occur in small groups of up to six, and dwarf sperm whales can form groups of up to 10 (Caldwell and Caldwell 1989). Mean group size for the dwarf sperm whale was 2.3 in Hawaii (Barlow 2006) and 1.6–1.7 for the ETP (Wade and Gerrodette 1993; Jackson et al. 2008). The mean group size of the pygmy sperm whale in Hawaiian waters was 1.0 (Barlow 2006), and for the ETP was 1.3 (Jackson et al. 2008).

Pygmy sperm whales feed mainly on various species of squid in the deep zones of the continental shelf and slope (McAlpine et al. 1997). In the Gulf of California, median dive and surface times for dwarf sperm whales or unidentified *Kogia* sp. were 8.6 min and 1.2 min, and dives of up to 25 min and surface times up to 3 min were common (J. Barlow, pers. comm. *in* Willis and Baird 1998). Little is known about dive depths of *Kogia* spp. A satellite-tagged pygmy sperm whale released off Florida made longer dives (>8 min and up to ~18 min) at night and on overcast days, and shorter dives (usually 2–5 min) on clear days, probably because of the distribution of their prey, vertically-migrating squid (Scott et al. 2001).

Eight strandings of pygmy sperm whales have been recorded for Oregon and Washington, five of which occurred during autumn and winter months (Norman et al. 2004). Although there are few useful estimates of abundance for pygmy or dwarf sperm whales anywhere in their range, they are thought to be fairly common in some areas (Jefferson et al. 2008). For waters off Oregon and Washington, Barlow (2010) used data collected in 1991–2008 to estimate an abundance of 229 *Kogia* sp., which were thought to be pygmy sperm because no dwarf sperm whales had been identified on the west coast since the early 1970s.

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. 2008) and is most common in water depths >1000 m (Heyning 1989). Ferguson et al. (2006a) reported that in the ETP, the mean water depth where Cuvier's beaked whales were sighted was ~3.4 km. It is rarely observed at sea and is mostly known from strandings. It 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).

Adult males of this species usually travel alone, but these whales can be seen in groups of up to 7 (Heyning and Mead 2009), with a mean group size of 2.3 (MacLeod and D'Amico 2006). Barlow (2010) reported a mean group size of 1.3 for California/Oregon/Washington in 2008. Cuvier's beaked whale dives generally last 30–60 min, but dives of 85 min have been recorded (Tyack et al. 2006). The maximum dive depth recorded by Baird et al. (2006) was 1450 m.

It is the most common beaked whale off the U.S. west coast (Barlow 2010), and the beaked whale species that stranded most frequently on the coasts of Oregon and Washington. Most (75%) Cuvier's beaked whale strandings reported occurred in Oregon (Norman et al. 2004). The abundance estimate for the U.S. west coast, based on survey data from 2005 and 2008, is 2143 (Carretta et al. 2011a). Four beaked whale sightings were reported in water depths >2000 m during the Oregon/Washington portions of the survey in 2008 (Barlow 2010), none was seen in 1996 or 2001 (Barlow 2003), and several were recorded there from 1991 to 1995 (Barlow 1997). The abundance estimate for Oregon and Washington waters, based on data from 1991–2008, is 137 (Barlow 2010).

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). It has been suggested that Baird's beaked whales can be divided into three distinct stocks: the Sea of Japan Stock, the Okhotsk Sea Stock, and the Bering Sea/Eastern North Pacific Stock (Balcomb 1989; Reyes 1991). Any animals in the vicinity of the proposed survey areas likely would be from the Bering Sea/Eastern North Pacific stock. The mean abundance estimate for the U.S west coast based on 2005–2008 ship surveys is 907 (Carretta et al. 2011a).

Baird's beaked whales feed on deep-water and bottom-dwelling fish, cephalopods, and crustaceans (Jefferson et al. 1993), and some pelagic fish (Reyes 1991; Kasuya 2009). Typical water depths for sightings are 1000–3000 m. Baird's beaked whales can stay submerged for up to 67 min (Kasuya 2009). That makes it very difficult to sight and to visually track them. Baird's beaked whales live in groups of 5–20, although larger groups are sometimes seen. There appears to be a calving peak in March and April (Jefferson et al. 2008).

Baird's beaked whales sometimes are seen close to shore where deep water approaches the coast, but their primary habitat is over or near the continental slope and oceanic seamounts (Jefferson et al. 2008). Along the U.S. west coast, they have been sighted primarily along the continental slope from late spring to early fall (Green et al. 1992; Carretta et al. 2011a). 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.

For Oregon/Washington waters, Barlow (2010) estimated an abundance of 380 Baird's beaked whales based on survey data collected in 1991–2008. 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. Two groups were sighted during summer/fall 2008 surveys off Washington/Oregon, both in waters >2000 m deep (Barlow 2010).

Mesoplodont Beaked Whales

Three species of *Mesoplodon* can occur off the coasts of Oregon and Washington: Blainville's beaked whale (*M. densirostris*), Stejneger's beaked whale (*M. stejnegeri*), and Hubb's beaked whale (*M. carlhubbsi*). In addition, records exist for Perrin's beaked whale (*M. perrini*) and the lesser beaked whale (*M. peruvianus*) and gingko-toothed beaked whale (*M. ginkgodens*) off the coast of California and/or Baja California (MacLeod et al. 2006). However, those species are unlikely to be seen in the proposed survey areas, and will not be discussed further.

Almost everything that is known regarding most mesoplodont species has come from stranded animals (Pitman 2009). Because of the scarcity of sightings, most are thought to be rare. The different mesoplodont species are difficult to distinguish in the field, and confirmed at-sea sightings are rare (Mead 1989; Jefferson et al. 2008; Carretta et al. 2011a).

Mesoplodonts are distributed primarily in deep waters (>2000 m) and along continental slopes at depths 200–2000 m; they are rarely found in continental shelf waters (Pitman 2009). Most mesoplodonts identified to species are known from strandings involving single individuals (Jefferson et al. 2008); thus, it is not possible to identify spatial or seasonal patterns in their distribution (Carretta et al. 2011a). Dive depths of most of these species are undocumented.

Typical group sizes range from one to six (Pitman 2009). Because of the scarcity of sightings, most are thought to be rare. However, based on stranding records, Blainville's beaked whale appears to be widespread and fairly common (Pitman 2009). In 1996, the estimated abundance of mesoplodont beaked whales was 2169 for Oregon and Washington, and in 2001, it was zero (Barlow 2003). In 2005, the estimated abundance in the area was 841, and in 2008, it was zero (Barlow 2010). The abundance of *Mesoplodon* species for Oregon and Washington waters is estimated at 565 based on data from 1991–2008 (Barlow 2010).

Blainville's beaked whale.—This species is found in tropical and temperate waters of all oceans (Jefferson et al. 2008). Blainville's beaked whale has the widest distribution throughout the world of all *Mesoplodon* species (Mead 1989). There is no evidence that Blainville's beaked whale undergoes seasonal migrations. It is most often found in singles or pairs, but also in groups of 3–7 (Jefferson et al. 2008). Barlow (2006) reported a mean group size of 2.3 for Hawaii.

Like other beaked whales, Blainville's beaked whales are generally found in waters 200–1400 m deep (Gannier 2000; Jefferson et al. 2008). Maximum dive depths have been reported as 1251 m (Tyack et al. 2006) and 1408 m (Baird et al. 2006), and dives have lasted as long as 54 min (Baird et al. 2006) to 57 min (Tyack et al. 2006). They also can occur in coastal areas and have been known to spend long periods of time at depths <50 m (Jefferson et al. 2008).

Occasional occurrences in cooler, higher-latitude waters are presumably related to warm-water incursions (Reeves et al. 2002). Strandings and sighting records in the eastern Pacific range from 37.3°N to 41.5°S (McLeod et al. 2006). None of the 36 beaked whale-stranding records in Oregon and Washington during 1930–2002 was Blainville's beaked whale (Norman et al. 2004). For California, Oregon, and Washington waters, Barlow (1997) estimated an abundance of 360 Blainville's beaked whales. It is unlikely to be present in the proposed survey area, as its main distribution is south of there (Carretta et al. 2011a).

Stejneger's beaked whale.—This species 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). This species occurs in groups of 3 to 4, ranging to ~15 (Reeves et al. 2002). 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).

Hubb's beaked whale.—This species occurs in temperate waters of the North Pacific (Mead 1989). Most of the records are from California, but it has been sighted as far north as Prince Rupert, British Columbia (Mead 1989). Two strandings are known from Washington/Oregon (Norman et al. 2004). The distribution of the species appears to be correlated with the deep subarctic current (Mead et al. 1982). Hubb's beaked whales are often killed in drift gillnets off California (Reeves et al. 2002).

Common Bottlenose Dolphin (*Tursiops truncatus*)

The bottlenose dolphin is distributed worldwide. It is found mainly where surface temperatures are 10–32ºC (Reeves et al. 2002). Generally, 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). As well as inhabiting different areas, these ecotypes differ in their diving abilities (Klatsky 2004) and prey types (Mead and Potter 1995). Bottlenose dolphins have been reported to dive regularly to depths >450 m for periods of >5 min, and even to depths of 600–700 m for up to 12 min (Klatsky et al. 2007). Mean group size was 8.02 for California, Oregon, and Washington in 2008 (Barlow 2010).

Bottlenose dolphins occur frequently off the coast of California, and sightings have been made as far north as 41ºN (Carretta et al. 2011a). The most recent abundance estimate of offshore bottlenose dolphins for California/Oregon/Washington is 1006 (Carretta et al. 2011a). In the proposed survey areas, it is possible that offshore bottlenose dolphins could be encountered during warm-water periods (see Carretta et al. 2002), although none have been sighted in waters off Oregon or Washington (Barlow 2010). No takes of bottlenose dolphins are anticipated or requested.

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). In the eastern North Pacific, its distribution extends as far north as Washington, although there have been few sightings (Appler et al. 2004). 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). It is fairly gregarious (groups of 20 or more are common) and active at the surface (Whitehead et al. 1998). Barlow (2010) reported a mean group size of 15.0 for California/Oregon/Washington in 2008. For the ETP, reported mean group sizes were 52–61 (Wade and Gerrodette 1993; Ferguson et al. 2006b; Jackson et al. 2008).

Off California, striped dolphins have been sighted within 185–556 km of the coast (Carretta et al. 2002). They also occur in coastal waters (Isaksen and Syvertsen 2002). There are 10 stranding records of this species in Oregon and two in Washington during 1930–2002 (Norman et al. 2004). The abundance of striped dolphins off the coasts of California/Oregon/Washington appears to be variable among years and could be affected by oceanographic conditions (Carretta et al. 2011a). The 1991–1996 average abundance estimate for was 20,235 (Barlow 1997), and the 2008 estimate was 4655 (Barlow 2010). Based on survey data from 2005 and 2008, the mean abundance estimate for California, Oregon, and Washington waters is 10,908 (Carretta et al. 2011a). However, very few sightings have been reported for Oregon or Washington, with the exception of a survey by Barlow (2003) in 1996. No striped dolphins were sighted off Washington and Oregon during the summer/fall survey in 2008 (Barlow 2010). Barlow (2010) gave an abundance estimate of 12 for waters off Oregon and Washington, based on data collected in 1991–2008.

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). There are two species of common dolphin: the short-beaked common dolphin (*D. delphis*) and the long-beaked common dolphin (*D. capensis*). The long-beaked common dolphin is less abundant, and only recently has been recognized as a separate species (Heyning and Perrin 1994). Short-beaked common dolphins have been sighted as far as 550 km from shore, and are likely present farther offshore (Barlow et al. 1997). Long-beaked common dolphins are usually found within 90 km of shore (Barlow et al. 1997), are not found north of central California (Carretta et al. 2011a). Common dolphins found in the survey area likely would be the short-beaked species.

Common dolphins often travel in large groups; schools of hundreds or even thousands are common. The groups are thought to be composed of smaller subunits of perhaps 20–30 closely related individuals (Evans 1994). Barlow (2010) reported a mean group size of 178 for the U.S. west coast in 2008. Common dolphins are easily identified from their fast swimming speed (typically 40 km/h) and their propensity for bow riding. Perrin (2009) reported foraging dives to 200 m.

The distribution of short-beaked common dolphins along the U.S. west coast is variable and likely is related to oceanographic changes (Heyning and Perrin 1994; Forney and Barlow 1998). The short-beaked common dolphin is the most abundant cetacean off California, but it is not abundant off Oregon and Washington (Carretta et al. 2011a). There were single sightings in 2001 and 2005 of common dolphins in Oregon/Washington, both off southern Oregon (Forney 2007). Only one sighting was reported off Oregon and Washington during the summer/fall survey in 2008 (Barlow 2010). Based on survey data in 2005 and 2008, the mean abundance in the area is estimated at 411,211 (Carretta et al. 2011a). The abundance estimates for waters off Oregon/Washington alone is 3312 for pooled 1991–2008 surveys (Barlow 2010).

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 marine mammal species, occurring primarily in shelf and slope waters (Green et al. 1993; Barlow 2003; Barlow 2010). It is known to occur close to shore in certain regions, including (seasonally) southern California (Brownell et al. 1999).

Pacific white-sided dolphins are very gregarious, commonly occurring in groups of 10–100, and occasionally in groups of thousands (Reeves et al. 2002). They often associate with other species, including cetaceans, pinnipeds, and seabirds. In particular, they are frequently seen in mixed-species schools with Risso's and northern right whale dolphins (Green et al. 1993). Barlow (2010) reported a mean group size of 72.4 for California/Oregon/Washington in 2008.

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; Carretta et al. 2002). During winter, this species is most abundant in California slope and offshore areas; as northern marine waters begin to warm in the spring, it appears to move north to slope and offshore waters off Oregon/Washington (Green et al. 1992, 1993; Forney 1994; Forney et al.

1995; Buchanan et al. 2001; Barlow 2003). Seasonal abundance estimates off the coast of California are an order of magnitude higher in February–April than in August–November, whereas the highest abundance estimates off Oregon and Washington are in April–May.

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). The highest encounter rates were associated with the 1992 El Niño year. Mean group sizes were significantly higher in slope (11.6) *vs*. offshore waters (6.7). 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 the second most abundant species reported during the 2008 survey (Barlow 2010). Its abundance off the coasts of California/Oregon/Washington was estimated at 26,930 based on summer/autumn ship surveys conducted in 2005 and 2008 (Carretta et al. 2011a). The abundance estimate for pooled 1991–2008 surveys off Oregon/Washington was 11,250 (Barlow 2010).

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 m to >2000 m deep (Green et al. 1993; Carretta et al. 2002; 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).

Northern right whale dolphins are gregarious, and groups of several hundred to over a thousand are not uncommon (Reeves et al. 2002). Barlow (2010) reported a mean group size of 23.7 for California, Oregon, and Washington in 2008. Northern right whale dolphins are often seen in mixed-species schools with Pacific white-sided dolphins. Calving appears to occur primarily in July and August (Reeves et al. 2002). The species presumably feeds primarily at night on small fish and squid that migrate vertically in the water column.

Recent 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; Carretta et al. 2002). 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.

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 waters 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. The abundance off the coasts of California, Oregon, and Washington was estimated at 8334 based on summer/autumn ship surveys conducted in 2005 and 2008 (Carretta et al. 2011a). The abundance estimate for pooled 1991–2008 surveys off Oregon/Washington was 4152 (Barlow 2010).

Risso's Dolphin (*Grampus griseus*)

Risso's dolphin is primarily a tropical and mid-temperate species distributed worldwide. It occurs between 60ºN and 60ºS, where surface water temperatures are at least 10ºC (Kruse et al. 1999). Water temperature appears to be an important factor affecting its distribution (Kruse et al. 1999; see also Becker 2007). 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).

Risso's dolphins are pelagic, mostly occurring on the upper continental slope shelf edge in waters 350–1000 m deep (Baumgartner 1997; Davis et al. 1998). They occur individually or in small to moderate-sized groups, normally 10–50, although groups as large as 4000 have been sighted (Baird 2009a). The majority of groups consist of <50 individuals (Kruse et al. 1999; Miyashita 1993). Mean group size was 20.3 for California/Oregon/Washington (Barlow 2010). Risso's dolphins in the Gulf of Mexico were distributed non-uniformly with respect to depth and depth gradient, occurring mainly in the steep sections of upper continental slope bounded by the 350 m and 975 m isobaths (Baumgartner 1997). Prey items collected in the stomach of stranded Risso's dolphins suggested they feed on the middle slope at depths 600–800 m (Blanco et al. 2006).

Throughout the region from California to Washington, the distribution and abundance of Risso's dolphin are highly variable, presumably in response to changing oceanographic conditions on both annual and seasonal time scales (Forney and Barlow 1998; Buchanan et al. 2001; Carretta et al. 2002). 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 that most Risso's dolphin groups sighted off Oregon were primarily at ~45–47ºN. Risso's dolphin sightings during ship surveys in summer/fall 2008 were mostly from ~30º N to ~38ºN; none were reported in Oregon/Washington (Barlow 2010). The mean abundance off the coasts of California/Oregon/Washington was estimated at 6272 based on summer/autumn ship surveys conducted in 2005 and 2008 (Carretta et al. 2011a). The abundance estimate for pooled 1991–2008 surveys off Oregon and Washington was 3607 (Barlow 2010).

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). False killer whales travel in groups of 20–100 (Baird 2009b), although groups of several hundred are sometimes observed. Mean group sizes were 10 for Hawaii (Barlow 2006) and 11–12 for the ETP (Wade and Gerrodette 1993; Ferguson et al. 2006b; Jackson et al. 2008).

In the eastern North Pacific, the species has been reported only rarely north of Baja California (Leatherwood et al. 1982, 1987; Mangels and Gerrodette 1994). Their occurrence in Washington/Oregon is associated with warm-water incursion years (Buchanan et al. 2001). They were not seen 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). Two were reported stranded along the Washington coast during 1930–2002, both in El Niño years (Norman et al. 2004). No takes of false killer whales are anticipated or requested.

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 B.C. through parts of southeast Alaska; (3) Southern Residents, mainly in inland waters of Washington State and southern B.C.; (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. 2011a). Individuals from the Southern Resident Stock, the Offshore Stock, and the West Coast Transient Stock could be encountered in the proposed survey areas. Movements of resident groups between different geographic areas have also been documented (Leatherwood et al. 1990; Dahlheim et al. 1997; Matkin et al. 1997, 1999 *in* Allen and Angliss 2011). Most killer whale stocks in the northeast Pacific are not listed under the ESA; the Southern Resident Killer Whale Stock, occurring in inland waters of Washington and southern British Columbia, is listed as ***Endangered*** under the ESA. The northeast Pacific population is estimated at 2250–2700 (NMFS 2011).

High densities of the species occur in high latitudes, especially in areas where prey is abundant. Although resident in some parts of its range, the killer whale can also be transient. Killer whale movements generally appear to follow the distribution of their prey, which includes marine mammals, fish, and squid. Killer whales are large and conspicuous, often traveling in close-knit matrilineal groups of a few to tens of individuals (Dahlheim and Heyning 1999). Group sizes of residents are 5–50, whereas those of transients are 1–7 (Bigg et al. 1987). The mean group size off killer wales off California, Oregon, and Washington was 14.8 (Barlow 2010). The maximum depth to which seven tagged free-ranging killer whales dove off B.C. was 228 m, but only an average of 2.4 % of their time was spent deeper than 30 m (Baird et al. 2003). Diving studies on killer whales have been undertaken mainly on "resident" (fish-eating) killer whales in Puget Sound and may not be applicable across all populations of killer whales. Marine mammal-eating killer whales could display different dive patterns.

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. Barlow (1997) estimated the number of killer whales within 550 km of the coasts of California, Oregon, and Washington to be 819, of which perhaps 35% were offshore whales (Carretta et al. 2011a). Six of the 17 (35%) stranded killer whales in Washington and Oregon were confirmed as southern residents (Osborne 1999 *in* Norman et al. 2004). Two of the stranded killer whales in Oregon were confirmed as transient (Stevens et al. 1989 *in* Norman et al. 2004). Barlow (2010) reported a mean abundance estimate of 536 for pooled 1991–2008 surveys off Oregon and Washington.

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. 2008). Pilot whales are generally nomadic, but may be resident in certain locations, including California and Hawaii (Olson 2009). It is an occasional visitor as far north as the Alaska Peninsula. In the southern California Bight, the occurrence of short-finned pilot whales was associated with high-relief topography (Hui 1985).

Pilot whales are very social and are usually seen in groups of 20–90 with matrilineal associations (Olson 2009). Mean group sizes have been reported as 22.5 for Hawaii (Barlow 2006) and 18.0–18.3 for the ETP (Wade and Gerrodette 1993; Ferguson et al. 2006b; Jackson et al. 2008). Both pilot whale species (short-finned and long-finned) are known for single and mass strandings. Long-finned pilot whales outfitted with time-depth recorders dove to depths up to 828 m, although most of their time was spent above depths of 7 m (Heide-Jørgensen et al. 2002). The species' maximum recorded dive depth is 971 m (Baird pers. comm. *in* DoN 2005).

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. 2002). 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). Only two groups of pilot whales (of 26 and 43 animals) were seen during the two most recent ship surveys conducted off California, Oregon, and Washington in 2005 and 2008 (Barlow 2010). The mean abundance off the coasts of California/Oregon/Washington was estimated at 760 based on summer/autumn ship surveys conducted in 2005 and 2008 (Carretta et al. 2011a). The abundance estimate for pooled 1991–2008 surveys off Oregon/Washington was 0 (Barlow 2010). No takes of short-finned pilot whales are anticipated or requested.

Harbor Porpoise (*Phocoena phocoena*)

The harbor porpoise inhabits temperate, subarctic, and arctic waters. In the eastern North Pacific, the harbor porpoise's usual 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) the Washington Inland Waters Stock, (2) the Northern Oregon/Washington Coast Stock, (3) the Northern California/Southern Oregon Stock, (4) the San Francisco-Russian River Stock, (5) the Monterey Bay Stock, and (6) the Morro Bay Stock (Carretta et al. 2011b). Harbor porpoises from the Northern Oregon/Washington and the Northern California/Southern Oregon stocks could occur in the proposed survey areas; the abundance estimates for those stocks are 15,674 and 39,581, respectively (Carretta et al. 2011a,b).

Harbor porpoises feed primarily near the seafloor but also in the water column, consuming schooling fish such as herring, capelin, sprat, and silver hake (Reeves et al. 2002). They also prey on squid and octopus, and their seasonal changes in abundance and distribution could be related to the movements of squid (Green et al. 1992). Harbor porpoises are normally found in small groups of up to 3 that often contain at least one mother-calf pair. Larger groups of 6–8 are not uncommon, and rarely, much larger aggregations are seen. Mean group size was 2.65 for northern California (Carretta et al. 2001). Harbor porpoises are generally not found in water deeper than 100 m, and abundance declines linearly as depth increases (Barlow 1988; Angliss and Outlaw 2011). Tagged harbor porpoises in the Bay of Fundy dove to mean depths of 14–41 m for mean durations of 44–103 s, and to a maximum depth of 226 m (Westgate et al. 1995).

The harbor porpoise inhabits shallow coastal and inland waters (Reeves et al. 2002; Carretta et al. 2011a). Based on year-round surveys spanning coastal to offshore waters of Oregon/Washington, Green et al. (1992) reported that 96% of harbor porpoise sightings occurred in coastal waters <100 m deep, with a few sightings made on the slope near the 200-m isobath. 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), south of the proposed survey area, to California, from fall through spring. During summer, the reported encounter rates decreased notably from inner shelf to offshore waters.

Dall's Porpoise (*Phocoenoides dalli*)

Dall's porpoise is found only in temperate to cold, ice-free waters of the North Pacific and adjacent seas. It is widely distributed across the North Pacific over the continental shelf and slope waters, and over deep (>2500 m) oceanic waters (Hall 1979; Allen and Angliss 2011). 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; Jefferson et al. 2008). The most recent estimate of Dall's porpoise abundance in the eastern Pacific U.S. EEZ is 42,000, based on the mean of estimates from 2005 and 2008 summer/autumn surveys of California, Oregon, and Washington waters (Carretta et al. 2011a).

Dall's porpoises are typically seen in groups of 2–12; groups of >20–30 are uncommon, and aggregations of several thousands have been reported (Jefferson et al. 2008). In the Bering Sea, average group size was 2.7–3.7 (Moore et al. 2002). Mean group size on the U.S. west coast was 4.2 in 2008 (Barlow 2010). They are fast swimming and active porpoises, and readily approach vessels to ride the bow wave. Data from one tagged Dall's porpoise showed a mean dive depth of 33.4 m for a mean duration of 1.3 min (Hanson and Baird 1998).

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; Carretta et al. 2011a). 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).

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. 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). 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). The abundance estimate for pooled 1991–2008 surveys off Oregon/Washington was 27,010 (Barlow 2010).

Pinnipeds

Northern Fur Seal (*Callorhinus ursinus*)

The northern fur seal is endemic to the North Pacific Ocean, and it occurs from southern California to the Bering Sea, the Okhotsk Sea, and Honshu Island, Japan (Allen and Angliss 2011). Two stocks are recognized in U.S. waters: the Eastern Pacific and the San Miguel Island 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. 2011a; Allen and Angliss 2011). 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 653,171 (Allen and Angliss 2011). They were subjected to large-scale harvests on the Pribilof Islands to supply a lucrative fur trade. Abundance of the Eastern Pacific Stock has been decreasing at the Pribilof

Islands since the 1940s and increasing on Bogoslof Island. The San Miguel Island stock is much smaller, estimated at 9968 (Carretta et al. 2011a).

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 British Columbia, Washington, Oregon, and California before migrating north again to the rookeries in spring (Ream et al. 2005). 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). The San Miguel Island stock is believed to remain predominantly offshore from California year round (Carretta et al. 2011a).

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, 2002a). The remainder of its life is spent on or near rookery islands or haulouts on rocky shorelines (Carretta et al. 2011a). Adult males usually occur on shore from May to August, though some may be present until November, and females are usually found ashore from June to November. 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 2002a). Kooyman and Goebel (1986) reported that the mean dive depth for tagged females was 32–207 m. The mean dive depth for tagged juvenile males was 17.5 m, with a maximum depth of 175 m. Deeper diving tended to occur on the shelf, with shallower diving off the shelf (Sterling and Ream 2004).

Bonnell et al. (1992) noted the presence of northern fur seals year-round off Oregon and 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). During the proposed survey period (July), only juveniles would be at sea.

California Sea Lion (*Zalophus californianus*)

The California sea lion is distributed along the mainland and offshore islands of the eastern North Pacific Ocean from British Columbia, Canada, to central Mexico, including the Gulf of California (Jefferson et al. 2008). The species is occasionally recorded outside of its normal range, as far as Alaska to the north (Maniscalco et al. 2004) and southern Mexico to the south (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. Five genetically distinct geographic populations have recently been identified: (1) Pacific Temperate (which includes rookeries within U.S. waters and the Coronados Islands), (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 survey areas. Based on a 2008 pup count, the California sea lion population is estimated at 296,750 (Carretta et al. 2011b).

In California and Baja California, births occur on land from mid May to late June. Females are ready to breed and actively solicit mates ~3 weeks after giving birth (Odell 1984; Trillmich 1986). Males establish territories that they defend from other males. Pups are able to swim soon after birth, and at 2–3 weeks of age, they form groups with other young pups. During August and September, after the mating season, the adult males migrate northward to feeding areas in Oregon, Washington, and B.C. (Lowry et al. 1992). They remain there until spring (March–May), when they migrate back to the breeding colonies (Lowry et al. 1992; Weise et al. 2006). The distribution of immature 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 immature seals are presumed to remain near the rookeries for most of the year (Lowry et al. 1992). Adult females remain near the rookeries throughout the year.

California sea lions are coastal animals that often haul out on shore throughout the year. 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 (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). Most dives of tagged females on San Miguel Island were <80 m deep, and less than 5% of dives were in water depths >200 m. The deepest dive recorded was estimated at 274 m (Feldkamp et al. 1989).

Off Oregon/Washington, most California sea lions occur in the fall (Bonnell et al. 1992). California sea lions are likely to be rare in the proposed survey areas during the planned July survey period, and no takes are anticipated or requested.

Steller Sea Lion (*Eumetopias jubatus*)

The Steller sea lion ranges along the North Pacific Rim from northern Japan to California (Loughlin et al. 1984). The species is listed under the ESA as ***Threatened*** in the eastern portion of its range and as ***Endangered*** in the western portion, west of 144°W. It is listed as ***Endangered*** on the IUCN Red List of Threatened Species (IUCN 2011). The major anthropogenic factors that likely contributed to a decline of the western population are by-catch in fisheries, commercial hunting of sea lions, and legal and illegal shooting of sea lions (Atkinson et al. 2008). Minimum population sizes of the U.S. Eastern Stock, including animals in Alaska, B.C., Washington, Oregon, and California, and the U.S. Western Stock are estimated at 58,334–72,223 and 42,366, respectively (Allen and Angliss 2011). The eastern stock is thought to be increasing at a rate of 3.1% annually (Pitcher et al. 2007).

In August–September 2010, the states of Oregon and Washington and the State of Alaska petitioned NMFS to delist the Eastern Designated Population Segment (DPS) of Steller sea lions. In a 90-day petition finding issued on 13 December 2010, NMFS found that the petitions' action could be warranted (NMFS 2010a). The federal agency is now in the ESA process of determining whether or not delisting is indeed warranted.

Breeding adults occupy rookeries from late May to early July (NMFS 2008b). The eastern stock of Steller sea lion rookeries are located in southeast Alaska, British Columbia, Oregon, and California (Allen and Angliss 2011). Males arrive at rookeries in May to establish their territory and are soon followed by females. Non-breeding males use haulouts or occupy sites at the periphery of rookeries during the breeding season (NRC 2003). Pupping occurs from mid May to mid July (Pitcher and Calkins 1981) and peaks in June (Pitcher et al. 2002). In Oregon, breeding occurs during the months of June and July (USFWS 2011).

Territorial males fast and remain on land during the breeding season (NMFS 2008b). 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 2008b).

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). 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, with the farthest sighting ~40 km from shore; all sightings occurred near or in waters <200 m deep.

Three rookeries and seven haul-out sites are located in Oregon; several haul-out sites are also located in Washington (NMFS 2008b). Jeffries et al. (2000) identified four haul-out sites in the Split Rock area (47.4°N); animals at these haulout locations are assumed to be immatures and non-breeding adults associated with rookeries in Oregon and British Columbia (Pitcher et al. 2007). The mean count of non-pups on Washington haul-out sites during 16 June–15 July 2001 was 516. The total number of Steller sea lions at rookeries and haul-out sites in Oregon in 2002 was estimated at 5076–5753 (NMFS 2008b).

The Steller sea lion rookery closest to the survey area is the Three Arch Rocks rookery (Fig. 1) located ~120 km from the survey area. Two other rookeries, Orford Reef and Rogue Reef, are designated as Critical Habitat; they are located ~400 and ~455 km south of the survey area, respectively. The eastern boundary of the seismic survey lines is located ~32 km from shore, potentially within Stellar sea lion foraging range.

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. 2011a). Three separate stocks of harbor seals are recognized along the U.S. west coast: (1) Washington Inland Waters Stock, (2) Oregon and Washington Coastal Stock from Cape Flaherty (~48.4°N) to ~42°N, and (3) California Stock (Carretta et al. 2011a). The Oregon and Washington Coast Stock occurs in the proposed survey areas. The most recent estimate for the Oregon/Washington coastal stock is 24,732 (based on counts in 1999). The 1999 count of harbor seals along the outer Olympic Peninsula region alone was 7117 (Jeffries et al. 2003).

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). Juvenile harbor seals can travel significant distances (525 km) to forage or disperse, whereas adults were generally found within 190 km of their tagging location in PWS (Lowry et al. 2001). The smaller home range used by adults is suggestive of a strong site fidelity (Pitcher and Calkins 1979; Pitcher and McAllister 1981; Lowry et al. 2001). Pups tagged in the 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 PWS 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). Most diving activity occurs at night (Hastings et al. 2004). Bowen et al. (1999) found that lactating females from Sable Island, Nova Scotia, spent 45% of time on land with their pups, 55% of time at sea, and only 9% of the total time actively diving. Median depth and duration of dive are positively correlated with body mass; large adult male harbor seals in Monterey Bay generally dove deeper (mean 51.9 m) and longer than smaller adult females (mean 39.8 m). Most dives were to <100 m (Eguchi and Harvey 2005).

Female harbor seals give birth to a single pup while hauled out on shore or on glacial ice flows; pups are born from May to mid July. The mother and pup remain together until weaning occurs at 3–6 weeks (Bigg 1969). Little is known about breeding behavior in harbor seals. When molting, which occurs primarily in late August, seals spend the majority of the time hauled out on shore, glacial ice, or other substrates.

Harbor seals haul out on rocks, reefs, beaches, and offshore islands along the U.S. west coast (Carretta et al. 2011b). Jeffries et al. (2000) documented several harbor seal rookeries and haulouts along the Washington coastline. This is the only pinniped species that breeds in Washington State. 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. 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).

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 was later 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 124,000 in 2005 (Carretta et al. 2011a).

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. Females spend only ~34 days on shore. Juvenile elephant seals typically leave the rookeries in April or May and head north, traveling an average of 900–1000 km. Most elephant seals return to their natal rookeries when they start breeding (Huber et al. 1991).

When not 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). Elephant seals feed on deep-water fish and squid (Condit and Le

Boeuf 1984). Davis et al. (2001) recorded an average dive depth of 186 m with range of 8–430 m for an elephant seal returning to the beach. Hindell (2009) noted that traveling likely takes place at depths >200 m.

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 British Columbia (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). Most elephant seal sightings at sea were during June, July, and September off Washington; sightings recorded from November through May were off southern Oregon (Bonnell et al. 1992). During the survey period in July, elephant seals occurring in the survey area could include adult females, juveniles, and pups of the year.

V. Type of Incidental Take Authorization Requested

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

L-DEO requests an IHA pursuant to Section 101 (a)(5)(D) of the Marine Mammal Protection Act (MMPA) for incidental take by harassment during its planned seismic survey in the northeastern Pacific Ocean during July 2012.

The operations outlined in § I have the potential to take marine mammals by harassment. Sounds will be generated by the airguns used during the survey, by echosounders, and by general vessel operations. “Takes” by harassment will potentially result when marine mammals near the activities are exposed to the pulsed sounds generated by the airguns or echosounders. The effects will depend on the species of marine mammal, the behavior of the animal at the time of reception of the stimulus, as well as the distance and received level of the sound (see § VII). Disturbance reactions are likely amongst some of the marine mammals near the tracklines of the source vessel. No take by serious injury is anticipated, given the nature of the planned operations and the mitigation measures that are planned (see § XI, Mitigation Measures). No lethal takes are expected.

VI. Numbers of Marine Mammals That Could be Taken

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

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

VII. Anticipated Impact on Species or Stocks

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

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

- First we summarize the potential impacts on marine mammals of airgun operations, as called for in § VII. A more comprehensive review of the relevant background information appears in Appendix B of the EA that supports this application.
- Then we discuss the potential impacts of operations by the echosounders.
- Finally, we estimate the numbers of marine mammals that could be affected by the proposed survey in the northeastern Pacific Ocean during July 2012. This section includes a description of the rationale for the estimates of the potential numbers of harassment "takes" during the planned survey, as called for in § VI.

Summary of Potential Effects of Airgun Sounds

The effects of sounds from airguns could include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and at least in theory, temporary or permanent hearing impairment, or non-auditory physical or physiological effects (Richardson et al. 1995; Gordon et al. 2004; Nowacek et al. 2007; Southall et al. 2007). Permanent hearing impairment, in the unlikely event that it occurred, would constitute injury, but temporary threshold shift (TTS) is not an injury (Southall et al. 2007). Although the possibility cannot be entirely excluded, it is unlikely that the project would result in any cases of temporary or especially permanent hearing impairment, or any significant non-auditory physical or physiological effects. Some behavioral disturbance is expected, but this would be localized and short-term.

Tolerance

Numerous studies have shown that pulsed sounds from airguns are often readily detectable in the water at distances of many kilometers. For a summary of the characteristics of airgun pulses, see Appendix B (3) of the EA. Several studies have shown that marine mammals at distances more than a few kilometers from operating seismic vessels often show no apparent response—see Appendix B (5) of the EA. That is often true even in cases when the pulsed sounds must be readily audible to the animals based on measured received levels and the hearing sensitivity of that mammal group. Although various baleen whales and toothed whales have been shown to react behaviorally to airgun pulses under some conditions, at other times mammals of both types have shown no overt reactions. The relative responsiveness of baleen and toothed whales are quite variable.

Masking

Masking effects of pulsed sounds (even from large arrays of airguns) on marine mammal calls and other natural sounds are expected to be limited, although there are very few specific data on this. Because of the intermittent nature and low duty cycle of seismic pulses, animals can emit and receive sounds in the relatively quiet intervals between pulses. However, in exceptional situations, reverberation occurs for much or all of the interval between pulses (e.g., Simard et al. 2005; Clark and Gagnon 2006) which could mask calls. Some baleen and toothed whales are known to continue calling in the presence of seismic pulses, and their calls usually can be heard between the seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999a,b; Nieukirk et al. 2004; Smultea et al. 2004; Holst et al. 2005a,b, 2006; Dunn and Hernandez 2009). However, Clark and Gagnon (2006) reported that fin whales in the northeast Pacific Ocean went silent for an extended period starting soon after the onset of a seismic survey in the area. Similarly, there has been one report that sperm whales ceased calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994). However, more recent studies found that they continued calling in the presence of seismic pulses (Madsen et al. 2002; Tyack et al. 2003; Smultea et al. 2004; Holst et al. 2006; Jochens et al. 2008). Dolphins and porpoises commonly are heard calling while airguns are operating (e.g., Gordon et al. 2004; Smultea et al. 2004; Holst et al. 2005a,b; Potter et al. 2007). The sounds important to small odontocetes are predominantly at much higher frequencies than are the dominant components of airgun sounds, thus limiting the potential for masking. In general, masking effects of seismic pulses are expected to be minor, given the normally intermittent nature of seismic pulses. Masking effects on marine mammals are discussed further in Appendix B (4) of the EA.

Disturbance Reactions

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

Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors (Richardson et al. 1995; Wartzok et al. 2004; Southall et al. 2007; Weilgart 2007). If a marine mammal does react briefly to an underwater sound by changing its behavior or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or population. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on individuals and populations could be significant (e.g., Lusseau and Bejder 2007; Weilgart 2007). Given the many uncertainties in predicting the quantity and types of impacts of noise on marine mammals, it is common practice to estimate how many mammals would be present within a particular distance of industrial activities and/or exposed to a particular level of industrial sound. In most cases, this approach likely overestimates the numbers of marine mammals that would be affected in some biologically-important manner.

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

Baleen Whales.—Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to pulses from large arrays of airguns at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, as reviewed in Appendix B (5) of the EA, baleen whales exposed to strong noise pulses from airguns often react by deviating from their normal migration route and/or interrupting their feeding and moving away. In the cases of migrating gray and bowhead whales, the observed changes in behavior appeared to be of little or no biological consequence to the animals. They simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors.

Studies of gray, bowhead, and humpback whales have shown that seismic pulses with received levels of 160–170 dB re 1 μPa_{rms} seem to cause obvious avoidance behavior in a substantial fraction of the animals exposed (Richardson et al. 1995). In many areas, seismic pulses from large arrays of airguns diminish to those levels at distances ranging from 4 to 15 km from the source. A substantial proportion of the baleen whales within those distances may show avoidance or other strong behavioral reactions to the airgun array. Subtle behavioral changes sometimes become evident at somewhat lower received levels, and studies summarized in Appendix B (5) of the EA have shown that some species of baleen whales, notably bowhead and humpback whales, at times show strong avoidance at received levels lower than 160–170 dB re 1 μPa_{rms}.

Responses of *humpback whales* to seismic surveys have been studied during migration, on summer feeding grounds, and on Angolan winter breeding grounds; there has also been discussion of effects on the Brazilian wintering grounds. McCauley et al. (1998, 2000a) studied the responses of humpback whales off Western Australia to a full-scale seismic survey with a 16-airgun, 2678-in^3 array, and to a single 20-in^3 airgun with source level 227 dB re 1 μPa·m_{p-p}. McCauley et al. (1998) documented that avoidance reactions began at 5–8 km from the array, and that those reactions kept most pods ~3–4 km from the operating seismic boat. McCauley et al. (2000a) noted localized displacement during migration of 4–5 km by traveling pods and 7–12 km by more sensitive resting pods of cow-calf pairs. Avoidance distances with respect to the single airgun were smaller but consistent with the results from the full array in terms of the received sound levels. The mean received level for initial avoidance of an approaching airgun was 140 dB re 1 μPa_{rms} for humpback pods containing females, and at the mean closest point of approach (CPA) distance the received level was 143 dB re 1 μPa_{rms}. The initial avoidance response generally occurred at distances of 5–8 km from the airgun array and 2 km from the single airgun. However, some individual humpback whales, especially males, approached within distances of 100–400 m, where the maximum received level was 179 dB re 1 μPa_{rms}.

Data collected by observers during several seismic surveys in the Northwest Atlantic showed that sighting rates of humpback whales were significantly greater during periods of no seismic compared with periods when a full array was operating (Moulton and Holst 2010). In addition, humpback whales were more likely to swim away and less likely to swim towards a vessel during seismic vs. non-seismic periods (Moulton and Holst 2010).

Humpback whales on their summer feeding grounds in southeast Alaska did not exhibit persistent avoidance when exposed to seismic pulses from a 1.64-L (100-in^3) airgun (Malme et al. 1985). Some humpbacks seemed “startled” at received levels of 150–169 dB re 1 μPa. Malme et al. (1985) concluded that there was no clear evidence of avoidance, despite the possibility of subtle effects, at received levels up to 172 re 1 μPa on an approximate rms basis. However, Moulton and Holst (2010) reported that humpback whales monitored during seismic surveys in the Northwest Atlantic had lower sighting rates and were most often seen swimming away from the vessel during seismic periods compared with periods when airguns were silent.

It has been suggested that South Atlantic humpback whales wintering off Brazil may be displaced or even strand upon exposure to seismic surveys (Engel et al. 2004). The evidence for this was circumstantial and subject to alternative explanations (IAGC 2004). Also, the evidence was not consistent with subsequent results from the same area of Brazil (Parente et al. 2006), or with direct studies of humpbacks exposed to seismic surveys in other areas and seasons. After allowance for data from subsequent years, there was “no observable direct correlation” between strandings and seismic surveys (IWC 2007:236).

There are no data on reactions of *right whales* to seismic surveys, but results from the closely-related *bowhead whale* show that their responsiveness can be quite variable depending on their activity (migrating vs. feeding). Bowhead whales migrating west across the Alaskan Beaufort Sea in autumn, in particular, are unusually responsive, with substantial avoidance occurring out to distances of 20–30 km from a medium-sized airgun source at received sound levels of around 120–130 dB re 1 μPa_{rms} [Miller et al. 1999; Richardson et al. 1999; see Appendix B (5) of the EA]. However, more recent research on bowhead whales (Miller et al. 2005; Harris et al. 2007) corroborates earlier evidence that, during the summer feeding season, bowheads are not as sensitive to seismic sources. Nonetheless, subtle but statistically significant changes in surfacing–respiration–dive cycles were evident upon statistical analysis (Richardson et al. 1986). In summer, bowheads typically begin to show avoidance reactions at received levels of about 152–178 dB re 1 μPa_{rms} (Richardson et al. 1986, 1995; Ljungblad et al. 1988; Miller et al. 2005).

Reactions of migrating and feeding (but not wintering) *gray whales* to seismic surveys have been studied. Malme et al. (1986, 1988) studied the responses of feeding eastern Pacific gray whales to pulses from a single 100-in^3 airgun off St. Lawrence Island in the northern Bering Sea. They estimated, based on small sample sizes, that 50% of feeding gray whales stopped feeding at an average received pressure level of 173 dB re 1 μPa on an (approximate) rms basis, and that 10% of feeding whales interrupted feeding at received levels of 163 dB re 1 μPa_{rms}. Those findings were generally consistent with the results of experiments conducted on larger numbers of gray whales that were migrating along the California coast (Malme et al. 1984; Malme and Miles 1985), and western Pacific gray whales feeding off Sakhalin Island, Russia (Würsig et al. 1999; Gailey et al. 2007; Johnson et al. 2007; Yazvenko et al. 2007a,b), along with data on gray whales off British Columbia (Bain and Williams 2006).

Various species of *Balaenoptera* (blue, sei, fin, and minke whales) have occasionally been seen in areas ensonified by airgun pulses (Stone 2003; MacLean and Haley 2004; Stone and Tasker 2006), and calls from blue and fin whales have been localized in areas with airgun operations (e.g., McDonald et al. 1995; Dunn and Hernandez 2009; Castellote et al. 2010). Sightings by observers on seismic vessels off the United Kingdom from 1997 to 2000 suggest that, during times of good sightability, sighting rates for mysticetes (mainly fin and sei whales) were similar when large arrays of airguns were shooting vs. silent (Stone 2003; Stone and Tasker 2006). However, these whales tended to exhibit localized avoidance, remaining significantly further (on average) from the airgun array during seismic operations compared with non-seismic periods (Stone and Tasker 2006). Castellote et al. (2010) reported that singing fin whales in the Mediterranean moved away from an operating airgun array.

Ship-based monitoring studies of baleen whales (including blue, fin, sei, minke, and humpback whales) in the Northwest Atlantic found that overall, this group had lower sighting rates during seismic vs. non-seismic periods (Moulton and Holst 2010). Baleen whales as a group were also seen significantly farther from the vessel during seismic compared with non-seismic periods, and they were more often seen to be swimming away from the operating seismic vessel (Moulton and Holst 2010). Blue and minke whales were initially sighted significantly farther from the vessel during seismic operations compared to non-seismic periods; the same trend was observed for fin whales (Moulton and Holst 2010). Minke whales were most often observed to be swimming away from the vessel when seismic operations were underway (Moulton and Holst 2010).

Data on short-term reactions by cetaceans to impulsive noises are not necessarily indicative of long-term or biologically significant effects. It is not known whether impulsive sounds affect reproductive rate or distribution and habitat use in subsequent days or years. However, gray whales have continued to migrate annually along the west coast of North America with substantial increases in the population over recent years, despite intermittent seismic exploration (and much ship traffic) in that area for decades (Appendix A *in* Malme et al. 1984; Richardson et al. 1995; Allen and Angliss 2011). The western Pacific gray whale population did not seem affected by a seismic survey in its feeding ground during a previous year (Johnson et al. 2007). Similarly, bowhead whales have continued to travel to the eastern Beaufort Sea each summer, and their numbers have increased notably, despite seismic exploration in their summer and autumn range for many years (Richardson et al. 1987; Allen and Angliss 2011).

Toothed Whales.—Little systematic information is available about reactions of toothed whales to noise pulses. Few studies similar to the more extensive baleen whale/seismic pulse work summarized above and (in more detail) in Appendix B of the EA have been reported for toothed whales. However, there are recent systematic studies on sperm whales (e.g., Gordon et al. 2006; Madsen et al. 2006; Winsor and Mate 2006; Jochens et al. 2008; Miller et al. 2009). There is an increasing amount of information about responses of various odontocetes to seismic surveys based on monitoring studies (e.g., Stone 2003;

Smultea et al. 2004; Moulton and Miller 2005; Bain and Williams 2006; Holst et al. 2006; Stone and Tasker 2006; Potter et al. 2007; Hauser et al. 2008; Holst and Smultea 2008; Weir 2008; Barkaszi et al. 2009; Richardson et al. 2009; Moulton and Holst 2010).

Seismic operators and marine mammal observers on seismic vessels regularly see dolphins and other small toothed whales near operating airgun arrays, but in general there is a tendency for most delphinids to show some avoidance of operating seismic vessels (e.g., Goold 1996a,b,c; Calambokidis and Osmek 1998; Stone 2003; Moulton and Miller 2005; Holst et al. 2006; Stone and Tasker 2006; Weir 2008; Barkaszi et al. 2009; Richardson et al. 2009; Moulton and Holst 2010). Some dolphins seem to be attracted to the seismic vessel and floats, and some ride the bow wave of the seismic vessel even when large arrays of airguns are firing (e.g., Moulton and Miller 2005). Nonetheless, small toothed whales more often tend to head away, or to maintain a somewhat greater distance from the vessel, when a large array of airguns is operating than when it is silent (e.g., Stone and Tasker 2006; Weir 2008; Barry et al. 2010; Moulton and Holst 2010). In most cases, the avoidance radii for delphinids appear to be small, on the order of 1 km less, and some individuals show no apparent avoidance. The beluga is a species that (at least at times) shows long-distance avoidance of seismic vessels. Aerial surveys conducted in the southeastern Beaufort Sea during summer found that sighting rates of beluga whales were significantly lower at distances 10–20 km compared with 20–30 km from an operating airgun array, and observers on seismic boats in that area rarely see belugas (Miller et al. 2005; Harris et al. 2007).

Captive bottlenose dolphins and beluga whales exhibited changes in behavior when exposed to strong pulsed sounds similar in duration to those typically used in seismic surveys (Finneran et al. 2000, 2002, 2005). However, the animals tolerated high received levels of sound before exhibiting aversive behaviors.

Results for porpoises depend on species. The limited available data suggest that harbor porpoises show stronger avoidance of seismic operations than do Dall's porpoises (Stone 2003; MacLean and Koski 2005; Bain and Williams 2006; Stone and Tasker 2006). Dall's porpoises seem relatively tolerant of airgun operations (MacLean and Koski 2005; Bain and Williams 2006), although they too have been observed to avoid large arrays of operating airguns (Calambokidis and Osmek 1998; Bain and Williams 2006). This apparent difference in responsiveness of these two porpoise species is consistent with their relative responsiveness to boat traffic and some other acoustic sources (Richardson et al. 1995; Southall et al. 2007).

Most studies of sperm whales exposed to airgun sounds indicate that the sperm whale shows considerable tolerance of airgun pulses (e.g., Stone 2003; Stone and Tasker 2006; Weir 2008; Moulton and Holst 2010). In most cases, the whales do not show strong avoidance, and they continue to call (see Appendix B of the EA for review). However, controlled exposure experiments in the Gulf of Mexico indicate that foraging behavior was altered upon exposure to airgun sound (Jochens et al. 2008; Miller et al. 2009; Tyack 2009).

There are almost no specific data on the behavioral reactions of beaked whales to seismic surveys. However, some northern bottlenose whales remained in the general area and continued to produce high-frequency clicks when exposed to sound pulses from distant seismic surveys (Gosselin and Lawson 2004; Laurinolli and Cochrane 2005; Simard et al. 2005). Most beaked whales tend to avoid approaching vessels of other types (e.g., Würsig et al. 1998). They may also dive for an extended period when approached by a vessel (e.g., Kasuya 1986), although it is uncertain how much longer such dives may be as compared to dives by undisturbed beaked whales, which also are often quite long (Baird et al. 2006; Tyack et al. 2006). Based on a single observation, Aguilar-Soto et al. (2006) suggested that foraging efficiency of Cuvier's beaked whales may be reduced by close approach of vessels. In any event, it is likely that most beaked whales would also show strong avoidance of an approaching seismic vessel, although this has not been documented explicitly. In fact, Moulton and Holst (2010) reported 15 sightings of beaked whales during seismic studies in the Northwest Atlantic; seven of those sightings were made at times when at least one airgun was operating. There was little evidence to indicate that beaked whale behavior was affected by airgun operations; sighting rates and distances were similar during seismic and non-seismic periods (Moulton and Holst 2010).

There are increasing indications that some beaked whales tend to strand when naval exercises involving mid-frequency sonar operation are ongoing nearby (e.g., Simmonds and Lopez-Jurado 1991; Frantzis 1998; NOAA and USN 2001; Jepson et al. 2003; Hildebrand 2005; Barlow and Gisiner 2006; see also the "Strandings and Mortality" subsection, later). These strandings are apparently at least in part a disturbance response, although auditory or other injuries or other physiological effects may also be involved. Whether beaked whales would ever react similarly to seismic surveys is unknown (see "Strandings and Mortality", below). Seismic survey sounds are quite different from those of the sonars in operation during the above-cited incidents.

Odontocete reactions to large arrays of airguns are variable and, at least for delphinids and Dall's porpoises, seem to be confined to a smaller radius than has been observed for the more responsive of the mysticetes, belugas, and harbor porpoises (Appendix B of the EA). A ≥170 dB re 1 µPa disturbance criterion (rather than ≥160 dB) is considered appropriate for delphinids, Dall's porpoise, and pinnipeds, which tend to be less responsive than the more responsive cetaceans.

Pinnipeds.—Pinnipeds are not likely to show a strong avoidance reaction to the airgun array. Visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds, and only slight (if any) changes in behavior—see Appendix B (5) of the EA. In the Beaufort Sea, some ringed seals avoided an area of 100 m to (at most) a few hundred meters around seismic vessels, but many seals remained within 100–200 m of the trackline as the operating airgun array passed by (e.g., Harris et al. 2001; Moulton and Lawson 2002; Miller et al. 2005). Ringed seal sightings averaged somewhat farther away from the seismic vessel when the airguns were operating than when they were not, but the difference was small (Moulton and Lawson 2002). Similarly, in Puget Sound, sighting distances for harbor seals and California sea lions tended to be larger when airguns were operating (Calambokidis and Osmek 1998). Previous telemetry work suggests that avoidance and other behavioral reactions may be stronger than evident to date from visual studies (Thompson et al. 1998).

Additional details on the behavioral reactions (or the lack thereof) by all types of marine mammals to seismic vessels can be found in Appendix B (5) of the EA.

Hearing Impairment and Other Physical Effects

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds. TTS has been demonstrated and studied in certain captive odontocetes and pinnipeds exposed to strong sounds (reviewed in Southall et al. 2007). However, there has been no specific documentation of TTS let alone permanent hearing damage, i.e., permanent threshold shift (PTS), in free-ranging marine mammals exposed to sequences of airgun pulses during realistic field conditions. Current NMFS policy regarding exposure of marine mammals to high-level sounds is that cetaceans should not be exposed to impulsive sounds with received levels ≥180 dB re 1 μPa_{rms} (NMFS 2000). This criterion has been used in establishing the exclusion (=shut-down) zones planned for the proposed seismic survey. However, this criterion was established before there was any information about minimum received levels of sounds necessary to cause auditory impairment in marine mammals. As discussed in Appendix B (6) of the EA and summarized here,

- the 180-dB criterion for cetaceans is probably quite precautionary, i.e., lower than necessary to avoid temporary auditory impairment let alone permanent auditory injury, at least for delphinids.
- TTS is not injury and does not constitute "Level A harassment" in U.S. MMPA terminology.
- the minimum sound level necessary to cause permanent hearing impairment ("Level A harassment") is higher, by a variable and generally unknown amount, than the level that induces barely-detectable TTS.
- the level associated with the onset of TTS is often considered to be a level below which there is no danger of permanent damage. The actual PTS threshold is likely to be well above the level causing onset of TTS (Southall et al. 2007).

Recommendations for new science-based noise exposure criteria for marine mammals, frequency-weighting procedures, and related matters have been published (Southall et al. 2007). Those recommendations have not, as of mid 2011, been formally adopted by NMFS for use in regulatory processes and during mitigation programs associated with seismic surveys. However, some aspects of the recommendations have been taken into account in certain environmental impact statements and small-take authorizations. NMFS has indicated that it may issue new noise exposure criteria for marine mammals that account for the now-available scientific data on TTS, the expected offset between the TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive (e.g., M-weighting or generalized frequency weightings for various groups of marine mammals, allowing for their functional bandwidths), and other relevant factors. Preliminary information about possible changes in the regulatory and mitigation requirements, and about the possible structure of new criteria, was given by Wieting (2004) and NMFS (2005).

Several aspects of the planned monitoring and mitigation measures for this project are designed to detect marine mammals occurring near the airgun array, and to avoid exposing them to sound pulses that might, at least in theory, cause hearing impairment (see § XI and § XIII). In addition, many cetaceans and (to a limited degree) sea turtles show some avoidance of the area where received levels of airgun sound are high enough such that hearing impairment could potentially occur. In those cases, the avoidance responses of the animals themselves will reduce or (most likely) avoid any possibility of hearing impairment.

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might (in theory) occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, and other types of organ or tissue damage. It is possible that some marine mammal species (i.e., beaked whales) may be especially susceptible to injury and/or stranding when exposed to strong transient sounds. However, as discussed below, there is no definitive evidence that any of these effects occur even for marine mammals in close proximity to large arrays of airguns. It is unlikely that any effects of these types would occur during the present project given the brief duration of exposure of any given mammal, and the planned monitoring and mitigation measures (see below). The following subsections discuss in somewhat more detail the possibilities of TTS, PTS, and non-auditory physical effects.

Temporary Threshold Shift.—TTS is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter 1985). While experiencing TTS, the hearing threshold rises and a sound must be stronger in order to be heard. At least in terrestrial mammals, TTS can last from minutes or hours to (in cases of strong TTS) days. For sound exposures at or somewhat above the TTS threshold, hearing sensitivity in both terrestrial and marine mammals recovers rapidly after exposure to the noise ends. Few data on sound levels and durations necessary to elicit mild TTS have been obtained for marine mammals, and none of the published data concern TTS elicited by exposure to multiple pulses of sound. Available data on TTS in marine mammals are summarized in Southall et al. (2007).

For toothed whales exposed to single short pulses, the TTS threshold appears to be, to a first approximation, a function of the energy content of the pulse (Finneran et al. 2002, 2005). Based on these data, the received energy level of a single seismic pulse (with no frequency weighting) might need to be ~186 dB re 1 $\mu Pa^2 \cdot s$ (i.e., 186 dB SEL or ~196–201 dB re 1 μPa_{rms}) in order to produce brief, mild TTS[1]. Exposure to several strong seismic pulses that each have received levels near 190 dB re 1 μPa_{rms} might result in cumulative exposure of ~186 dB SEL and thus slight TTS in a small odontocete assuming the TTS threshold is (to a first approximation) a function of the total received pulse energy; however, this 'equal-energy' concept is an oversimplification. The distances from the *Langseth*'s airguns at which the received energy level (per pulse, flat-weighted) would be expected to be ≥190 dB re 1 μPa_{rms} are estimated in Table 1. Levels ≥190 dB re 1 μPa_{rms} are expected to be restricted to radii no more than 865 m (Table 1). For an odontocete closer to the surface, the maximum radius with ≥190 dB re 1 μPa_{rms} would be smaller.

The above TTS information for odontocetes is derived from studies on the bottlenose dolphin and beluga. For the one harbor porpoise tested, the received level of airgun sound that elicited onset of TTS was lower (Lucke et al. 2009). If these results from a single animal are representative, it is inappropriate to assume that onset of TTS occurs at similar received levels in all odontocetes (*cf.* Southall et al. 2007). Some cetaceans apparently can incur TTS at considerably lower sound exposures than are necessary to elicit TTS in the beluga or bottlenose dolphin.

For baleen whales, there are no data, direct or indirect, on levels or properties of sound that are required to induce TTS. The frequencies to which baleen whales are most sensitive are assumed to be lower than those to which odontocetes are most sensitive, and natural background noise levels at those low frequencies tend to be higher. As a result, auditory thresholds of baleen whales within their frequency band of best hearing are believed to be higher (less sensitive) than are those of odontocetes at their best frequencies (Clark and Ellison 2004). From this, it is suspected that received levels causing TTS onset may also be higher in baleen whales (Southall et al. 2007). In any event, no cases of TTS are expected given three considerations: (1) the low abundance of baleen whales in the planned study area at the time of the survey; (2) the strong likelihood that baleen whales would avoid the approaching airguns (or vessel) before being exposed to levels high enough for TTS to occur; and (3) the mitigation measures that are planned.

In pinnipeds, TTS thresholds associated with exposure to brief pulses (single or multiple) of underwater sound have not been measured. Initial evidence from more prolonged (non-pulse) exposures suggested that some pinnipeds (harbor seals in particular) incur TTS at somewhat lower received levels than do small odontocetes exposed for similar durations (Kastak et al. 1999, 2005; Ketten et al. 2001). The TTS threshold for pulsed sounds has been indirectly estimated as being an SEL of ~171 dB re 1 $\mu Pa^2 \cdot s$ (Southall et al. 2007), which would be equivalent to a single pulse with received level ~181–186 dB re 1 $\mu Pa_{rms,}$ or a series of pulses for which the highest rms values are a few dB lower. Corresponding values for California sea lions and northern elephant seals are likely to be higher (Kastak et al. 2005).

NMFS (1995, 2000) concluded that cetaceans and pinnipeds should not be exposed to pulsed underwater noise at received levels exceeding, respectively, 180 and 190 dB re 1 μPa_{rms}. Those sound levels are ***not*** considered to be the levels above which TTS might occur. Rather, they were the received levels above

[1] If the low frequency components of the watergun sound used in the experiments of Finneran et al. (2002) are downweighted as recommended by Miller et al. (2005) and Southall et al. (2007) using their M_{mf}-weighting curve, the effective exposure level for onset of mild TTS was 183 dB re 1 $\mu Pa^2 \cdot s$ (Southall et al. 2007).

which, in the view of a panel of bioacoustics specialists convened by NMFS before TTS measurements for marine mammals started to become available, one could not be certain that there would be no injurious effects, auditory or otherwise, to marine mammals. As summarized above and in Southall et al. (2007), data that are now available imply that TTS is unlikely to occur in most odontocetes (and probably mysticetes as well) unless they are exposed to a sequence of several airgun pulses stronger than 190 dB re 1 μPa_{rms}. For the harbor seal and any species with similarly low TTS thresholds, TTS may occur upon exposure to one or more airgun pulses whose received level equals the NMFS "do not exceed" value of 190 dB re 1 μPa_{rms}. That criterion corresponds to a single-pulse SEL of 175–180 dB re 1 $\mu Pa^2 \cdot s$ in typical conditions, whereas TTS is suspected to be possible (in harbor seals) with a cumulative SEL of ~171 dB re 1 $\mu Pa^2 \cdot s$.

Permanent Threshold Shift.—When PTS occurs, there is physical damage to the sound receptors in the ear. In severe cases, there can be total or partial deafness, whereas in other cases, the animal has an impaired ability to hear sounds in specific frequency ranges (Kryter 1985).

There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal, even with large arrays of airguns. However, given the possibility that mammals close to an airgun array might incur at least mild TTS, there has been further speculation about the possibility that some individuals occurring very close to airguns might incur PTS (e.g., Richardson et al. 1995, p. 372*ff*; Gedamke et al. 2008). Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage, but repeated or (in some cases) single exposures to a level well above that causing TTS onset might elicit PTS.

Relationships between TTS and PTS thresholds have not been studied in marine mammals, but are assumed to be similar to those in humans and other terrestrial mammals. PTS might occur at a received sound level at least several decibels above that inducing mild TTS if the animal were exposed to strong sound pulses with rapid rise time—see Appendix B (6) of the EA. Based on data from terrestrial mammals, a precautionary assumption is that the PTS threshold for impulse sounds (such as airgun pulses as received close to the source) is *at least* 6 dB higher than the TTS threshold on a peak-pressure basis, and probably >6 dB (Southall et al. 2007). On an SEL basis, Southall et al. (2007:441-4) estimated that received levels would need to exceed the TTS threshold by at least 15 dB for there to be risk of PTS. Thus, for cetaceans they estimate that the PTS threshold might be an M-weighted SEL (for the sequence of received pulses) of ~198 dB re 1 $\mu Pa^2 \cdot s$ (15 dB higher than the M_{mf}-weighted TTS threshold, in a beluga, for a watergun impulse), where the SEL value is cumulated over the sequence of pulses. Additional assumptions had to be made to derive a corresponding estimate for pinnipeds, as the only available data on TTS-thresholds in pinnipeds pertain to non-impulse sound. Southall et al. (2007) estimate that the PTS threshold could be a cumulative M_{pw}-weighted SEL of ~186 dB re 1 $\mu Pa^2 \cdot s$ in the harbor seal exposed to impulse sound. The PTS threshold for the California sea lion and northern elephant seal would probably be higher, given the higher TTS thresholds in those species.

Southall et al. (2007) also note that, regardless of the SEL, there is concern about the possibility of PTS if a cetacean received one or more pulses with peak pressure exceeding 230 or 218 dB re 1 μPa (peak), respectively. Thus, PTS might be expected upon exposure of cetaceans to *either* SEL ≥198 dB re 1 $\mu Pa^2 \cdot s$ *or* peak pressure ≥ 230 dB re 1 μPa. Corresponding proposed dual criteria for pinnipeds (at least harbor seals) are ≥ 186 dB SEL and ≥ 218 dB peak pressure (Southall et al. 2007). These estimates are all first approximations, given the limited underlying data, assumptions, species differences, and evidence that the "equal energy" model may not be entirely correct. A peak pressure of 230 dB re 1 μPa (3.2 bar·m, 0-pk) would only be found within a few meters of the largest (360-in^3) airguns in the planned airgun array (e.g., Caldwell and Dragoset 2000). A peak pressure of 218 dB re 1 μPa could be received somewhat farther away; to estimate that specific distance, one would need to apply a model that accurately calculates peak pressures in the near-field around an array of airguns.

Given the higher level of sound necessary to cause PTS as compared with TTS, it is considerably less likely that PTS would occur. Baleen whales generally avoid the immediate area around operating seismic vessels, as do some other marine mammals and sea turtles. The planned monitoring and mitigation measures, including visual monitoring, passive acoustic monitoring (PAM) to complement visual observations (if practicable), power downs, and shut downs of the airguns when mammals are seen within or approaching the "exclusion zones", will further reduce the probability of exposure of marine mammals to sounds strong enough to induce PTS.

Stranding and Mortality.— Marine mammals close to underwater detonations of high explosives can be killed or severely injured, and the auditory organs are especially susceptible to injury (Ketten et al. 1993; Ketten 1995). However, explosives are no longer used for marine waters for commercial seismic surveys or (with rare exceptions) for seismic research; they have been replaced entirely by airguns or related non-explosive pulse generators. Airgun pulses are less energetic and have slower rise times, and there is no specific evidence that they can cause serious injury, death, or stranding even in the case of large airgun arrays. However, the association of strandings of beaked whales with naval exercises and, in one case, an L-DEO seismic survey (Malakoff 2002; Cox et al. 2006), has raised the possibility that beaked whales exposed to strong "pulsed" sounds may be especially susceptible to injury and/or behavioral reactions that can lead to stranding (e.g., Hildebrand 2005; Southall et al. 2007). Appendix B (6) of the EA provides additional details.

Specific sound-related processes that lead to strandings and mortality are not well documented, but may include (1) swimming in avoidance of a sound into shallow water; (2) a change in behavior (such as a change in diving behavior) that might contribute to tissue damage, gas bubble formation, hypoxia, cardiac arrhythmia, hypertensive hemorrhage or other forms of trauma; (3) a physiological change such as a vestibular response leading to a behavioral change or stress-induced hemorrhagic diathesis, leading in turn to tissue damage; and (4) tissue damage directly from sound exposure, such as through acoustically mediated bubble formation and growth or acoustic resonance of tissues. Some of these mechanisms are unlikely to apply in the case of impulse sounds. However, there are increasing indications that gas-bubble disease (analogous to "the bends"), induced in supersaturated tissue by a behavioral response to acoustic exposure, could be a pathologic mechanism for the strandings and mortality of some deep-diving cetaceans exposed to sonar. However, the evidence for this remains circumstantial and associated with exposure to naval mid-frequency sonar, not seismic surveys (Cox et al. 2006; Southall et al. 2007).

Seismic pulses and mid-frequency sonar signals are quite different, and some mechanisms by which sonar sounds have been hypothesized to affect beaked whales are unlikely to apply to airgun pulses. Sounds produced by airgun arrays are broadband impulses with most of the energy below 1 kHz. Typical military mid-frequency sonars emit non-impulse sounds at frequencies of 2–10 kHz, generally with a relatively narrow bandwidth at any one time. A further difference between seismic surveys and naval exercises is that naval exercises can involve sound sources on more than one vessel. Thus, it is not appropriate to assume that there is a direct connection between the effects of military sonar and seismic surveys on marine mammals. However, evidence that sonar signals can, in special circumstances, lead (at least indirectly) to physical damage and mortality (e.g., Balcomb and Claridge 2001; NOAA and USN 2001; Jepson et al. 2003; Fernández et al. 2004, 2005; Hildebrand 2005; Cox et al. 2006) suggests that caution is warranted when dealing with exposure of marine mammals to any high-intensity pulsed sound.

There is no conclusive evidence of cetacean strandings or deaths at sea as a result of exposure to seismic surveys, but a few cases of strandings in the general area where a seismic survey was ongoing have led to speculation concerning a possible link between seismic surveys and strandings. Suggestions that there was a link between seismic surveys and strandings of humpback whales in Brazil (Engel et al. 2004) were not well founded (IAGC 2004; IWC 2007). In September 2002, there was a stranding of two Cuvier's beaked whales in the Gulf of California, Mexico, when the L-DEO vessel R/V *Maurice Ewing* was operating a 20-airgun, 8490-in^3 airgun array in the general area. The link between the stranding and the seismic surveys was inconclusive and not based on any physical evidence (Hogarth 2002; Yoder 2002). Nonetheless, the Gulf of California incident plus the beaked whale strandings near naval exercises involving use of mid-frequency sonar suggests a need for caution in conducting seismic surveys in areas occupied by beaked whales until more is known about effects of seismic surveys on those species (Hildebrand 2005). No injuries of beaked whales are anticipated during the proposed study because of (1) the high likelihood that any beaked whales nearby would avoid the approaching vessel before being exposed to high sound levels, (2) the proposed monitoring and mitigation measures, and (3) differences between the sound sources operated by L-DEO and those involved in the naval exercises associated with strandings.

Non-auditory Physiological Effects.—Non-auditory physiological effects or injuries that theoretically might occur in marine mammals exposed to strong underwater sound include stress, neurological effects, bubble formation, resonance, and other types of organ or tissue damage (Cox et al. 2006; Southall et al. 2007). Studies examining such effects are limited. However, resonance effects (Gentry 2002) and direct noise-induced bubble formation (Crum et al. 2005) are implausible in the case of exposure to an impulsive broadband source like an airgun array. If seismic surveys disrupt diving patterns of deep-diving species, this might perhaps result in bubble formation and a form of "the bends", as speculated to occur in beaked whales exposed to sonar. However, there is no specific evidence of this upon exposure to airgun pulses.

In general, very little is known about the potential for seismic survey sounds (or other types of strong underwater sounds) to cause non-auditory physical effects in marine mammals. Such effects, if they occur at all, would presumably be limited to short distances and to activities that extend over a prolonged period. The available data do not allow identification of a specific exposure level above which non-auditory effects can be expected (Southall et al. 2007), or any meaningful quantitative predictions of the numbers (if any) of marine mammals that might be affected in those ways. Marine mammals that show behavioral avoidance of seismic vessels, including most baleen whales, some odontocetes, and some pinnipeds are especially unlikely to incur non-auditory physical effects. Also, the planned mitigation measures (§ XI), including shut downs of the airguns, will reduce any such effects that might otherwise occur.

Possible Effects of Multibeam Echosounder Signals

The Kongsberg EM 122 MBES will be operated from the source vessel during the planned study. Information about this equipment was provided in § II. Sounds from the MBES are very short pulses, occurring for 2–15 ms once every 5–20 s, depending on water depth. Most of the energy in the sound emitted by this MBES is at frequencies near 12 kHz, and the maximum source level is 242 dB re 1 $\mu Pa_{rms} \cdot m$. The beam is narrow (1–2º) in fore-aft extent and wide (150º) in the cross-track extent. Each ping consists of eight (in water >1000 m deep) or four (<1000 m deep) successive fan-shaped transmissions (segments) at different cross-track angles. Any given mammal at depth near the trackline would be in the main beam for only one or two of the segments. Also, marine mammals that encounter the Kongsberg EM 122 are unlikely to be subjected to repeated pulses because of the narrow fore–aft width of the beam and will receive only limited amounts of pulse energy because of the short pulses. Animals close to the ship (where the beam is narrowest) are especially unlikely to be ensonified for more than one 2–15 ms pulse (or two pulses if in the overlap area). Similarly, Kremser et al. (2005) noted that the probability of a cetacean swimming through the area of exposure when an MBES emits a pulse is small. The animal would have to pass the transducer at close range and be swimming at speeds similar to the vessel in order to receive the multiple pulses that might result in sufficient exposure to cause TTS.

Navy sonars that have been linked to avoidance reactions and stranding of cetaceans (1) generally have a longer pulse duration than the Kongsberg EM 122, and (2) are often directed close to horizontally vs. more downward for the MBES. The area of possible influence of the MBES is much smaller—a narrow band below the source vessel. The duration of exposure for a given marine mammal can be much longer for a naval sonar. During L-DEO's operations, the individual pulses will be very short, and a given mammal would not receive many of the downward-directed pulses as the vessel passes by. Possible effects of an MBES on marine mammals are outlined below.

Masking

Marine mammal communications will not be masked appreciably by the MBES signals given the low duty cycle of the echosounder and the brief period when an individual mammal is likely to be within its beam. Furthermore, in the case of baleen whales, the MBES signals (12 kHz) do not overlap with the predominant frequencies in the calls, which would avoid any significant masking.

Behavioral Responses

Behavioral reactions of free-ranging marine mammals to sonars, echosounders, and other sound sources appear to vary by species and circumstance. Observed reactions have included silencing and dispersal by sperm whales (Watkins et al. 1985), increased vocalizations and no dispersal by pilot whales (Rendell and Gordon 1999), and the previously-mentioned beachings by beaked whales. During exposure to a 21–25 kHz "whale-finding" sonar with a source level of 215 dB re 1 µPa·m, gray whales reacted by orienting slightly away from the source and being deflected from their course by ~200 m (Frankel 2005). When a 38-kHz echosounder and a 150-kHz acoustic Doppler current profiler were transmitting during studies in the ETP, baleen whales showed no significant responses, whereas spotted and spinner dolphins were detected slightly more often and beaked whales less often during visual surveys (Gerrodette and Pettis 2005).

Captive bottlenose dolphins and a white whale exhibited changes in behavior when exposed to 1-s tonal signals at frequencies similar to those that will be emitted by the MBES used by L-DEO, and to shorter broadband pulsed signals. Behavioral changes typically involved what appeared to be deliberate attempts to avoid the sound exposure (Schlundt et al. 2000; Finneran et al. 2002; Finneran and Schlundt 2004). The relevance of those data to free-ranging odontocetes is uncertain, and in any case, the test sounds were quite different in duration as compared with those from an MBES.

Very few data are available on the reactions of pinnipeds to echosounder sounds at frequencies similar to those used during seismic operations. Hastie and Janik (2007) conducted a series of behavioral response tests on two captive gray seals to determine their reactions to underwater operation of a 375-kHz multibeam imaging echosounder that included significant signal components down to 6 kHz. Results indicated that the two seals reacted to the signal by significantly increasing their dive durations. Because of the likely brevity of exposure to the MBES sounds, pinniped reactions are expected to be limited to startle or otherwise brief responses of no lasting consequence to the animals.

Hearing Impairment and Other Physical Effects

Given recent stranding events that have been associated with the operation of naval sonar, there is concern that mid-frequency sonar sounds can cause serious impacts to marine mammals (see above). However, the MBES proposed for use by L-DEO is quite different than sonars used for navy operations. Pulse duration of the MBES is very short relative to the naval sonars. Also, at any given location, an individual marine mammal would be in the beam of the MBES for much less time given the generally downward orientation of the beam and its narrow fore-aft beamwidth; navy sonars often use near-horizontally-directed sound. Those factors would all reduce the sound energy received from the MBES rather drastically relative to that from the sonars used by the navy.

Given the maximum source level of 242 dB re 1 μPa·m_{rms} (see § I), the received level for an animal within the MBES beam 100 m below the ship would be ~202 dB re 1 μPa_{rms}, assuming 40 dB of spreading loss over 100 m (circular spreading). Given the narrow beam, only one pulse is likely to be received by a given animal as the ship passes overhead. The received energy level from a single pulse of duration 15 ms would be about 184 dB re 1 $\mu Pa^2 \cdot s$, i.e., 202 dB + 10 log (0.015 s). That is below the TTS threshold for a cetacean receiving a single non-impulse sound (195 dB re 1 $\mu Pa^2 \cdot s$) and even further below the anticipated PTS threshold (215 dB re 1 $\mu Pa^2 \cdot s$) (Southall et al. 2007). In contrast, an animal that was only 10 m below the MBES when a ping is emitted would be expected to receive a level ~20 dB higher, i.e., 204 dB re 1 $\mu Pa^2 \cdot s$ in the case of the EM 122. That animal might incur some TTS (which would be fully recoverable), but the exposure would still be below the anticipated PTS threshold for cetaceans. As noted by Burkhardt et al. (2007, 2008), cetaceans are very unlikely to incur PTS from operation of scientific sonars on a ship that is underway.

In the harbor seal, the TTS threshold for non-impulse sounds is about 183 dB re 1 $\mu Pa^2 \cdot s$, as compared with ~195 dB re 1 $\mu Pa^2 \cdot s$ in odontocetes (Kastak et al. 2005; Southall et al. 2007). TTS onset occurs at higher received energy levels in the California sea lion and northern elephant seal than in the harbor seal. A harbor seal as much as 100 m below the *Langseth* could receive a single MBES ping with received energy level of ≥184 dB re 1 $\mu Pa^2 \cdot s$ (as calculated in the toothed whale subsection above) and thus could incur slight TTS. Species of pinnipeds with higher TTS thresholds would not incur TTS unless they were closer to the transducers when a ping was emitted. However, the SEL criterion for PTS in pinnipeds (203 dB re 1 $\mu Pa^2 \cdot s$) might be exceeded for a ping received within a few meters of the transducers, although the risk of PTS is higher for certain species (e.g., harbor seal). Given the intermittent nature of the signals and the narrow MBES beam, only a small fraction of the pinnipeds below (and close to) the ship would receive a ping as the ship passed overhead.

Possible Effects of the Sub-bottom Profiler Signals

An SBP will also be operated from the source vessel during the planned study. Details about this equipment were provided in § I. Sounds from the SBPs are very short pulses, occurring for up to 64 ms once every second. Most of the energy in the sound pulses emitted by the SBPs is at 3.5 kHz, and the beam is directed downward. The sub-bottom profiler on the *Langseth* has a maximum source level of 222 dB re 1 μPa·m (see § I). Kremser et al. (2005) noted that the probability of a cetacean swimming through the area of exposure when a bottom profiler emits a pulse is small—even for an SBP more powerful than that on the *Langseth*—if the animal was in the area, it would have to pass the transducer at close range and in order to be subjected to sound levels that could cause TTS.

Masking

Marine mammal communications will not be masked appreciably by the SBP signals given the directionality of the signal and the brief period when an individual mammal is likely to be within its beam. Furthermore, in the case of most baleen whales, the SBP signals do not overlap with the predominant frequencies in the calls, which would avoid significant masking.

Behavioral Responses

Marine mammal behavioral reactions to other pulsed sound sources are discussed above, and responses to the SBP are likely to be similar to those for other pulsed sources if received at the same levels. However, the pulsed signals from the SBP are considerably weaker than those from the MBES. Therefore, behavioral responses are not expected unless marine mammals are very close to the source.

Hearing Impairment and Other Physical Effects

It is unlikely that the SBP produces pulse levels strong enough to cause hearing impairment or other physical injuries even in an animal that is (briefly) in a position near the source. The SBP is usually operated simultaneously with other higher-power acoustic sources. Many marine mammals will move away in response to the approaching higher-power sources or the vessel itself before the mammals would be close enough for there to be any possibility of effects from the less intense sounds from the SBP. In the case of mammals that do not avoid the approaching vessel and its various sound sources, mitigation measures that would be applied to minimize effects of other sources (see § XI) would further reduce or eliminate any minor effects of the SBP.

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

All anticipated takes would be "takes by harassment", involving temporary changes in behavior. The mitigation measures to be applied will minimize the possibility of injurious takes. (However, as noted earlier, there is no specific information demonstrating that injurious "takes" would occur even in the absence of the planned mitigation measures.) In the sections below, we describe methods to estimate the number of potential exposures to various received sound levels and present estimates of the numbers of marine mammals that could be affected during the proposed seismic program. The estimates are based on a consideration of the number of marine mammals that could be disturbed appreciably by operations with the 36-airgun array to be used during ~1150 km of seismic surveys in the northeast Pacific Ocean. The sources of distributional and numerical data used in deriving the estimates are described in the next subsection.

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

Basis for Estimating "Take by Harassment"

Extensive systematic aircraft- and ship-based surveys have been conducted for marine mammals offshore from Oregon and Washington (e.g., Bonnell et al. 1992; Green et al. 1992, 1993; Barlow 1997, 2003; Barlow and Taylor 2001; Calambokidis and Barlow 2004; Barlow and Forney 2007; Barlow 2010). The most comprehensive and recent density data available for cetacean species in slope and offshore waters of Oregon are from the 1991, 1993, 1996, 2001, 2005, and 2007 NMFS/SWFSC ship surveys as synthesized by Barlow and Forney (2007) and Barlow (2010). The surveys were conducted up to ~555 km offshore from June or July to November or December.

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

Oceanographic conditions, including occasional El Niño and La Niña events, influence the distribution and numbers of marine mammals present in the North Pacific Ocean, including waters off

Oregon and Washington, resulting in considerable year-to-year variation in the distribution and abundance of many marine mammal species (Forney and Barlow 1998; Buchanan et al. 2001; Escorza-Treviño 2002; Ferrero et al. 2002; Philbrick et al. 2003). Thus, cetacean densities used here were derived from the pooled results of the 1991–2008 surveys (abundances and survey area given for Oregon–Washington in Barlow 2010) with the exception of the gray whale and the harbor porpoise. (Abundance and density were not estimated for gray whales or harbor porpoises in the NMFS/SWFSC surveys because their inshore habitats were inadequately covered in those studies.) Gray whale density is from DoN (2010), based on the abundance of gray whales that remain between Oregon and B.C. in summer and the area out to 43 km from shore. Harbor porpoise densities were calculated using the population estimate for the Northern Oregon/Washington Coast stock (which occupies most of the proposed survey areas) and the range for that stock given in Carretta et al. (2011a).

Table 3 gives the densities for each species of cetacean reported off Oregon and Washington. The densities from NMFS/SWFSC vessel-based surveys have been corrected for both trackline detection probability and availability bias by the authors. Trackline detection probability bias is associated with diminishing sightability with increasing lateral distance from the trackline [*f*(0)]. Availability bias refers to the fact that there is less-than-100% probability of sighting an animal that is present along the survey trackline, and it is measured by *g*(0).

Table 3 also includes mean density information for 4 of the 5 pinniped species that occur off Oregon and Washington using the methods and calculations in DoN (2010) and population sizes that were updated based on Allen and Angliss (2011) and Carretta et al. (2011a). For the other species, the harbor seal, densities were calculated using the population estimate for the Oregon/Washington Coastal Stock and the range for that stock given in Carretta et al. (2011a).

The estimated numbers of individuals potentially exposed are based on the 160-dB re 1 μPa_{rms} criterion for all cetaceans and pinnipeds. It is assumed that marine mammals exposed to airgun sounds that strong might change their behavior sufficiently to be considered "taken by harassment".

It should be noted that the following estimates of exposures to various sound levels assume that the surveys will be fully completed; in fact, the ensonified areas calculated using the planned number of line-kilometers ***have been increased by 25%*** to accommodate turns, lines that may need to be repeated equipment testing, etc. As is typical during ship surveys, inclement weather and equipment malfunctions are likely to cause delays and may limit the number of useful line-kilometers of seismic operations that can be undertaken. Furthermore, any marine mammal sightings within or near the designated exclusion zone will result in the shut down of seismic operations as a mitigation measure. Thus, the following estimates of the numbers of marine mammals potentially exposed to 160-dB re 1 μPa_{rms} sounds are precautionary, and probably overestimate the actual numbers of marine mammals that might be involved. These estimates assume that there will be no weather, equipment, or mitigation delays, which is highly unlikely.

Furthermore, as summarized in § VII, above, and Appendix B (5) of the EA, delphinids and pinnipeds seem to be less responsive to airgun sounds than are some mysticetes. The 160-dB (rms) criterion currently applied by NMFS, on which the following estimates are based, was developed based primarily on data from gray and bowhead whales. A 170-dB re 1 µPa disturbance criterion (rather than 160 dB) is considered appropriate for delphinids (and pinnipeds), which tend to be less responsive than the more responsive cetaceans. The estimates of "takes by harassment" of delphinids and pinnipeds given below are thus considered precautionary.

TABLE 3. Densities of marine mammals off Oregon and Washington. Cetacean densities are from Barlow (2010) and are based on ship transect surveys conducted up to 555 km offshore in 1991, 1993, 1996, 2001, 2005, and 2007. Pinniped densities are from shore counts and calculations in DoN (2010). Cetacean densities from Barlow (2010) are corrected for *f*(0) and *g*(0). Species listed as "Endangered" under the ESA are in italics.

Species	Density (#/1000 km2)	Source[1]
Mysticetes		
North Pacific right whale	*0*	–
Gray whale	3.21	DoN (2010)
Humpback whale	*0.81*	*Barlow (2010)*
Minke whale	0.46	Barlow (2010)
Sei whale	*0.16*	*Barlow (2010)*
Fin whale	*1.29*	*Barlow (2010)*
Blue whale	*0.18*	*Barlow (2010)*
Odontocetes		
Sperm whale	*1.02*	*Barlow (2010)*
Pygmy/dwarf sperm whale	0.71	Barlow (2010)
Cuvier's beaked whale	0.43	Barlow (2010)
Baird's beaked whale	1.18	Barlow (2010)
Mesoplodont (unidentified)[2]	1.75	Barlow (2010)
Bottlenose dolphin	0	–
Striped dolphin	0.04	Barlow (2010)
Short-beaked common dolphin	10.28	Barlow (2010)
Pacific white-sided dolphin	34.91	Barlow (2010)
Northern right-whale dolphin	12.88	Barlow (2010)
Risso's dolphin	11.19	Barlow (2010)
False killer whale	0	–
Killer whale	1.66	Barlow (2010)
Short-finned pilot whale	0	–
Harbor porpoise	632.4	See text
Dall's porpoise	83.82	Barlow (2010)
Pinnipeds		
Northern fur seal	83.62	DoN (2010)[3]
California sea lion	0	DoN (2010)[3]
Steller sea lion	13.12	DoN (2010)[3]
Harbor seal	292.3	See text
Northern elephant seal	45.81	DoN (2010)[3]

[1] Where no source is given, the species was not included in Barlow (2010) and no takes are anticipated or requested.
[2] Includes Blainville's, Stejneger's, and Hubb's beaked whale.
[3] Population sizes in DoN (2010) were updated based on Allen and Angliss (2011) and Carretta et al. (2001)

Potential Number of Marine Mammals Exposed to ≥160 dB

The number of different individuals that could be exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} on one or more occasions can be estimated by considering the expected density of animals in the area along with the total marine area that would be within the 160-dB radius around the operating airgun array on at least one occasion. The number of possible exposures (including repeated exposures of the same individuals) can be estimated by considering the total marine area that would be within the 160-dB radius around the operating airguns, including areas of overlap. During the proposed survey, the transect lines are closely spaced. Thus, the area including overlap is 2.0 x the area excluding overlap, so a marine mammal that stayed in the survey area during the entire survey could be exposed ~2 times, on average. However, it is unlikely that a particular animal would stay in the area during the entire survey.

The numbers of different individuals potentially exposed to ≥160 dB re 1 μPa_{rms} were calculated by multiplying the expected species density, times the anticipated area to be ensonified to that level during airgun operations excluding overlap.

The area expected to be ensonified was determined by entering the planned survey lines (including contingency lines) into a MapInfo GIS, using the GIS to identify the relevant areas by "drawing" the applicable 160-dB buffer (see Table 1) around each seismic line, and then calculating the total area within the buffers. Areas of overlap were included only once when estimating the number of individuals exposed.

Applying the approach described above, ~11,387 km^2 (~14,234 km^2 including the 25% contingency) would be within the 160-dB isopleth during the survey. Because this approach does not allow for turnover in the mammal populations in the proposed survey area during the course of the survey, the actual number of individuals exposed could be underestimated. However, the approach assumes that no cetaceans will move away from or toward the trackline as the *Langseth* approaches in response to increasing sound levels prior to the time the levels reach 160 dB, which will result in overestimates for those species known to avoid seismic vessels (see § VII, above).

Table 4 shows estimates of the number of different individual marine mammals that potentially could be exposed to ≥160 dB re 1 μPa_{rms} during the seismic survey if no animals moved away from the survey vessel. The ***Requested Take Authorization*** is given in the far right column of Table 4. For non-listed cetacean species, the ***Requested Take Authorization*** has been increased to the mean group size off Washington and Oregon (Barlow and Forney 2007) for the particular species in cases where the calculated number of individuals exposed was between 1 and the mean group size.

Number of Cetaceans that could be Exposed to ≥160 dB.—The estimate of the number of individual cetaceans that could be exposed to seismic sounds with received levels ≥160 dB re 1 μPa_{rms} during the proposed survey is 4908 (Table 4). That total includes 49 cetaceans listed as ***Endangered*** under the ESA, including 18 fin whales (0.11% of the regional population), 15 sperm whales (0.06%), 11 humpback whales (0.06%), 3 blue whales (0.10%), and 2 sei whales (0.02%).

In addition, 48 beaked whales (6 Cuvier's beaked whale, 17 Baird's beaked whale, and 25 *Mesoplodon* spp.) could be exposed during the survey (Table 4). Most (52.6%) of the cetaceans potentially exposed are harbor porpoises. Another 44.4% are delphinids (including Dall's porpoise): Dall's porpoise, the Pacific white-sided dolphin, and the northern right whale dolphin are estimated to be the most common delphinid species in the area, with estimates of 1193 (2.84% of the regional population), 497 (1.85%), and 183 (2.20%) exposed to ≥160 dB re 1 μPa_{rms}, respectively. As noted above, a more meaningful estimate for delphinids would be for sound levels ≥170 dB.

Number of Pinnipeds that could be Exposed to ≥160 dB.— The estimate of the number of individual pinnipeds that could be exposed to seismic sounds with received levels ≥160 dB re 1 μPa_{rms} during the proposed survey is 3221 (Table 4), including 187 ***Threatened*** Steller sea lions (0.29% of the regional population). The harbor seal and northern fur seal are estimated to be the most common pinniped species in the area, with estimates of 1192 (4.82% of the regional population) and 1190 (0.18%) exposed to ≥160 dB re 1 μPa_{rms}, respectively. As noted above, a more meaningful estimate for most pinnipeds would be for sound levels ≥170 dB.

TABLE 4. Estimates of the possible numbers of different individuals that could be exposed during L-DEO's proposed seismic survey in the northeastern Pacific during 12–23 July 2012. The proposed sound source consists of an 36-airgun array with a total discharge volume of 6600 in^3. Received levels of seismic sounds are expressed in dB re 1 μPa (rms, averaged over pulse duration), consistent with NMFS' practice. Not all marine mammals will change their behavior when exposed to these sound levels, but some may alter their behavior when levels are lower (see text). Species in italics are listed under the ESA as endangered or threatened. The column of numbers in boldface shows the numbers of "takes" for which authorization is requested.

Species	**Number[1]**	**% Regional Pop'n[2]**	**Requested Take Authorization**
Mysticetes			
North Pacific right whale	*0*	*0*	***0***
Gray whale[3]	12	0.06	**12**
Humpback whale	*11*	*0.06*	***11***
Minke whale	6	0.07	**6**
Sei whale	*2*	*0.02*	***2***
Fin whale	*18*	*0.11*	***18***
Blue whale	*3*	*0.10*	***3***
Odontocetes			
Sperm whale	*15*	*0.06*	***15***
Pygmy/Dwarf sperm whale	10	NA	**10**
Cuvier's beaked whale	6	0.28	**6**
Baird's beaked whale	17	1.85	**17**
Mesoplodon spp.[4]	25	2.44	**25**
Bottlenose dolphin	0	0	**0**
Striped dolphin	1	<0.01	**2[5]**
Short-beaked common dolphin	146	0.04	**238[5]**
Pacific white-sided dolphin	497	1.85	**497**
Northern right-whale dolphin	183	2.20	**183**
Risso's dolphin	159	2.54	**159**
False killer whale	0	0	**0**
Killer whale	24	0.96	**24**
Short-finned pilot whale	0	0	**0**
Harbor porpoise[3]	2580	4.94	**2580**
Dall's porpoise	1193	2.84	**1193**
Pinnipeds			
Northern fur seal	1190	0.18	**1190**
California sea lion	0	0	**0**
Steller sea lion	*187*	*0.29*	***187***
Harbor seal[3]	1192	4.82	**1192**
Northern elephant seal	652	0.53	**652**

NA – not available.
[1] Estimates are based on densities from Table 3 and an ensonified area (including 25% contingency) of 14,234 km^2.
[2] Regional population size estimates are from Table 2.
[3] Estimates based on densities from Table 3 and an ensonified area in water depths <100 m (including 25% contingency) of 4080 km^2
[4] Includes Blainville's, Stejneger's, and Hubb's beaked whales.
[5] Requested Take Authorization increased to mean group size for cetaceans (see text).

Conclusions

The proposed seismic survey will involve towing an airgun array that introduces pulsed sounds into the ocean, along with simultaneous operation of an MBES and SBP. The survey will employ a 36-airgun array similar to the airgun arrays used for typical high-energy seismic surveys. The total airgun discharge volume is ~6600 in^3. Routine vessel operations, other than the proposed airgun operations, are conventionally assumed not to affect marine mammals sufficiently to constitute "taking". No "taking" of marine mammals is expected in association with echosounder operations given the considerations discussed in § I, i.e., sounds are beamed downward, the beam is narrow, and the pulses are extremely short.

Cetaceans.—Several species of mysticetes show strong avoidance reactions to seismic vessels at ranges up to 6–8 km and occasionally as far as 20–30 km from the source vessel when medium-large airgun arrays have been used. However, reactions at the longer distances appear to be atypical of most species and situations. If mysticetes are encountered, the numbers estimated to occur within the 160-dB isopleth in the survey area are expected to be relatively low.

Odontocete reactions to seismic pulses, or at least the reactions of delphinids and Dall's porpoise, are expected to extend to lesser distances than are those of mysticetes. Odontocete low-frequency hearing is less sensitive than that of mysticetes, and dolphins are often seen from seismic vessels. In fact, there are documented instances of dolphins approaching active seismic vessels. However, delphinids (along with other cetaceans) sometimes show avoidance responses and/or other changes in behavior when near operating seismic vessels.

Taking into account the mitigation measures that are planned (see § XI), effects on cetaceans are generally expected to be limited to avoidance of the area around the seismic operation and short-term changes in behavior, falling within the MMPA definition of "Level B harassment".

Estimates of the numbers of marine mammals that might be exposed to airgun sounds ≥160 dB re 1 μPa_{rms} during the proposed program have been presented with a corresponding requested "take authorization" for each species. Those figures likely overestimate the actual number of animals that will be exposed to and will react to the seismic sounds. The reasons for that conclusion are outlined above. The relatively short-term exposures are unlikely to result in any long-term negative consequences for the individuals or their populations.

The many cases of apparent tolerance by cetaceans of seismic exploration, vessel traffic, and some other human activities show that co-existence is possible. Mitigation measures such as look outs, ramp ups, and power downs or shut downs when marine mammals are seen within defined ranges should further reduce short-term reactions, and avoid or minimize any effects on hearing sensitivity. In all cases, the effects are expected to be short-term, with no lasting biological consequence.

Pinnipeds.— Four of the five pinniped species discussed in § III are likely to occur in the proposed survey areas. The California sea lion would be at or near its rookeries in California and Baha California during the proposed surveys, which coincide with its mating season. Estimates of 1190 northern fur seals, 187 Steller sea lions, 1192 harbor seals, and 652 northern elephant seals could be exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} during the survey. As for cetaceans, the estimated numbers of pinnipeds that could be exposed to received levels ≥160 dB are probably overestimates of the actual numbers that will be affected significantly.

VIII. ANTICIPATED IMPACT ON SUBSISTENCE

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

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

IX. ANTICIPATED IMPACT ON HABITAT

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

The proposed seismic survey will not result in any permanent impact on habitats used by marine mammals or to the food sources they use. The main impact issue associated with the proposed activity will be temporarily elevated noise levels and the associated direct effects on marine mammals, as discussed in § VII, above. The following sections briefly review effects of airguns on fish and invertebrates, and more details are included in Appendices D and E of the EA, respectively.

Effects on Fish

One reason for the adoption of airguns as the standard energy source for marine seismic surveys is that, unlike explosives, they have not been associated with large-scale fish kills. However, existing information on the impacts of seismic surveys on marine fish populations is limited (see Appendix D of the EA). There are three types of potential effects of exposure to seismic surveys: (1) pathological, (2) physiological, and (3) behavioral. Pathological effects involve lethal and temporary or permanent sub-lethal injury. Physiological effects involve temporary and permanent primary and secondary stress responses, such as changes in levels of enzymes and proteins. Behavioral effects refer to temporary and (if they occur) permanent changes in exhibited behavior (e.g., startle and avoidance behavior). The three categories are interrelated in complex ways. For example, it is possible that certain physiological and behavioral changes could potentially lead to an ultimate pathological effect on individuals (i.e., mortality).

The specific received sound levels at which permanent adverse effects to fish potentially could occur are little studied and largely unknown. Furthermore, the available information on the impacts of seismic surveys on marine fish is from studies of individuals or portions of a population; there have been no studies at the population scale. The studies of individual fish have often been on caged fish that were exposed to airgun pulses in situations not representative of an actual seismic survey. Thus, available information provides limited insight on possible real-world effects at the ocean or population scale. This makes drawing conclusions about impacts on fish problematic because, ultimately, the most important issues concern effects on marine fish populations, their viability, and their availability to fisheries.

Hastings and Popper (2005), Popper (2009), and Popper and Hastings (2009a,b) provided recent critical reviews of the known effects of sound on fish. The following sections provide a general synopsis of the available information on the effects of exposure to seismic and other anthropogenic sound as relevant to fish. The information comprises results from scientific studies of varying degrees of rigor plus some anecdotal information. Some of the data sources may have serious shortcomings in methods, analysis, interpretation, and reproducibility that must be considered when interpreting their results (see Hastings and Popper 2005). Potential adverse effects of the program's sound sources on marine fish are then noted.

Pathological Effects

The potential for pathological damage to hearing structures in fish depends on the energy level of the received sound and the physiology and hearing capability of the species in question (see Appendix D of the EA). For a given sound to result in hearing loss, the sound must exceed, by some substantial amount, the hearing threshold of the fish for that sound (Popper 2005). The consequences of temporary or permanent hearing loss in individual fish on a fish population are unknown; however, they likely depend on the number of individuals affected and whether critical behaviors involving sound (e.g., predator avoidance, prey capture, orientation and navigation, reproduction, etc.) are adversely affected.

Little is known about the mechanisms and characteristics of damage to fish that may be inflicted by exposure to seismic survey sounds. Few data have been presented in the peer-reviewed scientific literature. As far as we know, there are only two papers with proper experimental methods, controls, and careful pathological investigation implicating sounds produced by actual seismic survey airguns in causing adverse anatomical effects. One such study indicated anatomical damage, and the second indicated TTS in fish hearing. The anatomical case is McCauley et al. (2003), who found that exposure to airgun sound caused observable anatomical damage to the auditory maculae of “pink snapper” (*Pagrus auratus*). This damage in the ears had not been repaired in fish sacrificed and examined almost two months after exposure. On the other hand, Popper et al. (2005) documented only TTS (as determined by auditory brainstem response) in two of three fish species from the Mackenzie River Delta. This study found that broad whitefish (*Coregonus nasus*) that received a sound exposure level of 177 dB re 1 $\mu Pa^2 \cdot s$ showed no hearing loss. During both studies, the repetitive exposure to sound was greater than would have occurred during a typical seismic survey. However, the substantial low-frequency energy produced by the airguns [less than ~400 Hz in the study by McCauley et al. (2003) and less than ~200 Hz in Popper et al. (2005)] likely did not propagate to the fish because the water in the study areas was very shallow (~9 m in the former case and <2 m in the latter). Water depth sets a lower limit on the lowest sound frequency that will propagate (the “cutoff frequency”) at about one-quarter wavelength (Urick 1983; Rogers and Cox 1988).

Wardle et al. (2001) suggested that in water, acute injury and death of organisms exposed to seismic energy depends primarily on two features of the sound source: (1) the received peak pressure and (2) the time required for the pressure to rise and decay. Generally, as received pressure increases, the period for the pressure to rise and decay decreases, and the chance of acute pathological effects increases. According to Buchanan et al. (2004), for the types of seismic airguns and arrays involved with the proposed program, the pathological (mortality) zone for fish would be expected to be within a few meters of the seismic source. Numerous other studies provide examples of no fish mortality upon exposure to seismic sources (Falk and Lawrence 1973; Holliday et al. 1987; La Bella et al. 1996; Santulli et al. 1999; McCauley et al. 2000a,b, 2003; Bjarti 2002; Thomsen 2002; Hassel et al. 2003; Popper et al. 2005; Boeger et al. 2006).

Some studies have reported, some equivocally, that mortality of fish, fish eggs, or larvae can occur close to seismic sources (Kostyuchenko 1973; Dalen and Knutsen 1986; Booman et al. 1996; Dalen et al. 1996). Some of the reports claimed seismic effects from treatments quite different from actual seismic survey sounds or even reasonable surrogates. However, Payne et al. (2009) reported no statistical differences in mortality/morbidity between control and exposed groups of capelin eggs or monkfish larvae. Saetre and Ona (1996) applied a ‘worst-case scenario’ mathematical model to investigate the effects of seismic energy on fish eggs and larvae. They concluded that mortality rates caused by exposure to seismic surveys are so low, as compared to natural mortality rates, that the impact of seismic surveying on recruitment to a fish stock must be regarded as insignificant.

Physiological Effects

Physiological effects refer to cellular and/or biochemical responses of fish to acoustic stress. Such stress potentially could affect fish populations by increasing mortality or reducing reproductive success. Primary and secondary stress responses of fish after exposure to seismic survey sound appear to be temporary in all studies done to date (Sverdrup et al. 1994; Santulli et al. 1999; McCauley et al. 2000a,b). The periods necessary for the biochemical changes to return to normal are variable and depend on numerous aspects of the biology of the species and of the sound stimulus (see Appendix D of the EA).

Behavioral Effects

Behavioral effects include changes in the distribution, migration, mating, and catchability of fish populations. Studies investigating the possible effects of sound (including seismic survey sound) on fish behavior have been conducted on both uncaged and caged individuals (e.g., Chapman and Hawkins 1969; Pearson et al. 1992; Santulli et al. 1999; Wardle et al. 2001; Hassel et al. 2003). Typically, in these studies fish exhibited a sharp "startle" response at the onset of a sound followed by habituation and a return to normal behavior after the sound ceased.

There is general concern about potential adverse effects of seismic operations on fisheries, namely a potential reduction in the "catchability" of fish involved in fisheries. Although reduced catch rates have been observed in some marine fisheries during seismic testing, in a number of cases the findings are confounded by other sources of disturbance (Dalen and Raknes 1985; Dalen and Knutsen 1986; Løkkeborg 1991; Skalski et al. 1992; Engås et al. 1996). In other airgun experiments, there was no change in catch per unit effort (CPUE) of fish when airgun pulses were emitted, particularly in the immediate vicinity of the seismic survey (Pickett et al. 1994; La Bella et al. 1996). For some species, reductions in catch may have resulted from a change in behavior of the fish, e.g., a change in vertical or horizontal distribution, as reported in Slotte et al. (2004).

In general, any adverse effects on fish behavior or fisheries attributable to seismic testing may depend on the species in question and the nature of the fishery (season, duration, fishing method). They may also depend on the age of the fish, its motivational state, its size, and numerous other factors that are difficult, if not impossible, to quantify at this point, given such limited data on effects of airguns on fish, particularly under realistic at-sea conditions.

Effects on Invertebrates

The existing body of information on the impacts of seismic survey sound on marine invertebrates is very limited. However, there is some unpublished and very limited evidence of the potential for adverse effects on invertebrates, thereby justifying further discussion and analysis of this issue. The three types of potential effects of exposure to seismic surveys on marine invertebrates are pathological, physiological, and behavioral. Based on the physical structure of their sensory organs, marine invertebrates appear to be specialized to respond to particle displacement components of an impinging sound field and not to the pressure component (Popper et al. 2001; see also Appendix E of the EA).

The only information available on the impacts of seismic surveys on marine invertebrates involves studies of individuals; there have been no studies at the population scale. Thus, available information provides limited insight on possible real-world effects at the regional or ocean scale. The most important aspect of potential impacts concerns how exposure to seismic survey sound ultimately affects invertebrate populations and their viability, including availability to fisheries.

Literature reviews of the effects of seismic and other underwater sound on invertebrates were provided by Moriyasu et al. (2004) and Payne et al. (2008). The following sections provide a synopsis of available information on the effects of exposure to seismic survey sound on species of decapod crustaceans and cephalopods, the two taxonomic groups of invertebrates on which most such studies have been conducted. The available information is from studies with variable degrees of scientific soundness and from anecdotal information. A more detailed review of the literature on the effects of seismic survey sound on invertebrates is provided in Appendix E of the EA.

Pathological Effects

In water, lethal and sub-lethal injury to organisms exposed to seismic survey sound appears to depend on at least two features of the sound source: (1) the received peak pressure, and (2) the time required for the pressure to rise and decay. Generally, as received pressure increases, the period for the pressure to rise and decay decreases, and the chance of acute pathological effects increases. For the type of airgun array planned for the proposed program, the pathological (mortality) zone for crustaceans and cephalopods is expected to be within a few meters of the seismic source, at most; however, very few specific data are available on levels of seismic signals that might damage these animals. This premise is based on the peak pressure and rise/decay time characteristics of seismic airgun arrays currently in use around the world.

Some studies have suggested that seismic survey sound has a limited pathological impact on early developmental stages of crustaceans (Pearson et al. 1994; Christian et al. 2003; DFO 2004). However, the impacts appear to be either temporary or insignificant compared to what occurs under natural conditions. Controlled field experiments on adult crustaceans (Christian et al. 2003, 2004; DFO 2004) and adult cephalopods (McCauley et al. 2000a,b) exposed to seismic survey sound have not resulted in any significant pathological impacts on the animals. It has been suggested that giant squid strandings were caused by exposure to commercial seismic survey activities (Guerra et al. 2004), but there was little evidence to support the claim. André et al. (2011) exposed cephalopods, primarily cuttlefish, to continuous 50–400 Hz sinusoidal wave sweeps for two hours while captive in relatively small tanks, and reported morphological and ultrastructural evidence of massive acoustic trauma (i.e., permanent and substantial alterations of statocyst sensory hair cells). The received SPL was reported as 157±5 dB re 1µPa, with peak levels at 175 dB re 1µPa. As in the McCauley et al. (2003) paper on sensory hair cell damage in pink snapper as a result of exposure to seismic sound, the cephalopods were subjected to higher sound levels than they would be under natural conditions, and they were unable to swim away from the sound source.

Physiological Effects

Physiological effects refer mainly to biochemical responses by marine invertebrates to acoustic stress. Such stress potentially could affect invertebrate populations by increasing mortality or reducing reproductive success. Primary and secondary stress responses (i.e., changes in haemolymph levels of enzymes, proteins, etc.) of crustaceans have been noted several days or months after exposure to seismic survey sounds (Payne et al. 2007). The periods necessary for these biochemical changes to return to normal are variable and depend on numerous aspects of the biology of the species and of the sound stimulus.

Behavioral Effects

There is increasing interest in assessing the possible direct and indirect effects of seismic and other sounds on invertebrate behavior, particularly in relation to the consequences for fisheries. Changes in behavior could potentially affect such aspects as reproductive success, distribution, susceptibility to predation, and catchability by fisheries. Studies investigating the possible behavioral effects of exposure to seismic survey sound on crustaceans and cephalopods have been conducted on both uncaged and caged animals. In some cases, invertebrates exhibited startle responses (e.g., squid in McCauley et al. 2000a,b). In other cases, no behavioral impacts were noted (e.g., crustaceans in Christian et al. 2003, 2004; DFO 2004). There have been anecdotal reports of reduced catch rates of shrimp shortly after exposure to seismic surveys; however, other studies have not observed any significant changes in shrimp catch rate (Andriguetto-Filho et al. 2005). Similarly, Parry and Gason (2006) did not find any evidence that lobster catch rates were affected by seismic surveys. Any adverse effects on crustacean and cephalopod behavior or fisheries attributable to seismic survey sound depend on the species in question and the nature of the fishery (season, duration, fishing method).

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

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

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

The proposed activity is not expected to have any habitat-related effects that could cause significant or long-term consequences for individual marine mammals or their populations, because operations will be limited in duration.

XI. Mitigation Measures

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

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

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

Planning Phase

The PIs worked with L-DEO and NSF to identify potential time periods to carry out the survey taking into consideration key factors such as environmental conditions (i.e., the seasonal presence of marine mammals, sea turtles, and seabirds), weather conditions, equipment, and optimal timing for other proposed seismic surveys using the R/V *Langseth*. Most marine mammal species are expected to occur in the area year-round, so altering the timing of the proposed project likely would result in no net benefits for those species. After considering what energy source level was necessary to achieve the research goals, the PIs determined the use of the 36-airgun array with a total volume of ~6600 in^3 would be required. Given the research goals, this energy source level was viewed appropriate.

Proposed Exclusion Zones

Received sound levels have been predicted by L-DEO's model, in relation to distance and direction from the airguns, for the 36-airgun array and for a single 1900LL 40-in^3 airgun, which will be used during power downs. Results have been reported for propagation measurements of pulses from the 36-airgun array in two water depths (~1600 m and 50 m) in the Gulf of Mexico in 2007–2008 (Tolstoy et al. 2009). Results of the propagation measurements showed that radii around the airguns for various received levels varied with water depth (Tolstoy et al. 2009). As results for measurements in intermediate-depth water are still under analysis, values halfway between the deep and shallow-water measurements were used. In addition, propagation varies with array tow depth. The empirical values that resulted from Tolstoy et al. (2009) are used here to determine exclusion zones for the 36-airgun array. However, the depth of the array was different in the Gulf of Mexico calibration study (6 m) than in the proposed surveys (9, 12, and 15 m); thus, correction factors have been applied to the distances reported by Tolstoy et al. (2009). The correction factors used were the ratios of the 160-, 180-, and 190-dB distances from the modeled results for the 6600-in^3 airgun array towed at 6 m vs. 15 m, from LGL (2009): 1.647, 1.718, and 1.727, respectively.

Using the corrected measurements (array) or model (single airgun), Table 1 shows the distances at which three rms sound levels are expected to be received from the 36-airgun array and a single airgun. The 180- and 190-dB re 1 μPa_{rms} distances are the safety criteria as specified by NMFS (2000) and are applicable to cetaceans and pinnipeds, respectively. The 180-dB distance will also be used as the exclusion zone for sea turtles, as required by NMFS in most other recent seismic projects (e.g., Smultea et al. 2004; Holst et al. 2005b; Holst and Beland 2008; Holst and Smultea 2008; Hauser et al. 2008; Holst 2009; Antochiw et al. n.d.). If marine mammals or sea turtles are detected within or about to enter the appropriate exclusion zone, the airguns will be powered down (or shut down if necessary) immediately (see below).

Detailed recommendations for new science-based noise exposure criteria were published in early 2008 (Southall et al. 2007). L-DEO will be prepared to revise its procedures for estimating numbers of mammals “taken”, EZs, etc., as may be required by any new guidelines that result. As yet, NMFS has not specified a new procedure for determining EZs.

Mitigation During Operations

Mitigation measures that will be adopted during the proposed survey include (1) power-down procedures, (2) shut-down procedures, and (3) ramp-up procedures.

Power-down Procedures

A power down involves decreasing the number of airguns in use such that the radius of the 180-dB (or 190-dB) zone is decreased to the extent that marine mammals or turtles are no longer in or about to enter the EZ. A power down of the airgun array will also occur when the vessel is turning from one seismic line to another. During a power down, one airgun will be operated. The continued operation of one airgun is intended to alert marine mammals and turtles to the presence of the seismic vessel in the area. In contrast, a shut down occurs when all airgun activity is suspended.

If a marine mammal or turtle is detected outside the EZ but is likely to enter the EZ, the airguns will be powered down before the animal is within the EZ. Likewise, if a mammal or turtle is already within the EZ when first detected, the airguns will be powered down immediately. During a power down of the airgun array, the 40-in^3 airgun will be operated. If a marine mammal or turtle is detected within or near the smaller EZ around that single airgun (Table 1), it will be shut down (see next subsection).

Following a power down, airgun activity will not resume until the marine mammal or turtle has cleared the safety zone. The animal will be considered to have cleared the safety zone if

- it is visually observed to have left the EZ, or
- it has not been seen within the zone for 15 min in the case of small odontocetes (or pinnipeds), or
- it has not been seen within the zone for 30 min in the case of mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, and beaked whales, or
- the vessel has moved outside the EZ for turtles, e.g., if a turtle is sighted close to the vessel and the ship speed is 7.4 km/h, it would take the vessel ~8 min to leave the turtle behind.

During airgun operations following a shut down whose duration has exceeded the time limits specified above, the airgun array will be ramped up gradually. Ramp-up procedures are described below. During past R/V *Langseth* marine geophysical surveys, following an extended power-down period, the seismic source followed ramp-up procedures to return to the full seismic source level. Under a power-down scenario, however, a single mitigation airgun still would be operating to alert and warn animals of the on-going activity. Furthermore, under these circumstances, ramp-up procedures may unnecessarily extend the length of the survey time needed to collect seismic data. LDEO and NSF have discussed this mitigation practice and have concluded that a ramp-up procedure following an extended power down is not necessary, and are currently consulting with NMFS on the issue. This assessment therefore does not include this practice as part of the monitoring and mitigation plan.

Shut-down Procedures

The operating airgun(s) will be shut down if a marine mammal or turtle is seen within or approaching the EZ for the single airgun. Shut downs will be implemented (1) if an animal enters the EZ of the single airgun after a power down has been initiated, or (2) if an animal is initially seen within the EZ of the single airgun when more than one airgun (typically the full array) is operating. Airgun activity will not resume until the marine mammal or turtle has cleared the safety zone, or until the PSO is confident that the animal has left the vicinity of the vessel. Criteria for judging that the animal has cleared the safety zone will be as described in the preceding subsection.

Ramp-up Procedures

A ramp-up procedure will be followed when the airgun array begins operating after a specified period without airgun operations or when a power down has exceeded that period. It is proposed that, for the present survey, this period would be ~8 min. This period is based on the 180-dB radius for the 36-airgun array (940 m) in relation to the average planned speed of the *Langseth* while shooting (7.4 km/h). Similar periods (~8–10 min) were used during previous L-DEO surveys. Ramp up will not occur if a marine mammal or sea turtle has not cleared the safety zone as described earlier.

Ramp up will begin with the smallest airgun in the array (40 in^3). Airguns will be added in a sequence such that the source level of the array will increase in steps not exceeding 6 dB per 5-min period over a total duration of ~35 min. During ramp up, the PSOs will monitor the EZ, and if marine mammals or turtles are sighted, a power down or shut down will be implemented as though the full array were operational.

If the complete EZ has not been visible for at least 30 min prior to the start of operations in either daylight or nighttime, ramp up will not commence unless at least one airgun (40 in^3 or similar) has been operating during the interruption of seismic survey operations. Given these provisions, it is likely that the airgun array will not be ramped up from a complete shut down at night or in thick fog, because the outer part of the safety zone for that array will not be visible during those conditions. If one airgun has operated during a power-down period, ramp up to full power will be permissible at night or in poor visibility, on the assumption that marine mammals and turtles will be alerted to the approaching seismic vessel by the sounds from the single airgun and could move away. Ramp up of the airguns will not be initiated if a sea turtle or marine mammal is sighted within or near the applicable EZs during the day or night.

As noted above under "Power-down Procedures", during past R/V *Langseth* marine geophysical surveys, following an extended power-down period, the seismic source followed ramp-up procedures to return to the full seismic source level. Under a power-down scenario, however, a single mitigation airgun still would be operating to alert and warn animals of the on-going activity. Furthermore, under these circumstances, ramp-up procedures may unnecessarily extend the length of the survey time needed to collect seismic data. LDEO and NSF have discussed this mitigation practice and have concluded that a ramp-up procedure following an extended power down is not necessary, and are currently consulting with NMFS on the issue. This assessment therefore does not include this practice as part of the monitoring and mitigation plan.

XII. Plan of Cooperation

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

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

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

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

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

Not applicable. The proposed activity will take place in the northeast Pacific Ocean, and no activities will take place in or near a traditional Arctic subsistence hunting area.

XIII. Monitoring and Reporting Plan

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

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

L-DEO's proposed Monitoring Plan is described below. L-DEO understands that this Monitoring Plan will be subject to review by NMFS, and that refinements may be required.

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

Vessel-based Visual Monitoring

PSO observations will take place during daytime airgun operations and nighttime start ups of the airguns. Airgun operations will be suspended when marine mammals or turtles are observed within, or about to enter, designated exclusion zones [see § XI above] where there is concern about potential effects on hearing or other physical effects. PSOs will also watch for marine mammals and turtles near the seismic vessel for at least 30 min prior to the planned start of airgun operations. Observations will also be made during daytime periods when the *Langseth* is underway without seismic operations, such as during transits.

During seismic operations, at least four visual PSOs will be based aboard the *Langseth*. PSOs will be appointed by L-DEO with NMFS concurrence. During the majority of seismic operations, two PSOs will monitor for marine mammals and sea turtles around the seismic vessel. Use of two simultaneous observers will increase the effectiveness of detecting animals around the source vessel. However, during meal times, only one PSO may be on duty. PSO(s) will be on duty in shifts of duration no longer than 4 h. Other crew will also be instructed to assist in detecting marine mammals and turtles and implementing mitigation requirements (if practical). Before the start of the seismic survey, the crew will be given additional instruction regarding how to do so.

The *Langseth* is a suitable platform for marine mammal and turtle observations. When stationed on the observation platform, the eye level will be ~21.5 m above sea level, and the observer will have a good view around the entire vessel. During daytime, the PSO(s) will scan the area around the vessel systematically with reticle binoculars (e.g., 7×50 Fujinon), Big-eye binoculars (25×150), and with the naked eye. During darkness, night vision devices (NVDs) will be available (ITT F500 Series Generation 3 binocular-image intensifier or equivalent), when required. Laser rangefinding binoculars (Leica LRF 1200 laser rangefinder or equivalent) will be available to assist with distance estimation. Those are useful in training observers to estimate distances visually, but are generally not useful in measuring distances to animals directly; that is done primarily with the reticles in the binoculars.

Passive Acoustic Monitoring

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

The PAM system consists of hardware (i.e., hydrophones) and software. The "wet end" of the system consists of a towed hydrophone array that is connected to the vessel by a tow cable. The tow cable is 250 m long, and the hydrophones are fitted in the last 10 m of cable. A depth gauge is attached to the free end of the cable, and the cable is typically towed at depths <20 m. The array will be deployed from a winch located on the back deck. A deck cable will connect the tow cable to the electronics unit in the main computer lab where the acoustic station, signal conditioning, and processing system will be located. The acoustic signals received by the hydrophones are amplified, digitized, and then processed by the Pamguard software. The system can detect marine mammal vocalizations at frequencies up to 250 kHz.

One acoustic PSO or PSAO (in addition to the 4 visual PSOs) will be on board. The towed hydrophones will ideally be monitored 24 h per day while at the seismic survey area during airgun operations, and during most periods when the *Langseth* is underway while the airguns are not operating. However, PAM may not be possible if damage occurs to the array or back-up systems during operations. One PSO will monitor the acoustic detection system at any one time, by listening to the signals from two channels via headphones and/or speakers and watching the real-time spectrographic display for frequency ranges produced by cetaceans. The PSAO monitoring the acoustical data will be on shift for 1–6 h at a time. All observers are expected to rotate through the PAM position, although the most experienced with acoustics will be on PAM duty more frequently.

When a vocalization is detected while visual observations are in progress, the PSAO will contact the visual PSO immediately, to alert him/her to the presence of cetaceans (if they have not already been seen), and to allow a power down or shut down to be initiated, if required. The information regarding the call will be entered into a database. The data to be entered include an acoustic encounter identification number, whether it was linked with a visual sighting, date, time when first and last heard and whenever any additional information was recorded, position and water depth when first detected, bearing if determinable, species or species group (e.g., unidentified dolphin, sperm whale), types and nature of sounds heard (e.g., clicks, continuous, sporadic, whistles, creaks, burst pulses, strength of signal, etc.), and any other notable information. The acoustic detection can also be recorded for further analysis.

PSO Data and Documentation

PSOs will record data to estimate the numbers of marine mammals and turtles exposed to various received sound levels and to document apparent disturbance reactions or lack thereof. Data will be used to estimate numbers of animals potentially 'taken' by harassment (as defined in the MMPA). They will also provide information needed to order a power down or shut down of the airguns when a marine mammal or sea turtle is within or near the EZ.

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

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

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

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

Results from the vessel-based observations will provide

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

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

XIV. COORDINATING RESEARCH TO REDUCE AND EVALUATE INCIDENTAL TAKE

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

L-DEO and NSF will coordinate the planned marine mammal monitoring program associated with the seismic survey with other parties that may have interest in this area. L-DEO and NSF will coordinate with applicable U.S. agencies (e.g., NMFS), and will comply with their requirements. One actions of this type that is underway is consulting with Olympic Coast National Marine Sanctuary.

XV. LITERATURE CITED

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