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, August–September 2009

submitted by

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to

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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 Northeast Pacific Ocean (NEPO) during August–September 2009. The survey will take place in the Canadian Endeavour Marine Protected Area (MPA) ~250 km southwest of Vancouver Island, British Columbia, Canada, in water depths ranging from 1200 m to 3000 m. The seismic study will use a towed array of 36 airguns with a total discharge volume of ~6600 in^3, firing at relatively long intervals—once every 250 m (105 s) or 500 m (210 s), depending on location. 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 marine mammals inhabit offshore waters of the NEPO. Several of these species are listed as ***endangered*** under the U.S. Endangered Species Act (ESA), including the humpback, sei, fin, blue, North Pacific right, and sperm whales. Listed sea turtle species that could occur in the study area include the ***endangered*** leatherback and the ***threatened*** green turtles. L-DEO is proposing a monitoring and mitigation program to minimize the impacts of the proposed activity on marine mammals and sea turtles present during conduct of the proposed research, and to document the nature and extent of any effects.

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

Lamont-Doherty Earth Observatory (L-DEO) plans to conduct a seismic survey in the Northeast Pacific Ocean (NEPO; Fig. 1). The Endeavour Tomography (ETOMO) study will take place in the Exclusive Economic Zone (EEZ) of Canada, ~250 km southwest of Vancouver Island, British Columbia (B.C.), within the Endeavour Marine Protected Area (MPA). The survey is scheduled to occur from 17 August–22 September 2009.

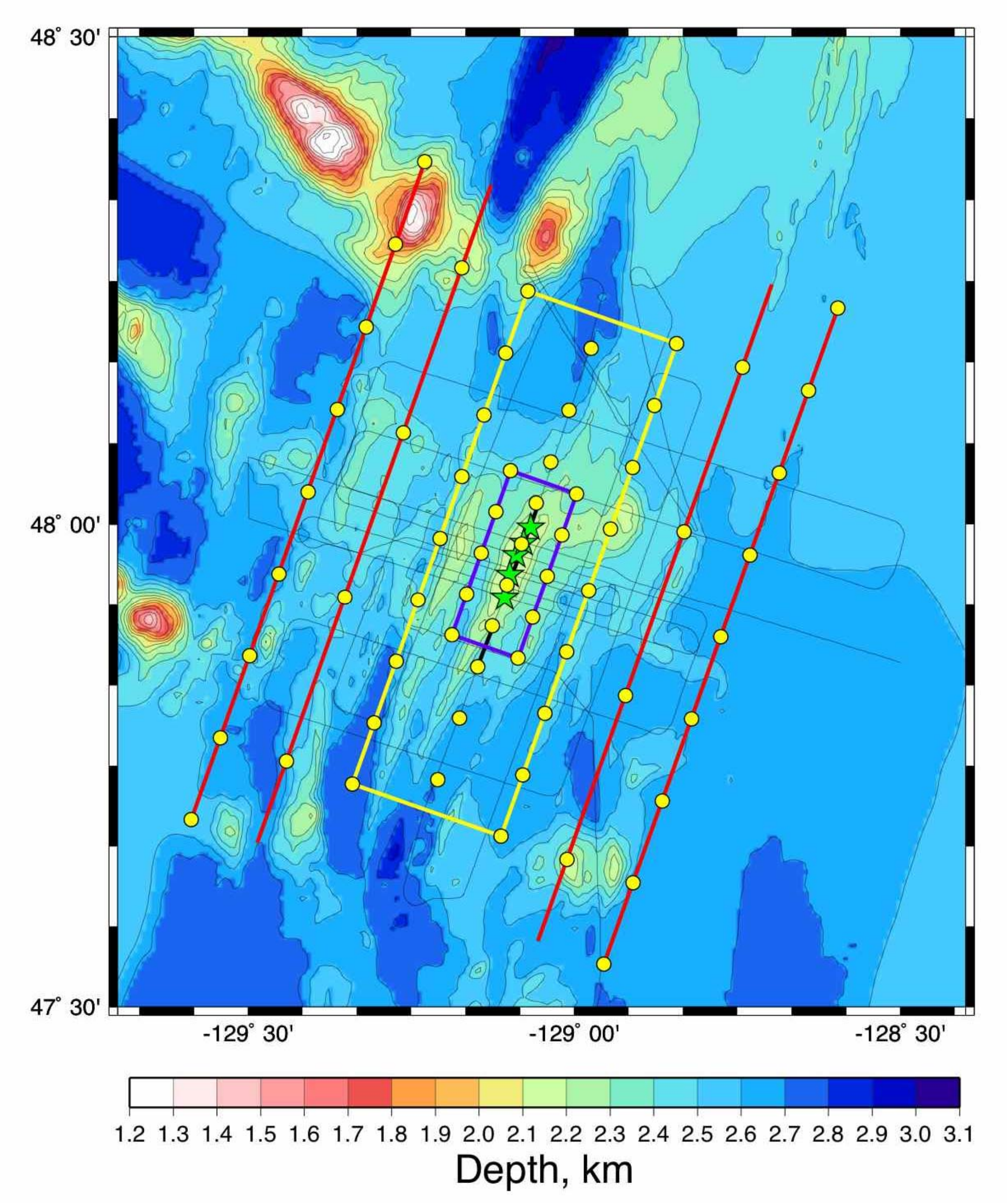

FIGURE 1. Geographic limits of tracklines and Ocean Bottom Seismometer (OBS) deployments for the ETOMO experiment proposed to be conducted along the Endeavour segment of the Juan de Fuca Ridge of the NEPO during August–September 2009. Planned OBS locations are indicated by yellow circles. The Vent Field and Crustal Magma Chamber grids (purple and yellow rectangles, respectively) are centered on the Endeavour hydrothermal system and will contain totals of 17 and 19 survey lines (respectively) oriented NNE–SSW. Four additional planned survey lines (off-axis and rise-parallel) are shown in red. Faint black lines indicate existing multichannel seismic profiles. Stars indicate vent fields. Thick black lines show the approximate location of the Axial Magma Chamber (AMC) reflector. The AMC reflector is a feature that sits ~2 km beneath the seafloor and is a sill filled with magma.

The ETOMO survey will obtain information on the sub-seafloor structure of volcanic and hydrothermal features that form as a result of movements of the Earth's plates. More specifically, the survey will obtain information on the 3-D seismic structure of the crust and top-most mantle along an 80-km-long section of the Endeavour segment of the Juan de Fuca Ridge. This information will define the distribution of magma beneath active volcanoes and the nature of the reaction zone that connects magmatic and hydrothermal systems. Such data will help us to better understand the transfer of energy and mass between the solid earth and the oceans. Past studies using manned submersibles and remotely piloted vehicles have mapped the locations and characteristics of vent fields along this ridge segment. The ETOMO study will extend that mapping beneath the seafloor and allow us to understand the dynamics of these systems. This study will provide information on basic subsurface constraints on the magmatic and hydrothermal processes that lead to the hydrothermal vents which are the focus of the MPA.

The ETOMO study will directly benefit one of the primary science nodes of a cable-linked seafloor observatory in the NEPO, which is being installed by the North-East Pacific Time-series Undersea Networked Experiments (NEPTUNE) Canada (http://www.neptunecanada.ca). More specifically, the information collected will improve knowledge of the regional seismic velocity structure. This information will in turn be used to obtain improved locations of earthquakes. Such information is vital to understanding plate tectonic processes and their effects on earthquake occurrence and distribution. In addition, the information will lead to a better understanding of the Endeavour magmatic and hydrothermal systems, and thus improve interpretations of time-series observations obtained by NEPTUNE Canada in and around the Endeavour vent fields.

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 6–15 m. The receiving system for the returning acoustic signals will consist of 64 Ocean Bottom Seismometers (OBSs) which the *Langseth* will also deploy and retrieve. As the airgun array is towed along the survey lines, the OBSs will receive the returning acoustic signals and record them internally for later analysis. A hydrophone streamer will not be used to receive geophysical data during this survey.

The experiment is designed to image structure along an 80-km-long segment of the Endeavour segment of the Juan de Fuca Ridge (Fig. 1). The principal components of the study are as follows:

***Vent Field Grid (purple box in Fig. 1)*.—**The densest receiver and source spacing is in a 24 x 8 km^2 area centered on the Endeavour vent field. Sixteen OBSs, spaced at intervals of ~4 km, will be positioned both on and near to the axial high and rise parallel survey lines. Seventeen survey lines will be spaced 500 m apart and oriented NNE–SSW; the shot spacing will be every ~250 m. The survey effort in this grid totals 340 line km.

***Crustal Magma Chamber Grid (yellow box in Fig. 1)*.—**The vent field grid will be enclosed by a 60 x 20 km^2 area grid in which 19 rise parallel survey lines oriented NNE–SSW will be spaced 1 km apart. The shot spacing will be ~250 m. The survey effort in this grid totals 1140 line km. Eighteen OBSs will be located on the outer edges of the grid, and an additional four will be located on axis.

***Mantle Tomography and Crustal Thickness Lines (red lines in Fig. 1)*.—**Four refraction lines will be located to either side of the rise axis at distances of 17 and 25 km from the axial high; along these lines the shot spacing will be increased to ~500 m to ensure better signal-to-noise ratio. These lines total 320 km. Along the outermost two lines, 18 OBSs will be located at intervals of 10 km. An additional eight OBSs, spaced at intervals of 20 km, will be located at a distance of 17 km from the ridge.

The planned seismic survey will consist of ~1800 km of survey lines. All survey effort will take place in deep (>1000 m) water. There will be additional operations associated with equipment testing, startup, line changes, and repeat coverage of any areas where initial data quality is sub-standard. In our calculations (see § VII), 25% has been added to the total planned line-length to allow for those additional operations.

In addition to the operations of the airgun array, a multibeam echosounder (MBES) will be operated from the *Langseth* continuously throughout the ETOMO cruise. A sub-bottom profiler (SBP) may also be used at times during the survey.

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 scientific team is headed by Dr. Douglas Toomey of the University of Oregon and also includes Dr. Emilie Hooft, also of the University of Oregon, and Dr. William Wilcock of the University of Washington. The vessel will be self-contained, and the crew will live aboard the vessel for the entire cruise.

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. The *Langseth* will also deploy and retrieve the OBSs. 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 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* can cruise at 20–24 km/h. The *Langseth* has a range of 25,000 km.

The *Langseth* will also serve as the platform from which vessel-based marine mammal (and sea turtle) observers (MMOs) will watch for animals 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:	2925
Accommodation Capacity:	55 including ~35 scientists

Airgun Description

During the survey, a 36-airgun array will be used, 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 distributed across an approximate area of 24×16 m behind the *Langseth* and will be towed ~50–100 m behind the vessel. The airgun array will fire every ~250 m (105

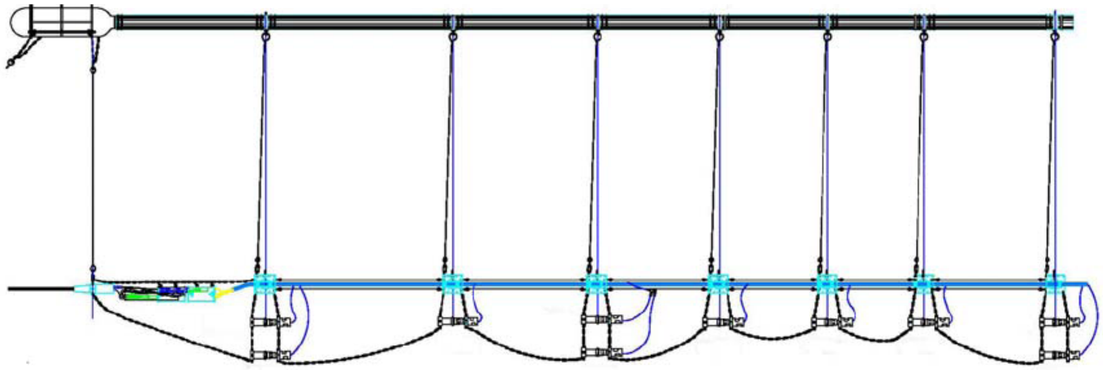

FIGURE 2. One linear airgun array or string with ten airguns, nine of which would be operating.

s) or 500 m (210 s) depending on which grid or line is being surveyed. 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 typically be 15 m, but the depth may be adjusted at times to 6, 9, or 12 m. The depth at which the source is towed (particularly a large source) affects the maximum near-field output and the shape of its frequency spectrum. If the source is towed at 15 m, the effective source level for sound propagating in near-horizontal directions is higher than if the array is towed at shallow depths (see Fig. 3–6). However, the nominal source levels of the array (or the estimates of the sound that would be measured from a theoretical point source emitting the same total energy as the airgun array) at various tow depths are nearly identical.

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.

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 Measurement Units

Received sound levels have been predicted by L-DEO, in relation to distance and direction from the airguns, for the 36-airgun array (Fig. 3–6) and for a single 1900LL 40-in^3 airgun (which will be used during power downs; Fig. 7). The maximum relevant depth shown on the Figures by the straight dashed line is the maximum assumed dive depth for deep-diving marine mammals and is relevant for predicting exclusion zones (EZ) in deep water (see below). A detailed description of the modeling effort is provided in Appendix A of the Environmental Assessment (EA).

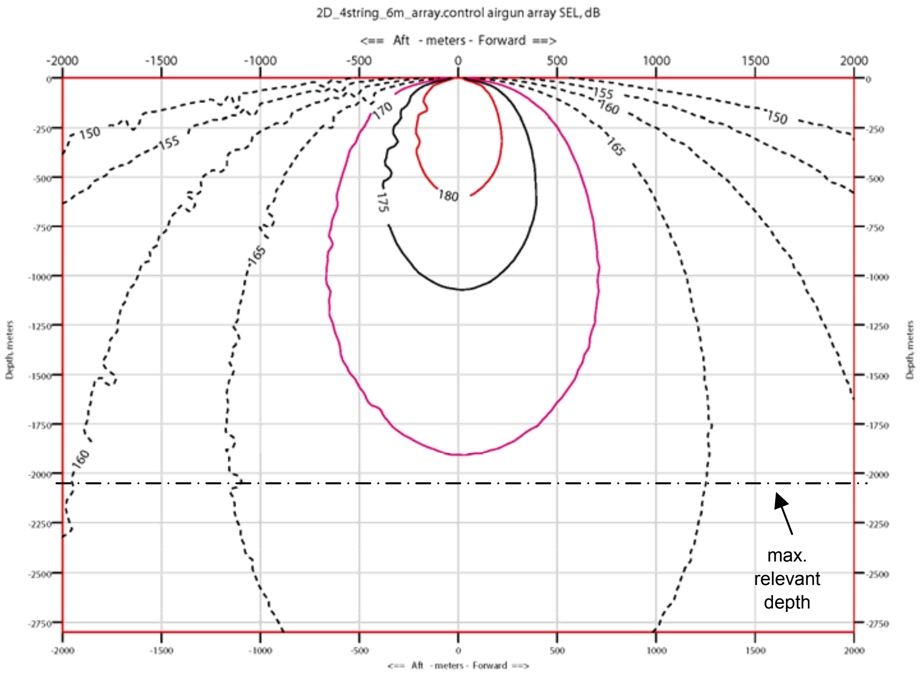

FIGURE 3. Modeled received sound levels (SELs) from the 36-airgun array operating in deep water at a ***6-m*** tow depth, planned for use during the ETOMO survey during 17 August–22 September 2009. Received rms levels (SPLs) are expected to be ~10 dB higher. Maximum relevant depth as applicable to marine mammals.

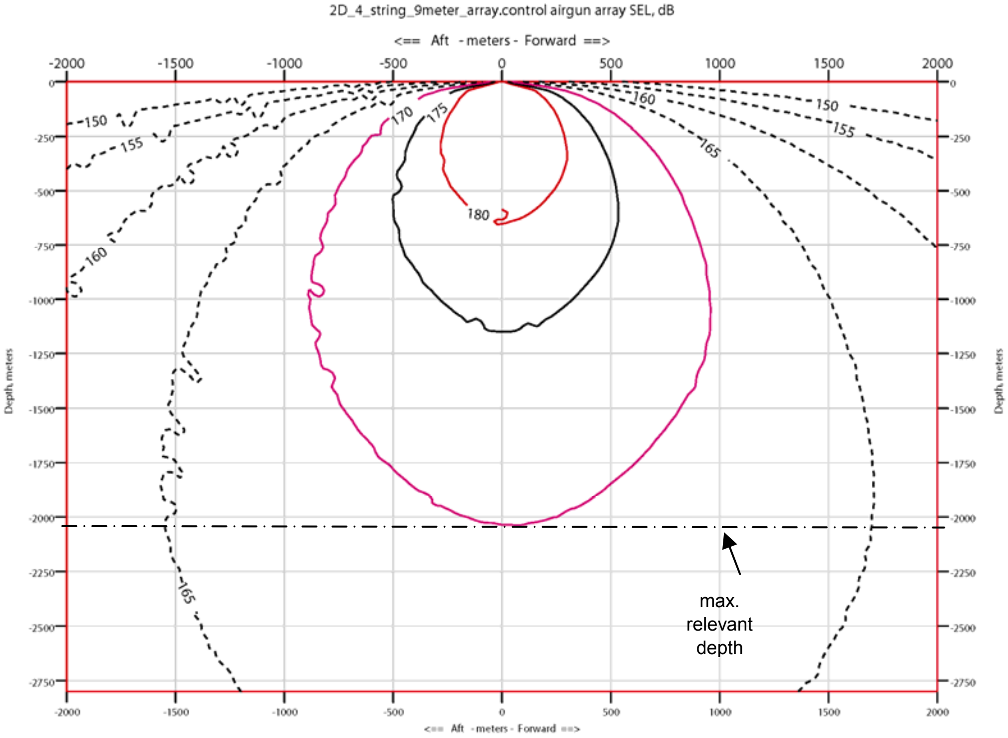

FIGURE 4. Modeled received sound levels (SELs) from the 36-airgun array operating in deep water at a ***9-m*** tow depth, planned for use during the ETOMO survey during 17 August–22 September 2009. Otherwise as above.

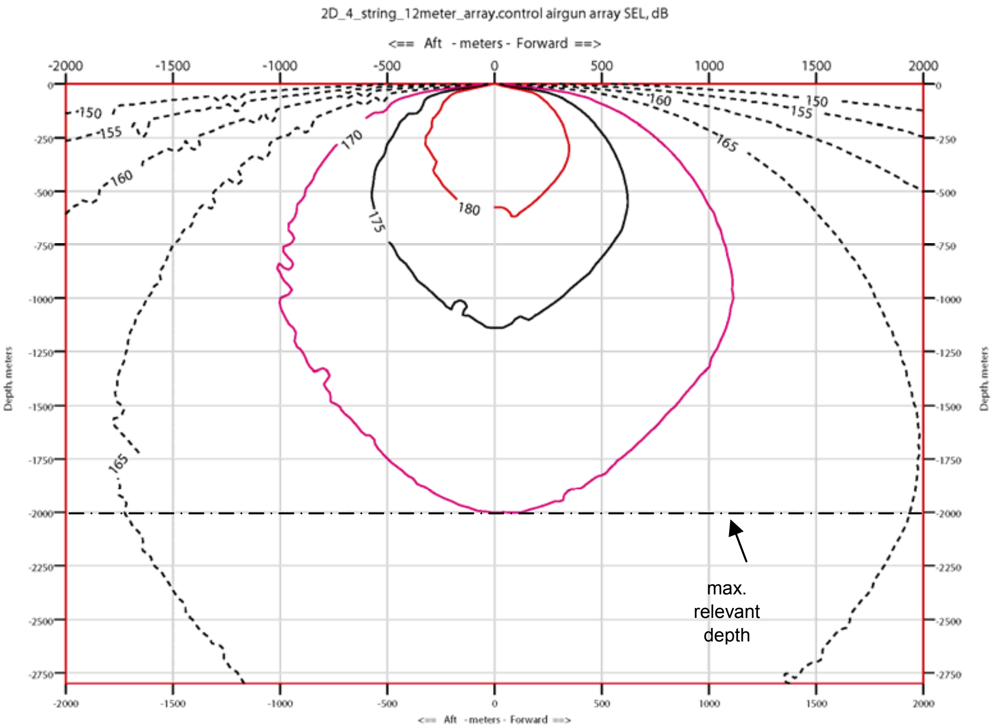

FIGURE 5. Modeled received sound levels (SELs) from the 36-airgun array operating in deep water at a ***12-m*** tow depth, planned for use during the ETOMO survey during 17 August–22 September 2009. Otherwise as above.

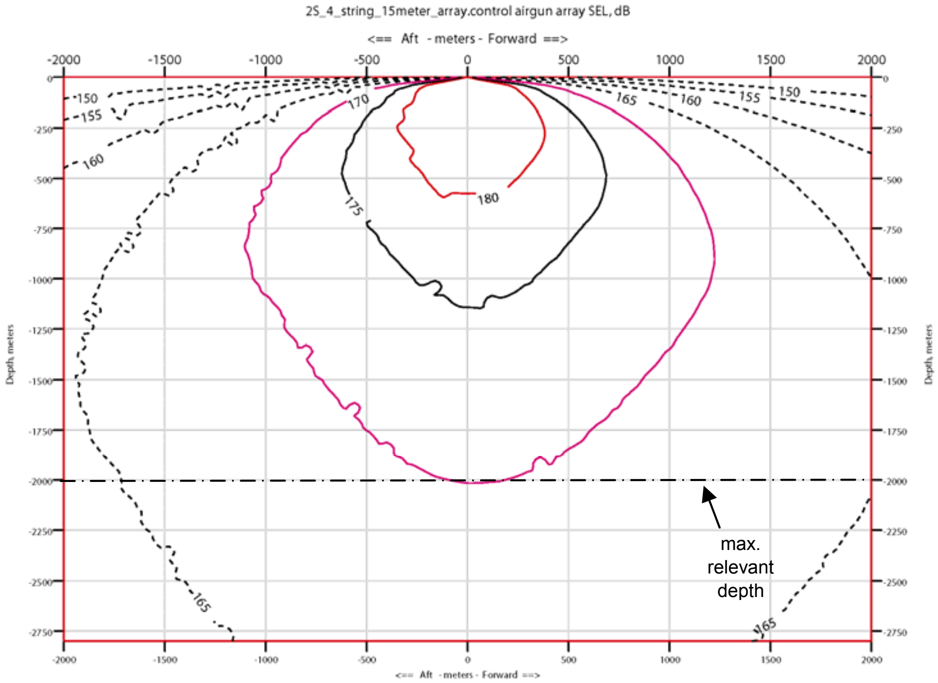

FIGURE 6. Modeled received sound levels (SELs) from the 36-airgun array operating in deep water at a ***15-m*** tow depth, planned for use during the ETOMO survey during 17 August–22 September 2009. Otherwise as above.

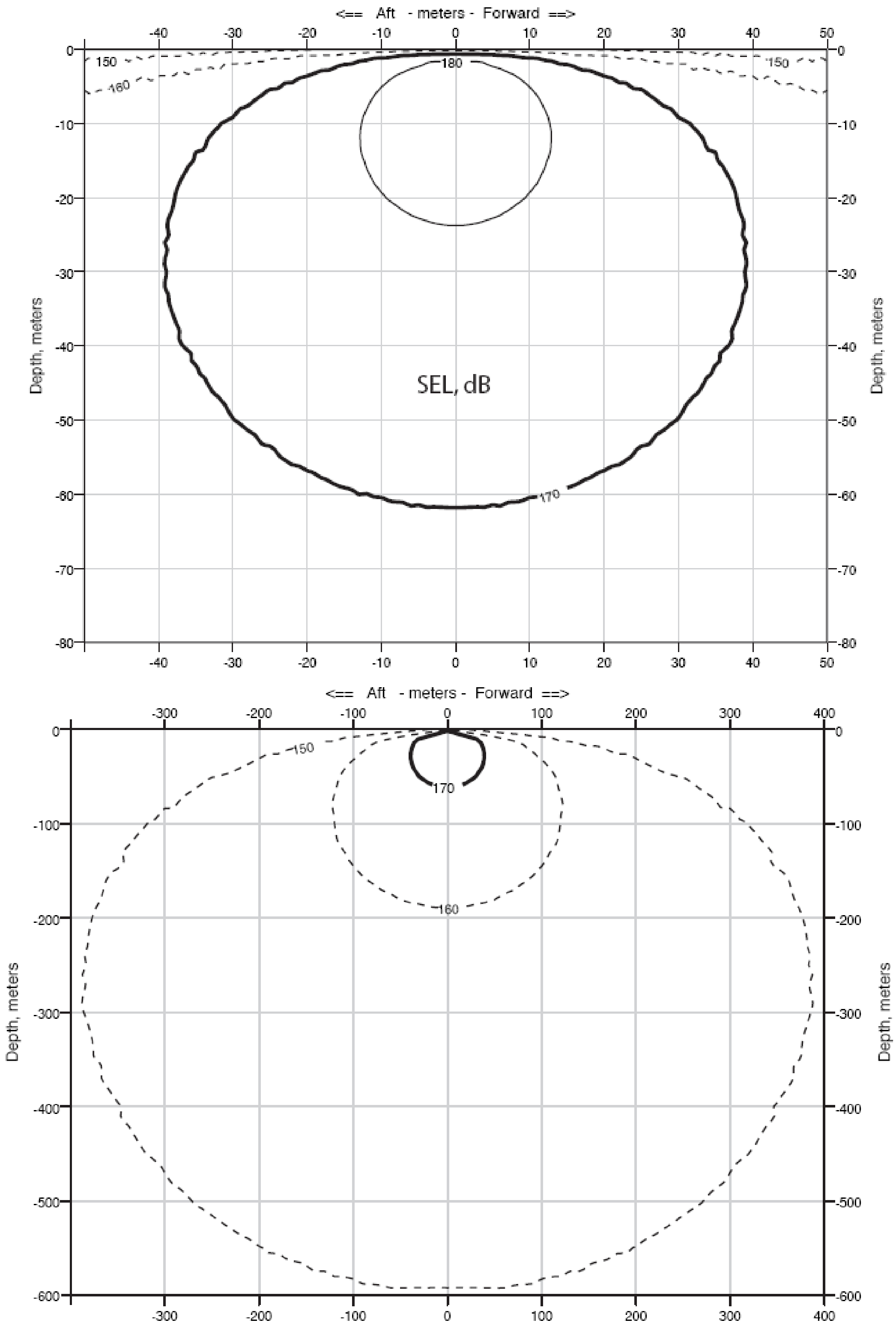

FIGURE 7. Modeled received sound levels (SELs) from a single 40 in^3 airgun operating in deep water at a 9-m tow depth which is planned for use during the ETOMO survey during 17 August–22 September 2009. Received rms levels (SPLs) are expected to be ~10 dB higher.

The predicted sound contours are shown 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 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). Here, 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 would typically 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 • 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 vs. Distance and Depth

Empirical data concerning 180-, 170-, and 160-dB re 1 µPa$_{rms}$ distances were acquired for various airgun configurations during the acoustic calibration study of the R/V *Ewing*'s 20-airgun 8600-in^3 array in 2003 (Tolstoy et al. 2004a,b). The results showed that radii around the airguns where the received level was 160 dB re 1 µPa$_{rms}$ varied with water depth. Similar depth-related variation is likely for the 180-dB and 190-dB re 1 µPa$_{rms}$ safety criteria applied by NMFS (2000) to cetaceans and pinnipeds, respectively, although these were not measured. The empirical data indicated that the L-DEO model (as applied to the *Ewing*'s airgun configurations) overestimated the measured received sound levels at a given distance in deep water (>1000 m deep), and it underestimated the measured levels in shallow water (<100 m deep; Tolstoy et al. 2004a,b).

During the ETOMO study, all survey effort will take place in deep (>1000 m) water. The L-DEO model does not allow for bottom interactions, and thus is most directly applicable to deep water and to relatively short ranges. The modeled distances shown in Figures 3–7 for the planned *Langseth* airgun configuration operating in deep water are summarized in Table 1. As very few, if any, mammals are expected to occur below 2000 m, this depth was used as the maximum relevant depth in determining these distances. The tabulated distances are expected to overestimate the actual distances to the corresponding SPLs, given the deep-water results of Tolstoy et al. (2004a,b).

Table 1 shows the distances at which four rms sound levels are expected to be received from the 36-airgun array and a single airgun operating in water >1000 m in depth. 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 EZ for sea turtles, as required by NMFS during most other recent L-DEO seismic projects. If marine mammals or turtles are detected within or about to enter the appropriate EZ, the airguns will be powered down (or shut down if necessary) immediately.

The conclusion that the model predictions in Table 1 are precautionary, relative to actual 180 and 190 dB (rms) radii, is based on empirical data from the acoustic calibration of different airgun configurations than those used on the *Langseth* (*cf.* Tolstoy et al. 2004a,b); that sound source verification study was done in the northern Gulf of Mexico. L-DEO has recently (late 2007/early 2008) conducted a more extensive acoustic calibration study of the *Langseth*'s 36-airgun (~6600-in^3) array, also in the northern Gulf of Mexico (LGL Ltd. 2006; Holst and Beland 2008). Distances where various sound levels (e.g., 190, 180, 170, and 160 dB re 1 μPa_{rms}) were received are being determined for various airgun configurations and water depths. Those results are not yet available. However, the empirical data from the 2007/2008 calibration study will be used to refine the EZs proposed above for use during the ETOMO cruise, if the data are appropriate and available at the time of the ETOMO survey.

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", EZs, etc., as may be required by any new guidelines that result. However, currently the procedures are based on best practices noted by Pierson et al. (1998) and Weir and Dolman (2007). As yet, NMFS has not specified a new procedure for determining EZs.

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 depth of 6–15 m. The receiving system for the returning acoustic signals will consist of 64 OBSs. As the airgun array is towed along the survey lines, the OBSs will receive the returning acoustic signals. Following recovery of the OBSs, the data will be transferred to the on-board processing system. A hydrophone streamer will not be used to receive geophysical data during this survey.

The planned seismic survey will consist of ~1800 km of survey lines. All survey effort will take place in deep (>1000 m) water. There will be additional operations associated with equipment testing, startup, line changes, and repeat coverage of any areas where initial data quality is sub-standard.

In addition to the operations of the airgun array, a 12-kHz Simrad EM120 MBES will be operated from the *Langseth* continuously throughout the ETOMO cruise. A 3.5-kHz SBP may also be used at times during the survey.

TABLE 1. Predicted distances to which sound levels ≥190, 180, 170 and 160 dB re 1 μPa_{rms} could be received in deep (>1000 m) water from the 36-airgun array, as well as a single airgun, planned for use during the ETOMO survey, 17 August–22 September 2009 (based on L-DEO modeling). Predicted radii are based on Fig. 3–7, assuming that received levels on an RMS basis are, numerically, 10 dB higher than the SEL values shown in Figures 3–7, and that mammals would not typically occur at depths >2000 m.

		Predicted RMS Radii (m)			
Source and Volume	**Tow Depth (m)**	**190 dB**	**180 dB**	**170 dB**	**160 dB**
Single Bolt airgun 40 in^3	6–15*	12	40	120	385
4 strings 36 airguns 6600 in^3	6	220	710	2100	4670
	9	300	950	2900	6000
	12	340	1120	3300	6850
	15	380	1220	3615	7690

* The tow depth has minimal effect on the maximum near-field output and the shape of the frequency spectrum for the single 40 in^3 airgun; thus, the predicted safety radii are essentially the same at each tow depth. The most precautionary distances (i.e., for the deepest tow depth, 15 m) are shown.

OBS Description and Deployment

A total of 64 OBSs will be deployed during the ETOMO study. Sixteen OBSs will be deployed in the vent field grid; the OBSs will be spaced ~4 km apart (Fig. 1). Twenty-two OBSs will be deployed in the Crustal Magma Chamber Grid (Fig. 1), and 26 OBSs will be deployed along the four refraction lines (Fig. 1). OBSs will be spaced 10 km apart on the two outer refraction lines and 20 km apart on the two inner refraction lines.

Two different types of OBSs will be used. The Woods Hole Oceanographic Institution (WHOI) “D2” 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 x 30.5 x 38.1 cm. The other OBS type is the LC4x4. This OBS unit has a volume of ~1 m^3, with an anchor that consists of a large piece of steel grating (~1 m^2). Once the OBS is ready to be retrieved, an acoustic release transponder interrogates the OBS 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.

Multibeam Echosounder

The Simrad EM120 MBES operates at 11.25–12.6 kHz and is hull-mounted on the *Langseth*. The beamwidth is 1° fore–aft and 150° athwartship. The maximum source level is 242 dB re 1 µPa · m (rms). For deep-water operation, each "ping" consists of nine successive fan-shaped transmissions, each 15 ms in duration and each ensonifying a sector that extends 1° fore–aft. The nine successive transmissions span an overall cross-track angular extent of about 150°, with 16 ms gaps between the pulses for successive sectors. A receiver in the overlap area between two sectors would receive two 15-ms pulses separated by a 16-ms gap. In shallower water, the pulse duration is reduced to 5 or 2 ms, and the number of transmit beams is also reduced. The ping interval varies with water depth, from ~5 s at 1000 m to 20 s at 4000 m (Kongsberg Maritime 2005).

Sub-bottom Profiler

The SBP is normally operated to provide information about the sedimentary features and the bottom topography that is being mapped simultaneously by the MBES. The energy from the SBP is directed downward by a 3.5-kHz transducer in the hull of the *Langseth*. The output varies with water depth from 50 watts in shallow water to 800 watts in deep water. The pulse interval is 1 s, but a common mode of operation is to broadcast five pulses at 1-s intervals followed by a 5-s pause.

<u>*Langseth* Sub-bottom Profiler Specifications</u>

Maximum source output (downward)	204 dB re 1 µPa·m; 800 watts
Normal source output (downward)	200 dB re 1 µPa·m; 500 watts
Dominant frequency components	3.5 kHz
Bandwidth	1.0 kHz with pulse duration 4 ms 0.5 kHz with pulse duration 2 ms 0.25 kHz with pulse duration 1 ms
Nominal beam width	30 degrees
Pulse duration	1, 2, or 4 ms

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 ETOMO survey will encompass the area 47°30'–48°30'N, 128°30'–130°W (Fig. 1). Water depths in the survey area range from 1200 to 3000 m. The seismic survey will be conducted in the EEZ of Canada ~250 km off the coast of Vancouver Island, B.C. The project is scheduled to occur 17 August–22 September 2009. Some minor deviation from these dates is possible, depending on logistics and weather.

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-three marine mammal species may occur off the coast of B.C., including 20 odontocetes (toothed cetaceans, such as dolphins), 7 mysticetes (baleen whales), 5 pinnipeds, and the sea otter (Table

2). Six of these species are listed as ***endangered*** under the U.S. Endangered Species Act (ESA), including the humpback, sei, fin, blue, North Pacific right, and sperm whales. The eastern stock of Steller sea lions is listed as ***threatened***, as is the northern sea otter.

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.

The marine mammals that occur in the NEPO belong to four taxonomic groups: odontocetes (toothed cetaceans, such as dolphins), mysticetes (baleen whales), pinnipeds (seals and sea lions), and fissipeds (the sea otter). Cetaceans and pinnipeds are the subject of this Incidental Harassment Authorization (IHA) application. Several of the 33 marine mammal species are common in the area (see below). Three of the 33 species are not expected in the project area because their occurrence off B.C. is limited to very shallow, coastal waters: the gray whale, long-beaked common dolphin, and the sea otter. The sea otter is managed by the U.S. Fish and Wildlife Service (USFWS) rather than by NMFS, and is not discussed further. Three others, the California sea lion, Steller sea lion, and harbor seal, are also mainly coastal, and would be rare at most in the offshore study area. Information on the habitat, abundance, and conservation status of the species that may occur in the study area are given in Table 2. Other vagrant species that theoretically might occur near the study area on rare occasions are not listed in Table 2. Vagrant ringed seals, hooded seals, and ribbon seals have been sighted or stranded on the coast of California (see Reeves et al. 2002) and presumably passed through B.C. waters. A vagrant beluga whale was seen off the coast of Washington (Reeves et al. 2002).

The four species of cetaceans expected to be most common in the deep pelagic waters of the study area are the Pacific white-sided dolphin, northern right whale dolphin, Risso's dolphin, and Dall's porpoise. However, abundances of the Pacific white-sided dolphin and Risso's dolphin are highest in spring (Green et al. 1992, 1993; Buchanan et al. 2001; Barlow 2003).

Mysticetes

North Pacific Right Whale

The North Pacific right whale is listed as ***endangered*** under the ESA, and the North Pacific stock is therefore considered depleted and strategic under the MMPA. It is also listed as ***endangered*** under the Canadian Species at Risk Act (SARA) and by the IUCN. It is considered by NMFS (1991) to be the most endangered baleen whale in the world. Although protected from commercial whaling since 1935, there has been little indication of recovery. The pre-exploitation stock may have exceeded 11,000 animals (NMFS 1991). Wada (1973; see also Braham and Rice 1984) provided an estimate of 100–200 right whales in the North Pacific.

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). Wintering areas are unknown, but have been suggested to include the Hawaiian Islands and the Ryukyu Islands

TABLE 2. The abundance and conservation status of marine mammals in the northeastern Pacific Ocean.

Species	Abundance for North Pacific	U.S. ESA[a]	IUCN[b]	SARA[c]	CITES[d]
Mysticetes North Pacific right whale (*Eubalaena japonica*)	100-200 [e]	EN	EN	EN	I
Gray whale (*Eschrichtius robustus*) *	18,813 [t]	-	LC	SC	I
Humpback whale (*Megaptera novaeangliae*)	>6000 [f]	EN	LC	T	I
Minke whale (*Balaenoptera acutorostrata*)	9000 [g]	-	LC	-	I
Sei whale (*Balaenoptera borealis*)	7260-12,620 [h]	EN	EN	EN	I
Fin whale (*Balaenoptera physalus*)	13,620-18,680 [i]	EN	EN	T	I
Blue whale (*Balaenoptera musculus*)	1186 [j, v]	EN	EN	EN	I
Odontocetes Sperm whale (*Physeter macrocephalus*)	24,000 [k]	EN	VU	-	I
Pygmy sperm whale (*Kogia breviceps*)	-	-	DD	-	II
Dwarf sperm whale (*Kogia sima*)	11,200 [l]	-	DD	-	II
Cuvier's beaked whale (*Ziphius cavirostris*)	20,000 [l]	-	LC	-	II
Baird's beaked whale (*Berardius bairdii*)	6000 [m]	-	DD	-	I
Blainville's beaked whale (*Mesoplodon densirostris*)	603 [j]	-	DD	-	II
Hubb's beaked whale (*Mesoplodon carlhubbsi*)	421 [n]	-	DD	-	II
Stejneger's beaked whale (*Mesoplodon stejnegeri*)	421 [n]	-	DD	-	II
Bottlenose dolphin – offshore ecotype (*Tursiops truncatus*)	3257 [j, v]	-	LC	-	II
Striped dolphin (*Stenella coeruleoalba*)	23,883 [j, v]	-	LC	-	II
Short-beaked common dolphin (*Delphinus delphis*)	487,622 [j,v]	-	LC	-	II
Long-beaked common dolphin * (*Delphinus capensis*)	21,902 [o]	-	LC	-	II
Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)	931,000 [p]	-	LC	-	II
Northern right whale dolphin (*Lissodelphis borealis*)	15,305 [j, v]	-	LC	-	II
Risso's dolphin (*Grampus griseus*)	12,093 [j, v]	-	LC	-	II
False killer whale (*Pseudorca crassidens*)	-	-	DD	-	II
Killer whale (*Orcinus orca*)	8500 [q]	-	DD	SC [r]	II
Short-finned pilot whale (*Globicephala macrorhynchus*)	160,200 [l]	-	DD	-	II
Harbor porpoise (*Phocoena phocoena*) *	202,988 [s, u]	-	LC	SC	II
Dall's porpoise (*Phocoenoides dalli*)	57,549 [j, v]	-	LC	-	II
Pinnipeds Northern fur seal (*Callorhinus ursinus*)	721,935 [t, u]	-	VU	- [w]	-
California sea lion (*Zalophus c. californianus*) *	238,000 [j]	-	LC	-	-
Steller sea lion (*Eumetopias jubatus*) *	48,519–54,989 [t, u] (Eastern stock, U.S.)	T	EN	SC	-
Harbor seal (*Phoca vitulina richardsi*) *	24,732 [j] (OR/WA)	-	LC	-	-
Northern elephant seal (*Mirounga angustirostris*)	124,000 [j] (CA)	-	LC	-	-
Mustelids Sea otter (*Enhydra lutris kenyoni*) *	70,658 [t]	EN	EN	SC	II

'-': Data not available or species status was not assessed (CITES), species not listed (ESA), Not at Risk (COSEWIC), or No Status (SARA).

* Coastal species unlikely to be encountered in the offshore study area.

[a] Endangered Species Act: EN = Endangered, T = Threatened.

[b] Codes for IUCN classifications: EN = Endangered; VU = Vulnerable; LC = Least Concern; DD = Data Deficient. Classifications are from the 2008 IUCN *Red List of Threatened Species* (IUCN 2008).

[c] Species at Risk under SARA based on designations by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2009), but may need to be reassessed; EN = Endangered, T = Threatened, SC = Special Concern.

[d] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2009).

[e] Eastern North Pacific Ocean (Wada 1973).

[f] Calambokidis et al. (1997).

[g] Wada (1976).

[h] Tillman (1977).

[i] Ohsumi and Wada (1974).

[j] Aundance given for U.S., Eastern North Pacific, or California/Oregon/Washington Stock, whichever is included in the 2007. U.S.Pacific Marine Mammal Stock Assessments (Carretta et al. 2007), unless otherwise stated.

[k] Eastern temperate North Pacific (Whitehead 2002).

[l] Eastern Tropical Pacific (Wade and Gerrodette 1993).

[m] Western North Pacific (Reeves and Leatherwood 1994; Kasuya 2002).

[n] Combined estimate for unidentified mesoplodont whales for U.S. west coast (Carretta et al. 2007).

[o] Barlow and Forney (2007).

[p] Buckland et al. (1993).

[q] Combined estimate for Eastern Tropical Pacific (Ford 2002).

[r] Status of offshore killer whale population is *threatened* under COSEWIC and *special concern* under SARA.

[s] Eastern North Pacific Ocean (totals from Carretta et al. 2007 and Angliss and Outlaw 2008).

[t] Angliss and Outlaw (2008).

[u] Numbale
ers are pending revision in the DRAFT 2008 Alaska Stock Assessment Report.

[v] Numbers are pending revision in the DRAFT 2008 Pacific Stock Assessment Report.

[w] Listed as *threatened* by COSEWIC and No Status by SARA.

(Allen 1942; Banfield 1974; Gilmore 1978; Reeves et al. 1978; Herman et al. 1980). In April 1996, a right whale was sighted off Maui, the first documented sighting of a right whale in Hawaiian waters since 1979 (Herman et al. 1980; Rowntree et al. 1980).

Whaling records indicate that right whales in the North Pacific once ranged across the entire North Pacific north of 35ºN and occasionally occurred as far south as 20ºN. However, since the 1960s sightings have been rare (e.g., Clapham et al. 2004; Shelden et al. 2005). Right whales were historically reported off the coast of Oregon, occasionally in large numbers (Scammon 1874; Rice and Fiscus 1968), but extensive shore-based and pelagic commercial whaling operations never took large numbers of the species south of Vancouver Island (Rowlett et al. 1994). Gilmore (1956) even 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).

Since 1996, right whales have been sighted regularly in the Southeast Bering Sea, including calves in some years (Goddard and Rugh 1998; LeDuc et al. 2001; Moore et al. 2000, 2002a; Wade et al. 2006). Right whale sightings and acoustic detections have also been made in the western Gulf of Alaska since 1998 (Waite et al. 2003; Mellinger et al. 2004). However, south of 50ºN in the NEPO, only 29 reliable sightings were recorded from 1900 to 1994 (Scarff 1986, 1991; Carretta et al. 1994). Despite many miles of systematic aerial and ship-based surveys for marine mammals off the coasts of California/Oregon/Washington over the years, only seven documented sightings of right whales were made from 1990 to 2000 (Waite et al. 2003). Three of these sightings involving seven animals were recorded for Washington from 1959 to 1992 (Fiscus and Niggol 1965; Rice and Fiscus 1968; Rowlett et al. 1994).

Between 1908 and 1967, eight right whales were taken in B.C. waters; the number is low because of reduced population size caused by exploitation from the mid 1800s to the early 1900s (Gregr et al.

2000). Right whale sightings have been scarce in B.C.; a right whale sighting was made near the Queen Charlotte Islands in 1970 (Wada 1975 *in* Brownell et al. 2001) and in Juan de Fuca Strait on 28 August 1983 (Reeves and Leatherwood 1985 *in* Brownell et al. 2001).

Based on the very low abundance of this species and its rarity off the B.C. and Washington coasts in recent decades, right whales are very unlikely to be encountered during the proposed project off B.C.

Gray Whale

The eastern gray whale population ranges from the Chukchi and Beaufort seas in summer to the Gulf of California in winter (Rice 1998). It was removed from the U.S. endangered species list in 1994, and is listed as least concern by the IUCN. Under SARA, it is listed as ***special concern***. The current best population estimate is 18,813 (Angliss and Outlaw 2008).

From late May to early October, the majority of the population concentrates in the northern and western Bering Sea and in the Chukchi Sea. However, some individuals spend the summer months scattered along the coasts of southeast Alaska, B.C., Washington, Oregon, and northern California (Rice and Wolman 1971; Nerini 1984; Darling et al. 1998; Dunham and Duffus 2001, 2002; Calambokidis et al. 2002). Rugh et al. (2001) analyzed data collected from two sites in California to estimate the timing of the gray whale southward migration. They estimated that the median date for the migration past various sites was 1 December in the central Bering Sea (a nominal starting point), 12 December at Unimak Pass, 18 December at Kodiak Island, and 5 January for Washington. By January and February, most of the whales are concentrated in the lagoons along the Pacific coast of the Baja Peninsula, Mexico. From late-February to June, the population migrates northward to arctic and subarctic seas (Rice and Wolman 1971).

Gray whales are found primarily in shallow water and are therefore unlikely to be encountered in the offshore study area. Gray whales were scarce during surveys of the inshore coastal waters of B.C., but are common along western Vancouver Island and along the west coast of the Queen Charlotte Islands (Williams and Thomas 2007). Most gray whales follow the coast during migration, staying within 2 km of the shoreline except when crossing major bays, straits, and inlets (Braham 1984). Green et al. (1992) noted that the mean distance of gray whale sightings off Oregon during surveys in 1989/1990 was 9.2 km. despite the fact that the surveys extended much farther offshore. Calambokidis et al. (2002) reported the results of a collaborative study to photo-identify a feeding aggregation of gray whales from California to southeast Alaska in 1998 and noted that feeding gray whales move along the coast and may not be seen in the same area each year.

Humpback Whale

The humpback whale is found in all of the oceans of the world (Clapham 2002). The species is listed as ***endangered*** under the ESA and is therefore considered depleted and strategic under the MMPA. It is listed as ***threatened*** under SARA. Commercial whaling has taken its toll on the humpback whale. Although various stock sizes are increasing over time, total numbers are still well below their pre-exploitation level despite near-complete protection since 1964. The population size of the entire North Pacific humpback whale stock is estimated at more than 6000 (Calambokidis et al. 1997).

Although the humpback whale is considered a mainly coastal species, it often traverses deep pelagic areas while migrating (Clapham and Mattila 1990; Norris et al. 1999; Calambokidis et al. 2001). However, recent acoustic data suggest that some individuals also use offshore areas during periods when they are not expected to be migrating (C.W. Clark cited *in* Baird 2003). Humpback whales are often sighted singly or in groups of two or three, but while in their breeding and feeding ranges, they may occur in groups of up to 15 (Leatherwood and Reeves 1983).

Humpback whale migrations between high-latitude summering grounds and low-latitude wintering grounds are reasonably well known (Winn and Reichley 1985; Calambokidis et al. 2000, 2001). The major wintering areas for the species in the North Pacific are (1) the west coast of Baja California, Gulf of California, mainland Mexican coast from southern Sonora to Jalisco, and around Isla Revillagigedo; (2) the Hawaiian Islands from Kauai to Hawaii; and (3) around the Mariana, Bonin, and Ryukyu Islands and Taiwan (Johnson and Wolman 1984). During summer, most eastern North Pacific humpback whales are on their feeding grounds in Alaska, with smaller numbers summering off the U.S. west coast and B.C. (Calambokidis et al. 2001). Humpback whales reach Vancouver Island in May or June (Calambokidis 1997; Calambokidis et al. 1997, 2000, 2001) and remain in B.C. waters until sometime in October (J. Ford, DFO, pers. comm. 2004). During a recent survey from Oregon to Alaska, humpback whales were seen off the west coast of the Queen Charlotte Islands in mid-September during the northward transit, but were not seen in early October during the southbound transit (Hauser and Holst 2009).

Off the coasts of Oregon/Washington, the humpback whale is the most common species of large cetacean reported 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, 2003). Shifts in seasonal abundance observed off Oregon/Washington suggest north–south movement (Green et al. 1992). They occur primarily over the continental shelf and slope during the summer and fall, with few reported in offshore pelagic waters. In particular, humpbacks tend to concentrate off Oregon along areas associated with upwelling. During extensive systematic aerial surveys conducted up to ~550 km off the coast of Oregon/Washington, only one humpback whale was reported in offshore waters >200 m deep (see Barlow and Forney 2007). Barlow and Forney (2007) estimated the abundance of humpback whales in Oregon/Washington at 231. Green et al. (1992) reported that encounter rates off Oregon/Washington in the summer are highest in slope areas; in the fall, they are highest on the shelf. No sightings were made offshore during the fall, winter, or summer (Green et al. 1992).

In B.C., humpback whales are thought to belong to at least two distinct feeding stocks; those identified off southern B.C. show little interchange with those seen off northern B.C. (Calambokidis et al. 2001; G. Ellis, DFO, pers. comm.. 2004). Humpback whales identified in southern B.C. show only a very low level of interchange with those seen off California/Oregon/Washington (see Calambokidis et al. 1996), and should probably not be considered part of this stock for management purposes (Baird 2003). Those in northern B.C. show some interchange with whales identified in Southeast Alaska that are considered part of the "Central North Pacific" stock. Humpback whales that feed off southern and northern B.C. migrate to several wintering grounds without a clear preference, including Mexico, Hawaii, and Ogasawara off Japan (Darling et al. 1996; Urban et al. 2000; Calambokidis et al. 2001).

Gregr et al. (2000) presented evidence of widespread winter foraging in B.C. based on whaling records, and suggested that pregnant and immature animals would choose to continue foraging rather than travel to the breeding grounds where they would gain little benefit. From 1908 to 1967, 5638 humpback whales were caught off the west coast of B.C.; most whales were taken from 1908 to 1917 (Gregr et al. 2000). Analysis of catch locations and dates showed that male and female humpbacks moved from ~35 km from shore in May to ~15 km from shore in September.

In some coastal areas of B.C. (e.g., the Queen Charlotte Islands) the humpback is the most frequently reported baleen whale (Ford et al. 1994). Off southern B.C. and northern Washington, 192 humpback whales were photographically identified from 1989 to 2002 (Calambokidis et al. 2004a). Off northern B.C., where analysis of a long-term dataset is still underway, over 500 different individuals were identified from 1989 to 2001 (see Baird 2003). Williams and Thomas (2007) estimated an abundance of 1310 humpback whales in the coastal waters of B.C. However, it is unlikely that humpback whales will be encountered in the offshore study area.

Minke Whale

The minke whale is not listed under SARA or the ESA and is classified as least concern by the IUCN. The minke whale inhabits all oceans of the world from high latitudes to near the equator (Leatherwood et al. 1982). In the Pacific, it is usually seen over continental shelves, but it is not considered abundant in the NEPO (Brueggeman et al. 1990). In the NEPO, minke whales range from the Chukchi Sea in summer to within 2º of the equator in winter (Perrin and Brownell 2002). In the far north, minke whales are thought to be migratory, but off the U.S. west coast, they are believed to be resident year-round (Dorsey et al. 1990).

In the Northern Hemisphere, minke whales are 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). Minke whales are relatively solitary, but may occur in aggregations of up to 100 when food resources are concentrated. 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).

The current best estimate of the population size for California/Oregon/Washington is 898 (Carretta et al. 2007). Barlow (2003) estimated 1015 for the U.S. west coast, and 411 and 127 animals for only Oregon/Washington in 1996 and 2001, respectively. Barlow and Forney (2007) noted an abundance of 211 minke whales in Oregon/Washington. Minke whales are sighted regularly in nearshore areas of B.C., but they are not abundant. Their estimated abundance in coastal waters of B.C. is 388 (Williams and Thomas 2007). A total of 30 recognizable individuals have been identified over a ten year period in the waters around the San Juan Islands (Calambokidis and Baird 1994).

Sei Whale

The sei whale has a cosmopolitan distribution, with a marked preference for temperate oceanic waters (Gambell 1985a). It is listed as ***endangered*** under the ESA, and the North Pacific stock is therefore considered depleted and strategic under the MMPA. It is also listed as ***endangered*** under SARA and by the IUCN. Sei whale populations were depleted by whaling, and their current status is generally uncertain (Horwood 1987). The global population is thought to be ~80,000 (Horwood 2002).

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 canyons or basins situated between banks and ledges (DoN 2007). The sei whale usually occurs in groups of up to six, and larger groups sometimes form on feeding grounds (Gambell 1985a). Its blow is not as high as those of blue and fin whales, and it tends to make only shallow dives and surfaces relatively frequently.

In the open ocean, sei whales generally migrate from temperate zones occupied in winter to higher latitudes in the summer, where most feeding takes place (Gambell 1985a). In the NEPO, sei whales range in the summer from the Bering Sea and the northern Gulf of Alaska to the coast of southern California. Winter sightings have been made between southern Baja California and the Islas Revillagigedo (Rice 1998).

Off the U.S. west coast, sei whales are rare (Brueggeman et al. 1990; Green et al. 1992; Barlow 1997; Forney et al. 1995). Barlow and Forney (2007) estimated the abundance of sei whales in Oregon/ Washington at 37 whales and in California at 61 whales. There had been no recent confirmed sei whale sightings off B.C. in recent years (Gregr et al. 2006) until a single sei whale was seen in Queen Charlotte Basin during coastal surveys in the summers of 2004/2005 (Williams and Thomas (2007)

Off the west coast of B.C., 4002 sei whales were caught from 1908 to 1967; the majority were taken from April to June and from 1960 to 1967. The pattern of seasonal abundance suggested that the whales were caught as they migrated to summer feeding grounds, with the peak of the migration in July and offshore movement in summer, from ~25 km to ~100 km from shore. Historical whaling data showed that sei whales used to be distributed along the continental slope of B.C. and over a large area off the northwest coast of Vancouver Island (Gregr and Trites 2001).

Fin Whale

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. 1999). It is listed as ***endangered*** under the ESA, and the Northeast Pacific stock is therefore considered depleted and strategic under the MMPA. It also listed as ***endangered*** by the IUCN and as ***threatened*** under SARA. Probably at least in part because of their initially high abundance, wide distribution, and diverse feeding habits, fin whales seem not to have been as badly depleted as the other large whales in the North Pacific.

Fin whales occur in coastal, shelf, and oceanic waters. Sergeant (1977) proposed 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. Fin whales are typically observed alone or in pairs, but on feeding grounds, up to 20 individuals can occur together (Gambell 1985b).

Fin whales mate and calve in temperate waters during the winter, and migrate to northern latitudes during the summer to feed (Mackintosh 1965 *in* Gambell 1985b). The North Pacific population summers from the Chukchi Sea to California, and winters from California southwards (Gambell 1985b). The most recent abundance estimate for California/Oregon/Washington is 3454 fin whales (Carretta et al. 2007). Barlow and Forney (2007) estimated an abundance of 299 in Oregon/Washington. Aggregations of fin whales are found year-round off southern and central California (Dohl et al. 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/Washington (Moore et al. 1998).

From 1908 to 1967, 7605 fin whales were caught off the west coast of B.C. Catches increased gradually from March to a peak in July, then decreased rapidly to very few in September and October (Gregr et al. 2000). Fin whales occurred mostly offshore, but frequently entered exposed coastal seas such as Hecate Strait and Queen Charlotte Sound (Gregr et al. 2000). Sightings are still made in Queen Charlotte Sound (Gregr and Trites 2001; Calambokidis et al. 2003; Williams and Thomas 2007). Williams and Thomas (2007) estimated fin whale abundance in coastal B.C. waters at 496. Fin whales in B.C. likely feed on euphausiids but also on copepods and fish (Flinn et al. 2002).

Blue Whale

The blue whale is widely distributed throughout most of the world's oceans, occurring in pelagic, continental shelf, and inshore waters (Leatherwood and Reeves 1983). It is listed as ***endangered*** under the ESA, and the North Pacific stock is therefore considered depleted and strategic under the MMPA. It is listed as ***endangered*** under SARA and by the IUCN. All blue whale populations have been exploited commercially, and many have been severely depleted as a result. The worldwide population has been estimated at 15,000, with 10,000 in the Southern Hemisphere (Gambell 1976), 3500 in the North Pacific, and up to 1400 in the North Atlantic (NMFS 1998). Blue whale calls monitored from the U.S. Navy Sound Surveillance System (SOSUS) and other offshore hydrophones suggest that separate populations occur in the eastern and western North Pacific (Stafford et al. 1999a, 2001, 2007; Watkins et al. 2000a; Stafford 2003).

Blue whales usually occur alone or in small groups (Leatherwood and Reeves 1983; Palacios 1999). Generally, blue whales are seasonal migrants between high latitudes in the summer, where they feed, and low latitudes in winter, where they mate and give birth (Lockyer and Brown 1981). Broad-scale acoustic monitoring indicates that blue whales of the North Pacific stock may range from the Eastern Tropical Pacific along the coast of North America to Canada, and offshore at least 500 km (Stafford et al. 1999b, 2001). Some individuals may stay in low or high latitudes throughout the year (Reilly and Thayer 1990; Watkins et al. 2000b). Moore et al. (2002b) reported that blue whale calls are received in the North Pacific year-round.

Blue whales 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 (Buchanan et al. 2001). Barlow (2003) estimated an abundance of 1736 blue whales in California/Oregon/Washington, based on data collected in 1996 and 2001, but only up to 101 animals in Oregon/Washington. Carretta et al. (2007) noted the best estimate of abundance off California/Oregon/Washington as 1186, and Barlow and Forney (2007) gave an estimate of 63 blue whales for Oregon/Washington.

From 1908 to 1967, 1398 blue whales were caught off the west coast of B.C., mostly before 1915 because they were the most lucrative to catch. Historical whaling records indicate that 33% of blue whales caught were over the outer part of the continental shelf in waters deeper than 200 m (Gregr 2002). The historical whaling records showed a summer migration of blue whales past Vancouver Island; the eastern Gulf of Alaska stock may have used southeast Alaska and northern B.C. as a feeding ground (Gregr et al. 2000; Gregr 2002).

Rice (1974 *in* Mansfield 1985) suggested that the blue whales off the coast of B.C. migrate from Baja, Mexico, arriving in June, and are also present in September on their return migration from feeding grounds in Alaska. Blue whales off B.C. are usually found well offshore (Pike and MacAskie 1969). They have been seen only rarely in recent years off B.C. or adjacent waters of Washington or southeastern Alaska. One blue whale was seen off the Queen Charlotte Islands on 7 August 2003 and was resighted several times off California (Calambokidis et al. 2004b). Another blue whale was seen on 12 June 1997 and was also resighted off California (Calambokidis et al. 2004b). There have also been a few isolated reports of blue whales sighted off southern Vancouver Island in summer months, and one blue whale was seen off Cape Scott, north Vancouver Island, on 1 October 2001. Acoustic recordings have been made of blue whales to the north of the Queen Charlotte Islands, and blue whales were regularly detected on bottom-mounted hydrophones deployed off B.C. and in the Gulf of Alaska (Sears and Calambokidis 2002). Williams and Thomas (2007) did not report any sightings of blue whales during their coastal surveys in 2004/2005.

Odontocetes

Sperm Whale

The sperm whale is the largest of the toothed whales, with an extensive worldwide distribution (Rice 1989). This species is listed as ***endangered*** under the ESA, and the North Pacific stock is, therefore, considered depleted and strategic under the MMPA, but on a worldwide basis it is abundant and not biologically endangered. It is listed as ***vulnerable*** by the IUCN, but is not listed under SARA. There is one estimate of abundance for the eastern temperate North Pacific, which is 24,000 (Whitehead 2003), while it is estimated that 2265 may be found off the U.S. west coast (Carretta et al. 2007).

Adult female and juvenile sperm whales generally occur in tropical and subtropical waters, in groups averaging 20–30 individuals (Whitehead 2003). Older males are commonly alone or in same-sex aggregations, often occurring in higher latitudes outside of the breeding season (Best 1979; Watkins and Moore 1982; Arnbom and Whitehead 1989; Whitehead and Waters 1990).

Sperm whales generally are distributed over large temperate and tropical areas that have high secondary productivity and steep underwater topography, such as volcanic islands (Jacquet and Whitehead 1996); their distribution and relative abundance can vary in response to prey availability, most notably squid (Jacquet and Gendron 2002). Sperm whales undertake some of the longest- and deepest-known dives among cetaceans. They can dive as deep as ~2 km and possibly deeper on rare occasions, for periods of over 1 h (Tyack et al. 2006, p. 4246); however, most of their foraging occurs at depths of ~300–800 m for 30–45 min (Whitehead 2003).

Off Oregon, they are seen in every season except winter (Green et al. 1992). During surveys off Oregon/Washington, 90% of sperm whales were seen in deeper offshore waters and the remainder occurred in slope waters (Green et al. 1992). Barlow and Taylor (2001) estimated sperm whale abundance off California/Oregon/Washington at 1407. Based on surveys conducted in 1996 and 2001, Barlow (2003) estimated the same population at 1233. For just Oregon/Washington waters, Barlow and Forney (2007) gave an abundance estimate of 448.

From 1908 to 1967, 6158 sperm whales were caught off the west coast of B.C. They were taken in large numbers in April, with a peak in May. Analysis of data on catch locations, sex of the catch, and fetus lengths indicated that males and females were both 50–80 km from shore while mating in April and May, and that by July and August, adult females had moved to waters >100 km offshore to calve (the gestation period is ~16 months), and adult males had moved to within ~25 km of shore (Gregr et al. 2000). At least in the whaling era, females did not travel north of Vancouver Island whereas males were observed in deep water off the Queen Charlotte Islands (Gregr et al. 2000). The present distribution and abundance of sperm whales in the study area is unknown. A few recent sightings west of Vancouver Island and the Queen Charlotte Islands indicate that this species still occurs in B.C. in small numbers (J. Ford unpubl. data; K. Morgan unpubl. data). Williams and Thomas (2007) did not report any sperm whales sightings during surveys of the coastal inshore waters of B.C.

Pygmy and Dwarf Sperm Whale

These two species of small whales are distributed widely in the world's oceans, generally in tropical and warm-temperate waters, but they are poorly known (Caldwell and Caldwell 1989). Neither of the species is listed under the ESA or SARA. Their small size, non-gregarious nature, and cryptic behavior make pygmy and dwarf sperm whales difficult to observe. The two species are also difficult to distinguish when sighted at sea, and are often jointly categorized as *Kogia* spp.

Strandings of pygmy sperm whales in the NEPO have been concentrated during autumn and winter (Eliason and Houck 1986) suggesting seasonal movements. Strandings of pygmy sperm whales have been recorded for California/Oregon/Washington (Caldwell and Caldwell 1989), and there are several unconfirmed sighting reports of the pygmy sperm whale from the Canadian west coast (Baird et al. 1996). There is only a single dwarf sperm whale stranding record for Vancouver Island; it was reported in 1983

(Willis and Baird 1998). However, Willis and Baird (1998) state that this species is likely found in B.C. waters more frequently than recognized. 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. 1993; Carwardine 1995). Barlow and Forney (2007) noted an abundance estimate of 397 *Kogia* spp. off Oregon/Washington.

Baird's Beaked Whale

Baird's beaked whale has a fairly extensive range across the North Pacific north of 30°N, and strandings have occurred as far north as the Pribilof Islands (Rice 1986). There is no immediate concern for the survival of the species (Reeves and Mitchell 1993). This species is not listed under the ESA or SARA.

It is estimated that 6000 Baird's beaked whales inhabit the western North Pacific (Reeves and Leatherwood 1994; Kasuya 2002). Concentrations are thought to occur in the Sea of Okhotsk and Bering Sea (Rice 1998; Kasuya 2002). In the eastern Pacific, Baird's beaked whales are reported to occur as far south as San Clemente Island, California (Rice 1998; Kasuya 2002). This species is divided into three distinct stocks: Sea of Japan, Okhotsk Sea, and Bering Sea/eastern North Pacific (Balcomb 1989; Reyes 1991). Any animals in or near the study area would be expected to come from the last of those stocks.

Baird's beaked whales sometimes are seen close to shore, but their primary habitat is over or near the continental slope and oceanic seamounts in waters 1000–3000 m deep (Jefferson et al. 1993; Kasuya and Ohsumi 1984). They can stay submerged for up to 67 min, although most (66%) dives are <20 min long, and time at the surface is 1–14 min (Kasuya 2002). Baird's beaked whales travel in groups of a few to several dozen (Balcomb 1989); Wade et al. (2003) reported a mean group size of 10.8.

Information gathered from sightings on both sides of the North Pacific indicates that Baird's beaked whales are present over the continental slope in summer and autumn, when water temperatures are highest. The whales move out from those areas in winter (Reyes 1991). In the 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. Barlow and Forney (2007) provided an abundance estimate of 520 for Oregon/Washington. There are whaler's reports of Baird's beaked whales off the west coast of Vancouver Island throughout the whaling season (May–September), especially in July and August (Reeves and Mitchell 1993). From 1908 to 1967, there was a recorded catch of 41 Baird's beaked whales, which were not favored because of their small size and low commercial value (Gregr et al. 2000).

Cuvier's Beaked Whale

Cuvier's beaked whale is probably the most widespread of the beaked whales, although it is not found in polar waters (Heyning 1989). The species is not listed under the ESA or SARA. There are an estimated 20,000 Cuvier's beaked whales in the eastern Tropical Pacific (Wade and Gerrodette 1993).

Cuvier's beaked whale is a deep-sea species that prefers slope waters with steep depth gradients and is seldom found near the coast, although it is rarely observed at sea and is mostly known from strandings. Cuvier's beaked whale 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 Gisner 2006). Adult males of this species usually travel alone, but these whales can be seen in groups of up to 15 individuals, with a mean group size of 2.3 (MacLeod and D'Amico 2006). Cuvier's beaked whales make long and deep dives (30–60 min or more) to find prey, with maximum depths as great as 1450 m (Baird et al. 2006) and 1888 m (Tyack et al. 2006). The latter authors reported the average duration of deep foraging dives (*n* = 28) was 58 min, to an average depth of 1070 m (*n* = 28).

Cuvier's beaked whale is the most common beaked whale off the U.S. west coast (Carretta et al. 2007). The most recent abundance estimate off the U.S. west coast is 2171 (Carretta et al. 2007), though past estimates for Califormia/Oregon/Washington were 5870 (Barlow 1997) and 1884 (Barlow 2003). No Cuvier's beaked whales were seen during the Oregon/Washington portions of surveys in 1996–2005 (Barlow 2003; Barlow and Forney 2007), but several were seen there from 1991 to 1995 (Barlow 1997). Records of Cuvier's beaked whale in B.C. are scarce, although at least 18 strandings, one sighting and one incidental catch have been reported (Willis and Baird 1998).

Mesoplodon spp.

Three species of *Mesoplodon* could occur off the coast of Vancouver Island: Blainville's beaked whale *M. densirostris*, Stejneger's beaked whale *M. stejnegeri*, and Hubb's beaked whale *M. carlhubbsi*. None of these are listed by the ESA or SARA.

Mesoplodonts are difficult to distinguish in the field. Off the west coast of the U.S., the most recent estimate is of 421 unidentified mesoplodont whales (Carretta et al. 2007). Previous estimates included 3738 off California/Oregon/Washington (Barlow 1997). Barlow and Forney (2007) noted an abundance estimate of 435 for Oregon/Washington.

Blainville's beaked whale is the *Mesoplodon* species with the widest distribution throughout the world (Mead 1989), although it is generally limited to tropical and warmer temperate waters (Leatherwood and Reeves 1983). It is mainly a pelagic species, and like other beaked whales, is generally found in deep slope waters ~500–1000 m deep (Davis et al. 1998; Reeves et al. 2002). However, it may also occur in coastal areas, particularly where deep water gullies come close to shore. Occasional occurrences in cooler higher-latitude waters are presumably related to warm-water incursions (Reeves et al. 2002). Tyack et al. (2006) reported that deep foraging dives (*n* = 16) of tagged Blainville's beaked whales lasted an average of 46.5 min to an average depth of 835 m (range 640–1251 m).

Blainville's beaked whale distribution is mainly derived from stranding data. Most strandings involved single individuals, although groups of 3–7 were observed in tropical waters (Jefferson et al. 1993). There are very few records for the North Pacific (Mead 1989), and the farthest north are from Japan and California (Reeves et al. 2002). The most recent abundance estimate off the U.S. west coast is 603 (Carretta et al. 2007), compared to a previous Blainville's beaked whale estimate of 360 (Barlow 1997). Although there appear to be no records for this beaked whale species for B.C., the offshore study area is not very far north of this species' known range.

Stejneger's beaked whale occurs in subarctic and cool temperate waters of the North Pacific (Mead 1989). In the NEPO, it is distributed from Alaska to southern California (Mead et al. 1982; Mead 1989). At least five stranding records exist for B.C. (Houston 1990a; Willis and Baird 1998). However, most records are from Alaskan waters, and the Aleutian Islands appear to be its center of distribution (Mead 1989). The species typically occurs in groups of 3–4, ranging to ~15 (Reeves et al. 2002).

Hubb's beaked whale occurs in temperate waters of the North Pacific (Mead 1989). Most of the stranding records are from California, but at least seven strandings have been recorded along the B.C. coast as far north as Prince Rupert (Houston 1990b; Willis and Baird 1998). Its distribution appears to be correlated with the deep subarctic current (Mead et al. 1982).

Bottlenose Dolphin

The bottlenose dolphin is distributed worldwide and is considered possibly the most adaptable species of cetacean, inhabiting a wide range of habitat types (Reeves et al. 2002). It is not listed under the ESA or SARA. There are two distinct types: a shallow-water type mainly found in coastal waters, and a deep-water type mainly found in oceanic waters (Duffield et al. 1983; Walker et al. 1999).

Offshore bottlenose dolphins occur frequently off the coast of California, and sightings have been made as far north as 41ºN (Carretta et al. 2007). It is possible that offshore bottlenose dolphins could be encountered even further north during warm-water periods, although none have been reported in waters off Oregon or Washington (see Carretta et al. 2007). The most recent abundance estimate for offshore bottlenose dolphins off Califormia/Oregon/Washington is 3257 (Carretta et al. 2007). There are no confirmed records of bottlenose dolphins for B.C., although an unconfirmed record exists for offshore B.C. (Baird et al. 1993b), northwest of the proposed study area.

Pacific White-sided Dolphin

The Pacific white-sided dolphin is found throughout the temperate North Pacific, in a relatively narrow distribution between 38°N and 47°N (Brownell et al. 1999). It is not listed under the ESA or SARA. Buckland et al. (1993) estimated that there were a total of 931,000 Pacific white-sided dolphins, rangewide, from surveys conducted in the North Pacific. Two stocks have been identified off North America: the North Pacific and the California/Oregon/Washington stock (Angliss and Lodge 2002). The most recent abundance estimate for the latter stock is 25,233 Pacific white-sided dolphins (Carretta et al. 2007).

The species is common both on the high seas and along the continental margins, and animals are known to enter the inshore passes of southeast Alaska, B.C., and Washington (Leatherwood et al. 1984; Dahlheim and Towell 1994; Ferrero and Walker 1996). Pacific white-sided dolphins often associate with other species, including cetaceans (especially Risso’s and northern right whale dolphins; Green et al. 1993), pinnipeds, and seabirds. Pacific white-sided dolphins are very inquisitive and may approach stationary boats (Carwardine 1995).

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 entire coast of California are an order of magnitude higher in February–April than in August–November, whereas the highest abundance estimates off Oregon/Washington are in April–May.

Extensive year-round aerial surveys off Oregon/Washington conducted by Green et al. (1992, 1993) found that the Pacific white-sided dolphin was the most abundant cetacean species, with nearly all (97%) sightings occurring in May. Off Oregon/Washington, highest encounter rates occured in slope areas. In offshore areas, encounter rates were highest during the spring, followed by summer, and then fall (Green et al. 1992). Barlow (2003) also found that the Pacific white-sided dolphin was the most abundant marine mammal species off Oregon/Washington. Barlow and Forney (2007) estimated that there are 7998 Pacific white-sided dolphins off Oregon/Washington.

There are frequent sightings of large pods Pacific white-sided dolphins in B.C. Stacey and Baird (1991a) compiled 156 published and unpublished records to 1988 of the Pacific white-sided dolphin within the Canadian 320-km extended economic zone. There were inshore records for all months except July, and offshore records from all months except December. These dolphins move inshore and offshore seasonally (Stacey and Baird 1991a). Offshore sightings were much more common than inshore sightings, especially in June–October; mean water depth was ~1100 m. Group sizes ranged from 1 to 1000, with a mean of 62 (Stacey and Baird 1991a). During a recent survey from Oregon to Alaska, Pacific white-sided dolphins were seen west of the Queen Charlotte Islands in mid-September during the northbound transit and in early October during the southbound transit (Hauser and Holst 2009). All sightings were made in water deeper than 1000 m, and group sizes ranged from 1 to 25 (Hauser and Holst 2009). There are an estimated 25,900 Pacific white-sided dolphins in inshore coastal B.C. waters (Williams and Thomas 2007). Pacific white-sided dolphins are by-caught by commercial inshore fisheries in B.C. (Stacey et al. 1997; Williams et al. 2008).

Northern Right Whale Dolphin

The northern right whale dolphin is found in cool temperate and sub-arctic waters of the North Pacific, from the Gulf of Alaska to waters off northern Baja California, ranging from 30°N to 50°N (Reeves et al. 2002). This species is not listed under the ESA or SARA. In the 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; Barlow 2003; Carretta et al. 2007). The northern right whale dolphin does, however, come closer to shore where there is deep water, such as over submarine canyons (Carwardine 1995; Reeves et al. 2002).

Northern right whale dolphins are gregarious, and groups of several hundred to over a thousand dolphins are not uncommon (Reeves et al. 2002). They are often seen in mixed-species schools with Pacific white-sided dolphins. As in the case of the Pacific white-sided dolphin, aerial and shipboard surveys suggest seasonal inshore–offshore and north–south movements in the North Pacific Ocean between California and Oregon/Washington. The movements are believed to be related to oceanographic influences, particularly seasonal and El Niño cycles in water temperature and presumably prey distribution (Green et al. 1993; Forney and Barlow 1998; Buchanan et al. 2001; Becker 2007). Green et al. (1992, 1993) found that northern right whale dolphins were most abundant off Oregon/Washington during the fall, with low abundance during spring and summer and none occurring there during the 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.

Extensive year-round aerial surveys off Oregon/Washington conducted by Green et al. (1992, 1993) found that 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 from shore. Barlow (2003) also found that it was one of the most abundant marine mammal species off Oregon/Washington during 1996 and 2001 ship surveys. The most recent abundance estimate off the west coast of the U.S. is 15,305 northern right whale dolphins (Carretta et al. 2007). Barlow and Forney (2007) noted an abundance estimate of 6242 for Oregon/Washington.

Baird and Stacey (1991a) compiled 18 published and unpublished records of the northern right whale dolphin within the Canadian 320-km extended economic zone. All but one were sighted in water depths >900 m, and most (12) were sighted off the west coast of Vancouver Island in water depths >1800 m. No seasonal trends were evident, with records from 7 months in all seasons (Baird and Stacey 1991a). In 1994, a group of northern right whale dolphins and Pacific white-sided dolphins was sighted 20 km offshore from Tofino (DFO 1999). One group of six northern right whale dolphins was sighted west of Vancouver Island in water deeper than 2500 m during a recent survey from Oregon to Alaska (Hauser and Holst 2009).

Risso's Dolphin

Risso's dolphin is primarily a tropical and mid-temperate species that is distributed worldwide. It generally occurs between 60ºN and 60ºS, where surface water temperatures are above 10ºC (Kruse et al. 1999). The species is not listed under the ESA or SARA. Risso's dolphin is pelagic, mostly occurring on the upper continental slope shelf edge in waters 350–1000 m deep (Baumgartner 1997; Davis et al. 1998). Risso's dolphins occur individually or in small to moderate-sized groups, normally of 2 to 250 individuals, although groups as large as 4000 have been sighted (Baird 2002). The majority of groups consist of <50 individuals (Kruse et al. 1999).

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; Becker 2007). Water temperature appears to be an important factor affecting their distribution (Kruse et al. 1999; see also Becker 2007). Like the Pacific white-sided dolphin, Risso's dolphin is believed to make seasonal north-south movements related to water temperature, spending colder winter months off California and moving north to waters off Oregon/Washington during the spring and summer as northern waters begin to warm (Green et al. 1992, 1993; Buchanan et al. 2001; Barlow 2003; Becker 2007).

The most recent abundance estimate for the west coast of the U.S. is 12,093 (Carretta et al. 2007). Off Oregon/Washington, Risso's dolphins are most abundant over continental slope and shelf waters during spring and summer, less so during fall, and rare during the winter months; 89% of all groups sighted were seen during May (Greene et al. 1992). Of those sightings, 94% occurred in slope waters 200–2000 m deep, and 79% were observed off Oregon, primarily from ~45º to 47ºN; none were seen in offshore waters. Barlow and Forney (2007) noted an abundance estimate of 4260 for Oregon/ Washington.

There are only a few records of occurrences in coastal waters in B.C. However, this species is more common offshore because of a preference for deeper waters at and beyond the shelf-break (NOAA 2000). Baird and Stacey (1991b) compiled 21 published and unpublished records of Risso's dolphin within the Canadian 320-km extended economic zone, of which 10 (4 sightings, 6 strandings) were from B.C. waters, from January to June.

Striped Dolphin

Striped dolphins have a cosmopolitan distribution in tropical to warm temperate waters (Perrin et al. 1994). They are pelagic and seem to prefer deep water along the edge and seaward of the continental shelf (Davis et al. 1998). This species is not listed under the ESA or SARA.

Off California, they are most often sighted 185–550 km from the coast (Becker 2007; Carretta et al. 2007), but they also occur in coastal waters (Isaksen and Syvertsen 2002). Few sightings have been reported for Oregon or Washington, with the exception of a survey by Barlow (2003) in 1996. The most recent abundance estimate for the west coast of the U.S. is 23,883 (Carretta et al. 2007), while previous estimates were 20,235 (Barlow 1997) and 13,934 (only 64 for Oregon/Washington; Barlow 2003). Baird et al. (1993a) compiled records from 1948 to 1987 of the striped dolphin within the Canadian 320-km extended economic zone. There were nine strandings, mostly from the west side of Vancouver Island, and two sightings in offshore waters.

Short-beaked and Long-beaked Common Dolphins

Common dolphins are found in tropical and temperate oceans around the world (Evans 1994). There are two species: the short-beaked common dolphin (*Delphinus delphis*) and the long-beaked common dolphin (*D. capensis*). Prior to the early 1990s, short-beaked and long-beaked common dolphins were not treated as separate species, and most of the earlier literature refers to all common dolphins combined. Neither species is listed under the ESA or SARA.

The short-beaked common dolphin (*D. delphis*) ranges in the northeastern Pacific from South America to southern B.C. (Ford 2005). The distribution of short-beaked common dolphins along the U.S. west coast is variable and likely related to oceanographic changes (Heyning and Perrin 1994; Forney and Barlow 1998). It is estimated that 487,622 short-beaked common dolphins occur off the west coast of the U.S. (Carretta et al. 2007). Previous abundance estimates off Califormia/Oregon/Washington were 373,573 (Barlow 1997) and 449,846 (Barlow 2003). Barlow and Forney (2007) estimated short-beaked common dolphin abundance for Oregon/Washington at 4555. There is only a single record of *D. delphis* in B.C. waters, that was a stranded individual on southern Vancouver Island in April 1953 (Ford 2005).

Off California, there are an estimated 21,902 long-beaked common dolphins (*D. capensis*) according to Barlow and Forney (2007). Until recently, they were thought to range no farther north than central and northern California (Becker 2007; Carretta et al. 2007). However, Ford (2005) reported seven confirmed *D. capensis* sightings in B.C. waters from 1993 to 2003, mostly in late summer and fall (August–November). Most *D. capensis* sightings off B.C. were of 1–2 individuals, but there was a sighting of 4 individuals in November 2002 (Ford 2005). All records occurred in inshore waters, and Ford (2005) described *D. capensis* as a “rare visitor” to B.C. waters, more likely during warm-water periods.

False Killer Whale

False killer whales are found in all tropical and warmer temperate oceans (Leatherwood et al. 1988; Bonnell and Dailey 1993), especially in deep offshore waters (Odell and McClune 1999), although sightings have also been reported from shallow (<200 m) waters. The false killer whale is not listed under the ESA and SARA.

In the NEPO, the species has rarely been reported north of Baja California (Leatherwood et al. 1982, 1987; Mangels and Gerrodette 1994). Off B.C., their presence has been confirmed by 3 strandings and 7 sightings of single individuals between 1887 and 1989 (Stacey and Baird 1991b). All of the records are from inshore waters around Vancouver Island. Stacey and Baird (1991b) suggested that they are at the limit of their distribution in Canada, and have always been rare.

Killer Whale

Killer whales are cosmopolitan and globally abundant; they have been observed in all oceans of the world (Ford 2002). High killer whale densities occur in high latitudes, especially in areas where prey is abundant. Along the North American west coast, killer whales occur from Alaska (Braham and Dahlheim 1982) south to California (Green et al. 1992; Barlow 1995, 1997; Forney et al. 1995; Baird 2001). The greatest abundance is thought to occur within 800 km of major continents (Mitchell 1975). Killer whales appear to prefer coastal areas, but are also known to occur in deep water (Dahlheim and Heyning 1999). They often travel in close-knit matrilineal groups of a few to tens of individuals (Dahlheim and Heyning 1999). It is estimated that there are 8500 killer whales in the eastern Tropical Pacific (Ford 2002).

Killer whales are segregated socially, genetically, and ecologically into three distinct groups: residents, transients, and offshore animals:

Residents: There are two communities of resident killer whales in B.C. The Northeast Pacific northern resident community inhabits the central and northern Strait of Georgia, Johnstone Strait, Queen Charlotte Strait, the northern half of the west coast of Vancouver Island, and the entire central and north coast of B.C. The northern resident population is listed as ***threatened*** under SARA. The southern resident community occupies southern Strait of Georgia, Juan de Fuca Strait, Puget Sound, and the southern half of the west coast of Vancouver Island (Ford et al. 1994; Baird 2001). Population sizes were ~200 for the northern residents as of 1993 (Ford et al. 1994) and 89 for the southern residents as of 1998 (Baird 2001). The Northeast Pacific southern resident population is listed as ***endangered*** under SARA, and NMFS has proposed that it be listed as ***threatened*** under the ESA. Holt (2008) summarizes possible acoustic impacts on southern resident killer whales.

Transients: These whales range throughout B.C. marine waters and feed primarily on marine mammals. The seasonal movements of transients are largely unpredictable, although there may be some tendency to investigate harbour seal haulouts more frequently during pupping season (Baird 1994). There is uncertainty as to the size of the transient killer whale population in B.C. A total of 170 individuals were identified in coastal waters up to 1993 (Ford et al. 1994). The Northeast Pacific transient population is listed as ***threatened*** under SARA.

Offshore: Little is known about offshore killer whales, which Baird (2001) suggested comprise a third group of residents. It is estimated that there are at least 422 offshore killer whales off California/Oregon/Washington (Carretta et al. 2007). From 1989 to 1993, 200 offshore individuals were photo-identified in B.C. waters (Ford et al. 1994). Most sightings are from the Queen Charlotte Islands and 15 km or more off the west coast of Vancouver Island near the continental slope (Ford et al. 1994). The Northeast Pacific offshore population is listed as a ***special concern*** under SARA, but as ***threatened*** by COSEWIC.

Short-finned Pilot Whale

The short-finned pilot whale can be found in tropical and warm temperate waters (Leatherwood and Reeves 1983; Bernard and Reilly 1999). This species is not listed under the ESA or SARA. The short-finned pilot whale is mainly pelagic and occurs in waters with a depth of ~1000 m (Davis et al. 1998). It is generally nomadic, but may be resident in certain locations, including California and Hawaii (Olson and Reilly 2002).

Pilot whales are very social and are usually seen in groups of 20–90 with matrilineal associations (Olson and Reilly 2002). Both species (short-finned and long-finned) are known for single and mass strandings. A trained short-finned pilot whale routinely made dives to depths >300 m and occasionally to 500 m, and stayed underwater up to 15 min (Bernard and Reilly 1999). Heide-Jørgensen et al. (2002) found that pilot whales outfitted with time-depth recorders dove to depths of up to 828 m, although most of their time was spent above depths of 7 m.

In the eastern Tropical Pacific, it is estimated that there are 160,200 short-finned pilot whales (Wade and Gerrodette 1993). The abundance of pilot whales in waters off California/Oregon/Washington is variable, and likely related to oceanographic conditions (Forney and Barlow 1998). The most recent estimate for the west coast of the U.S. is 245 short-finned pilot whales (Carretta et al. 2007). Previous estimates off the U.S. west coast were as high as 970, including sightings off Oregon/Washington

(Barlow 1997). However, no short-finned pilot whales were seen during surveys off Oregon/Washington in 1989–2005 (Barlow 2003; Barlow and Forney 2007)

Baird and Stacey (1993) reported that there were 16 sightings of 1–150 short-finned pilot whales within the 320-km extended economic zone off the west coast of Vancouver Island in 1985–1989, and concluded that the species should be considered rare in the waters off B.C. However, their occurrence may be underestimated because of limited sighting effort (Baird and Stacey 1993). The pilot whales were sighted in inshore (9 sightings) and offshore (7 sightings) waters. Another three records from incidental catches were in offshore waters. All were sighted or caught between April and September, with 12 in June or August.

Harbor Porpoise

The harbor porpoise is not listed under the ESA. In Canada, it is a species of ***special concern*** under SARA. The harbor porpoise inhabits temperate, subarctic, and occasionally arctic waters. Along the U.S. west coast, it ranges from Point Barrow, Alaska, to central California (Carretta et al. 2007). The harbor porpoise primarily inhabits coastal waters, although sightings have been made over deeper waters between land masses (Bjørge and Tolley 2002). Harbor porpoises are normally found in small groups of up to three that often contain at least one mother-calf pair. Larger groups of 6–8 are not uncommon, and rarely, much larger aggregations are seen. Harbor porpoises surface quickly, rarely leaping out of the water, and tend to avoid vessels.

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; no sightings were made in offshore waters. The most recent abundance estimate in waters off Oregon/Washington is 37,745 harbor porpoises (Carretta et al. 2007).

Harbour porpoises are found along the B.C. coast year-round, primarily in coastal shallow waters, harbors, bays, and river mouths (Osborne et al. 1988). Their seasonal movements appear to be inshore-offshore, rather than north-south, as a response to the abundance and distribution of food resources (Dohl et al. 1983; Barlow 1988). Genetic testing has shown that harbor porpoises along the west coast of North America are not migratory and occupy restricted home ranges (Rosel et al. 1995). It is estimated that 9120 harbor porpoises are present in inshore coastal B.C. waters (Williams and Thomas 2007). Harbor porpoises are sometimes taken by commercial inshore fisheries in B.C. (Stacey et al. 1997).

Dall's Porpoise

Dall's porpoise is only found in the North Pacific and adjacent seas. Dall's porpoise is not listed under the ESA or SARA. It is widely distributed across the North Pacific over the continental shelf and slope waters, and over deep (>2500 m) oceanic waters (Hall 1979), ranging from ~32ºN to 65ºN (Reeves et al. 2002). It usually occurs in small groups of 2 to 12 individuals, characterized by fluid associations (Reeves et al. 2002). Dall's porpoise are fast-swimming and active porpoises, and readily approach vessels to ride the bow wave.

Off Oregon/Washington, this species is widely distributed over shelf and slope waters, with concentrations near shelf edges, and is also commonly sighted in pelagic offshore waters (Morejohn 1979; Green et al. 1992). Combined results of various surveys out to ~550 km from shore indicate that the distribution and abundance of Dall's porpoise varies between seasons and years. North–south movements are believed to occur off Oregon, Washington, and California in response to changing oceanographic conditions, particularly temperature and distribution and abundance of prey (Green et al.

1992, 1993; Mangels and Gerrodette 1994; Barlow 1995; Forney and Barlow 1998; Buchanan et al. 2001; Becker 2007). The abundance and distribution of Dall's porpoise off Oregon/Washington also appears to shift from slope to shelf waters during the fall in pursuit of schooling fish and squid; during the winter, they move offshore again to slope waters (Fiscus and Niggol 1965; Green et al. 1992). Dall's porpoise are encountered offshore during all seasons, but the highest encounter rates are in the winter and spring (Greene et al. 1992).

Dall's porpoise was the most abundant species sighted off Oregon/Washington during 1996 and 2001 ship surveys up to ~550 km from shore (Barlow 2003). Abundance estimates for 1996 and 2001 were 76,874 and 8213, respectively. The most recent abundance estimate for Dall's porpoise off the west coast of the U.S. is 57,549 (Carretta et al. 2007). Dall's porpoise is found all along the B.C. coast, and is common inshore and offshore throughout the year, although there appears to be an offshore shift in abundance during the summer (Jefferson 1990). It is most common over the continental shelf and slope, but also occurs >2400 km from the coast (Pike and MacAskie 1969 *in* Jefferson 1990). During a survey from Oregon to Alaska, Dall's porpoises were sighted west of Vancouver Island and the Queen Charlotte Islands in early October during the southbound transit, but none were sighted in mid-September during the northward transit (Hauser and Holst 2009). All sightings were made in water deeper than 2000 m (Hauser and Holst 2009). Approximately 4910 Dall's porpoise are estimated to occur in inshore coastal B.C. waters (Williams and Thomas 2007). Dall's porpoises are by-caught by commercial inshore fisheries in B.C. (Stacey et al. 1997; Williams et al. 2008).

Pinnipeds

Steller Sea Lion

The Steller sea lion is listed under the ESA as ***threatened*** in the eastern portion of its range and ***endangered*** in the western portion, west of Cape Suckling, Alaska, at 144ºW. Both stocks are therefore considered depleted and strategic under the MMPA. The Steller sea lion is listed as ***endangered*** by the IUCN and as a species of ***special concern*** under SARA. Despite an increasing population in B.C. (3.2% average annual rate of increase since 1971; Pitcher et al. 2007), COSEWIC upgraded this species' listing from *Not at Risk* in November 2003, because (1) there are only three breeding locations in B.C., (2) the species is sensitive to human disturbance while on land, (3) the threat of acute oil spills, and (4) concerns about the unexplained declines in other populations to the north and west of B.C.

Steller sea lions occur in the coastal and immediate offshore waters of the North Pacific Rim. In the western Pacific, they are distributed from the Bering Strait along the Aleutian Islands, the Kuril Islands, and the Okhotsk Sea to Hokkaido, Japan. In the eastern Pacific, they occur along the coast of North America south to the Channel Islands off Southern California (Rice 1998). In the NEPO, they are most abundant in the Gulf of Alaska, southeastern Alaska, and B.C. (Reeves et al. 2002). Only animals from the eastern stock occur in waters off B.C.; the population size of the eastern stock, including animals in Alaska, B.C., Washington, Oregon, and California is estimated to be 48,519 (Angliss and Outlaw 2008).

In B.C., the three rookeries are situated at Cape St. James, North Danger Rocks, and on the Scott Islands (Pitcher et al. 2007). Some adults and juveniles are also found on sites known as year-round haulouts during the breeding season. Currently there are 24 major haulout sites (>50 sea lions) in B.C. (Pitcher et al. 2007). The total pup and non-pup count of Steller sea lions in B.C. in 2002 was 15,438; this represents a minimum population estimate (Pitcher et al. 2007). The two rookeries off southern Oregon are located along the coast at Rogue and Orford reefs near 42º25' and 42º45'N and 124º30'W, respectively (Bonnell et al. 1992). There are no rookeries in Washington (Pitcher et al. 2007). Adult males are found at breeding colonies in May. Females give birth from late May to early July, with the highest pup counts in July (Bigg 1988). Molting occurs from late summer to early winter. Steller sea lions feed predominantly within 30 km of the coastal rookeries (Bonnell et al. 1992).

Steller sea lions typically inhabit coastal waters when feeding and migrating. During surveys off the coasts of Oregon/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. The mean density was highest during Sept.-Nov. (0.0111/km^2); during May-July, it was 0.0059/km^2 (Bonnell et al. 1992). Although there have been occasional sightings of Steller sea lions up to 130 km from shore (Olesiuk and Bigg 1984), it is unlikely that any will be seen in the offshore study area.

California Sea Lion

The California sea lions found from southern Mexico to southwestern Canada are of the subspecies *Z. c. californianus* (other subspecies are found on the Galapagos Islands and in Japan, although the latter is likely extinct). This species is not listed under the ESA or SARA. The breeding areas of the California sea lion are on islands located in southern California, western Baja California, and the Gulf of California. The California sea lion population is growing at an annual rate of 5–6.2%. The present population is estimated at 238,000 (Angliss and Outlaw 2008). Sea lions are killed incidentally in set and drift-gillnet fisheries (Hanan et al. 1993; Barlow et al. 1994; Julian 1997; Julian and Beeson 1998; Cameron and Forney 1999).

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/Washington, mean distance from shore was ~13 km (Bonnell et al. 1992). In California and Baja California, births occur on land from mid-May to late June. Females are ready to breed ~3 weeks after giving birth (Odell 1984; Trillmich 1986) and actively solicit mates. 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 as far away as Washington (Puget Sound) and B.C. (Lowry et al. 1992). They remain there until spring (March to May), when they migrate back to the breeding colonies. 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). However, 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. Off Oregon/Washington, most California sea lions occur in the fall (Bonnell et al. 1992). Adult and sub-adult male California sea lions are mainly seen in B.C. during the winter (Olesiuk and Bigg 1984). Wintering California sea lion numbers have increased off southern Vancouver Island since the 1970s, likely as a result of the increasing California breeding population (Olesiuk and Bigg 1984). However, California sea lions are unlikely to occur far offshore in the proposed study area.

Northern Fur Seal

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. It is not listed under the ESA or SARA, however it is classified as ***vulnerable*** by the IUCN as ***threatened*** by COSEWIC. Two stocks are recognized, the Eastern Pacific and the San Miguel Island stocks. The Eastern Pacific stock ranges from the Pribilof Islands and Bogoslof Island in the Bering Sea during summer to the Channel Islands in Southern California during winter. The worldwide population of fur seals has declined from a peak of ~2.1 million in the 1950s to the current population estimate of ~721,935 (Angliss and Outlaw 2008).

During the breeding season, 74% of the worldwide population of northern fur seals inhabits the Pribilof Islands in the southern Bering Sea (Lander and Kajimura 1982). A small percentage of seals breed at San Miguel Island off southern California. When not on rookery islands, northern fur seals are primarily pelagic but occasionally haul-out on rocky shorelines. Bonnell et al. (1992) noted the presence of northern fur seals year-round off Oregon/Washington, with the greatest numbers occurring in January–May. The highest densities were seen in the Columbia River plume and in deep offshore waters (>2000 m) off central and southern Oregon (Bonnell et al. 1992). Offshore densities ranged up to 0.4/km^2 in January–May, but only reached up to 0.1/km^2 in June–December (Bonnell et al. 1992).

During the breeding season, adult males usually come ashore in May–August and may sometimes be present until November, and adult females are found ashore from June to November (Carretta et al. 2007). After reproduction, seals spend the next 7–8 months feeding at sea (Roppel 1984). Adult females and pups from the Pribilof Islands migrate to Oregon and California offshore waters, passing through B.C. water in early winter and returning northward in late spring. Adult males only migrate as far south as the Gulf of Alaska (Kajimura 1984). Bonnell et al. (1992) estimated that 1200 fur seals inhabit the Oregon/Washington area in January and 7000 in April. In January, 77% of sightings in that area were off northern Washington; in April, 77% of all sightings were off central and southern Oregon. Northern fur seals were 5–6 times more abundant in offshore waters than over the shelf or slope; densities for shelf, slope, and offshore waters were 0.017, 0.013, and 0.084/km^2, respectively. Northern fur seals were seen as far as 185 km from the coast (the offshore limit of the survey), and numbers increased with distance from land (Bonnell et al. 1992).

Off B.C., females and subadult males are typically found during the winter off the continental shelf (Bigg 1990). The use of continental shelf and slope waters of B.C. and the northwestern U.S. by adult females during winter is well documented from pelagic sealing data (Bigg 1990). A few animals are seen in inshore waters in B.C., and individuals occasionally come ashore, usually at sea lion haulouts (e.g., Race Rocks, off southern Vancouver Island) during winter and spring (Baird and Hanson 1997). In general, however, few come within ~16 km of the coast (NOAA 2001).

Harbor Seal

Harbor seals occur widely in the Northern Hemisphere, in temperate and subarctic waters. Two subspecies of harbor seal occur in the Pacific: *P.v. stejnegeri* in the northwest Pacific Ocean and *P.v. richardsi* in the NEPO. *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. 2007). It is likely the most abundant species of marine mammal in B.C. and is not listed as endangered or threatened under SARA or the ESA.

Along the U.S. west coast, there are three separate stocks of harbor seals: inland waters of Washington, coastal Oregon and Washington, and California (Boveng 1988). The Oregon/Washington coast stock is estimated to contain 24,732 harbor seals (see Carretta et al. 2007). Williams and Thomas (2007) noted an abundance estimate of 19,400 harbor seals for the inshore coastal waters of B.C. The total population in B.C. was estimated at ~108,000 by Olesiuk (1999). Overall, from California to southeast Alaska, harbor seal populations seem to be increasing, but those rates of increase have been declining in recent years in B.C. as population levels stabilize (Olesiuk 1999).

Harbor seals haul out on rocks, reefs, beaches, and offshore islands along the western coast of North America. Pupping in Oregon/Washington occurs from April to July (Brown 1988). In southern B.C., pups are born in July–August; in northern B.C. pupping occurs in May and June (Olesiuk and Bigg 1984). Harbor seals do not make extensive migrations, but do travel 300–500 km on occasion to forage (Herder 1986). They display strong site fidelity for haul-out sites (Pitcher and McAllister 1981).

Harbor seals generally are found near the coast, so are unlikely to be seen in the offshore study area. Bonnell et al. (1992) noted that most harbor seals sighted off Oregon/Washington were ≤20 km from shore, with the farthest sighting 92 km from the coast. During surveys off the Oregon/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). In the fall, most harbor seals are at sea; 67.8% of all at-sea sightings were recorded in September and November (Bonnell et al. 1992).

Northern Elephant Seal

Northern elephant seals breed and give birth in California and Baja California, primarily on offshore islands (Stewart et al. 1994), from December to March (Stewart and Huber 1993). They breed on numerous islands, from Cedros off the west coast of Baja California, north to the Farallons near San Francisco. Bonnell et al. (1992) noted a possible breeding colony at Shell Island, off southern Oregon. The U.S. and Mexican populations were estimated at 127,000 in the early 1990s (Stewart et al. 1994); the California stock was estimated at 124,000 in 2005 and is increasing (Carretta et al. 2007). This species is not listed under the ESA or SARA.

Females arrive at rookeries 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). 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). After the molt, adults then return to their northern feeding areas until the next winter breeding season. When not at their breeding rookeries, adults feed far offshore in deep water, far from the rookeries. Northern elephant seals can dive for up to 45 min and reach depths of 2600 ft (806 m) (Olesiuk and Bigg 1984). 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).

Bonnell et al. (1992) reported that northern elephant seals were distributed equally in shelf, slope, and offshore waters during surveys conducted off Oregon/Washington, as far as 150 km from shore, in waters >2000 m deep (Bonnell et al. 1992). Telemetry data indicate that they range much farther offshore than that (Stewart and DeLong 1995). Baird (1990) reported that northern elephant seals are sparsely but widely distributed in B.C. waters throughout the year and are usually seen singly. The account by Cowan and Carl (1945) suggests that, at least up to the mid-20th century, northern elephant seals were not as common in B.C. as they are at present.

Race Rocks Ecological Reserve, located off southern Vancouver Island, is one of the few spots in B.C. where elephant seals regularly haul out. Based on their size and general appearance, most animals using Race Rocks are adult females or subadults, although a few adult males also haul out there. Use of

Race Rocks by northern elephant seals has increased substantially in recent years, most likely as a result of the species' dramatic recovery from near extinction in the early 20th century and its tendency to be highly migratory. The peak number (22) of adults and subadults observed in spring 2003 (Demarchi and Bentley 2004) may represent a record number for B.C. during recorded history. During inshore coastal surveys of B.C. waters, Williams and Thomas (2007) noted seven sightings of northern elephant seals in Queen Charlotte Basin. In recent years, northern elephant seal pups have been sighted at haulouts in the inland waters of Washington State (Jeffries et al. 2000), and at least three are reported to have been born there (Hayward 2003).

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 NEPO during August–September 2009.

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 cetacean or pinniped, 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.
- 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 activity in the NEPO during August–September 2009. 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 might 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; Weilgart 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 brief summary of the characteristics of airgun pulses, see Appendix B (3). 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). 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, toothed whales, and (less frequently) pinnipeds have been shown to react behaviorally to airgun pulses under some conditions, at other times mammals of all three types have shown no overt reactions. In general, pinnipeds usually seem to be more tolerant of exposure to airgun pulses than are cetaceans, with the relative responsiveness of baleen and toothed whales being 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 some situations, multi-path arrivals and reverberation cause airgun sound to arrive 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 can usually be heard between the seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999; Nieukirk et al. 2004; Smultea et al. 2004; Holst et al. 2005a,b, 2006). In the NEPO, blue whale calls have been recorded during a seismic survey off Oregon (McDonald et al. 1995). Among odontocetes, 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 this species 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. 2006, 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 negligible, given the normally intermittent nature of seismic pulses. Masking effects on marine mammals are discussed further in Appendix B (4).

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 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, and on ringed seals. 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), 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 4–15 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) 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$_{p\text{–}p}$. 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$_{rms}$.

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.

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)]. 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 reported in areas ensonified by airgun pulses (Stone 2003; MacLean and Haley 2004; Stone and Tasker 2006). 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). In a study off Nova Scotia, Moulton and Miller (2005) found little difference in sighting rates (after accounting for water depth) and initial sighting distances of balaenopterid whales when airguns were operating vs. silent. However, there were indications that these whales were more likely to be moving away when seen during airgun operations. Similarly, ship-based monitoring studies of blue, fin, sei and minke whales offshore of Newfoundland (Orphan Basin and Laurentian Sub-basin) found no more than small differences in sighting rates and swim directions during seismic vs. non-seismic periods (Moulton et al. 2005, 2006a,b).

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; Angliss and Outlaw 2008). 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; Angliss and Outlaw 2008).

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 (Jochens et al. 2006, 2008; Miller et al. 2006). There is also 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; Weir 2008).

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). 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). 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; Moulton et al. 2005, 2006a; Stone and Tasker 2006; Weir 2008). 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. 2006, 2008). In the Sperm Whale Seismic Study (SWSS), D-tags (Johnson and Tyack 2003) were used to record the movement and acoustic exposure of eight foraging sperm whales before, during, and after controlled sound exposures of airgun arrays in the Gulf of Mexico (Jochens et al. 2008). Whales were exposed to maximum received sound levels between 111 and 147 dB re 1 μPa_{rms} (131–164 dB re 1 μPa_{pk-pk}) at ranges of ~1.4–12.6 km from the sound source. Although the tagged whales showed no horizontal avoidance, some whales changed foraging behavior during full-array exposure (Jochens et al. 2008).

There are almost no specific data on the behavioral reactions of beaked whales to seismic surveys. However, northern bottlenose whales continued to produce high-frequency clicks when exposed to sound pulses from distant seismic surveys (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). 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.

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 a 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, and in particular, the dominant frequencies in airgun pulses are at lower frequencies than used by mid-frequency naval sonars.

Odontocete reactions to large arrays of airguns are variable and, at least for delphinids and some porpoises (e.g., Dall's), 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 distur-bance criterion (rather than ≥160 dB) is considered appropriate for delphinids (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). 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). Even if reactions of any pinnipeds that might be encountered in the present study area are as strong as those evident in the telemetry study, reactions are expected to be confined to relatively small distances and durations, with no long-term effects on pinniped individuals or populations. As for delphinids, a ≥170 dB disturbance criterion is considered appropriate for pinnipeds, which tend to be less responsive than many cetaceans.

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 and pinnipeds should not be exposed to impulsive sounds with received levels ≥180 and 190 dB re 1 μPa_{rms}, respectively (NMFS 2000). Those criteria have been used in establishing the exclusion (=shut-down) zones planned for the proposed seismic survey. However, those criteria were 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 of the EA and below,

- 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 were published recently (Southall et al. 2007). Those recommendations have not, as of early 2009, 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 EISs 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, 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 , "Mitigation Measures"). In addition, many cetaceans and (to a limited degree) pinnipeds and 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, the deep water in the study area, 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 compiled and 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). Given the available 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. 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 380 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. There is no published TTS information for other types of cetaceans. However, preliminary evidence from a harbor porpoise exposed to airgun sound suggests that its TTS threshold may have been lower (Lucke et al. 2007).

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 most parts of the planned study area; (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 180 and 190 dB re 1 μPa_{rms}, respectively. 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 in which the strongest pulse has a received level substantially exceeding 180 dB re 1 μPa_{rms}. On the other hand, for the harbor seal and any species with similarly low TTS thresholds (possibly including the harbor

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[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).

porpoise), 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 (Richardson et al. 1995, p. 372*ff*). Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage.

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 could 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). 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 TTS threshold for an impulse). 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 the PTS threshold 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 or pinniped received one or more pulses with peak pressure exceeding 230 or 218 dB re 1 µPa, respectively. 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 (600 in^3) airguns in most airgun arraysy (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, PAM, 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.

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 (Gentry 2002) and direct noise-induced bubble formation (Crum et al. 2005) are not expected in the case of an impulsive 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.

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 seismic research or commercial seismic surveys, and 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 mass 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 (7) 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. As noted in the preceding subsection, some of these mechanisms are unlikely to apply in the cae 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. 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 Sept. 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.

Possible Effects of Multibeam Echosounder Signals

The Simrad EM120 12-kHz MBES will be operated from the source vessel during the planned study. Information about this equipment was provided in § I. 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 pulses emitted by this MBES is at frequencies near 12 kHz, and the maximum source level is 242 dB re 1 $\mu Pa_{rms} \cdot m$ (rms). The beam is narrow (1º) in fore-aft extent and wide (150º) in the cross-track extent. Each ping consists of nine 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 nine segments. Also, marine mammals that encounter the Simrad EM120 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 Simrad EM120, 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 Eastern Tropical Pacific, baleen whales showed no significant responses, while 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 sonar 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 sonar that included significant signal components down to 6 kHz. Results indicated that the two seals reacted to the sonar 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 µPa^2·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 µPa^2·s) and even further below the anticipated PTS threshold (215 dB re 1 µPa^2·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 µPa^2·s in the case of the EM120. 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 µPa^2·s, as compared with ~195 dB re 1 µPa^2·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 pulse with received energy level of ≥184 dB re 1 µPa^2·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 sonar ping was emitted. However, the SEL criterion for PTS in pinnipeds (203 dB re 1 µPa^2·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 pulse as the ship passed overhead.

Possible Effects of the Sub-bottom Profiler Signals

An SBP may be operated from the source vessel at times during the planned study. Details about this equipment were provided in § I. Sounds from the sub-bottom profiler are very short pulses, occurring for 1–4 ms once every second. Most of the energy in the sound pulses emitted by the SBP is at 3.5 kHz, and the beam is directed downward. The sub-bottom profiler on the *Langseth* has a maximum source level of 204 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 sub-bottom profiler signals given their directionality 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 § IX) would further reduce or eliminate any minor effects of the SBP.

Possible Effects of the 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 significantly affect 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 ETOMO seismic program. The estimates of "take by harassment" are based on consideration of the number of marine mammals that could be disturbed appreciably by ~1800 km of seismic surveys (plus an additional 25% contingency) in the Endeavour MPA. The main sources of distributional and numerical data used in deriving the estimates are described in the next subsection.

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

Basis for Estimating "Take by Harassment"

There is very little information on the cetaceans that occur in deep water off the west coast of Vancouver Island, but the waters off Oregon and Washington have been studied in some detail (e.g., Green et al. 1992, 1993; Barlow 1997, 2003; Barlow and Taylor 2001; Calambokidis and Barlow 2004; Barlow and Forney 2007). The primary data used to provide densities for the proposed project area off southwestern B.C. were obtained from the 1996, 2001, and 2005 NMFS/SWFSC "ORCAWALE" or "CSCAPE" ship surveys off Oregon/Washington, as synthesized by Barlow and Forney (2007). The surveys took place up to ~550 km offshore from June or July through November or December. Thus, the surveys included effort in coastal, shelf/slope, and offshore water, and they encompass the August–

September period for the proposed study. Systematic, offshore 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.

The waters off the west coast of Vancouver Island are included in the same ecological province as Oregon/Washington, the California Coastal Province (Longhurst 2007). Thus, information on cetaceans from Oregon/Washington is relevant to the proposed offshore study area far offshore of B.C. Although densities for B.C. are available for some cetacean species (see Williams and Thomas 2007), these are for inshore coastal waters and would not be representative of the densities occurring in offshore areas. Although the cetacean densities based on data from Barlow and Forney (2007) better reflect those that will be encountered during the ETOMO study, the actual densities in the Endeavour MPA are expected to be lower still, as the survey effort off Oregon/Washington covered offshore as well as shelf and coastal waters, and it included sightings for summer and fall.

Oceanographic conditions, including occasional El Niño and La Niña events, influence the distribution and numbers of marine mammals present in the NEPO, 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; Becker 2007). Thus, for some species the densities derived from recent surveys may not be representative of the densities that will be encountered during the proposed seismic survey.

Table 3 gives the average and maximum densities for each species of cetacean reported for Oregon/Washington, corrected for effort, based on sightings reported for the 1996, 2001, and 2005 surveys (Barlow and Forney 2007). The densities had been corrected, by the original authors, for both detectability bias and availability bias. Detectability 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 and maximum density information for one species of pinniped (northern fur seal) that may occur in the offshore waters of the study area; densities could not be calculated for the other pinniped species (northern elephant seal), because of the small number of sightings on systematic transect surveys off Oregon/Washington (from Bonnell et al. 1992). The best estimates of exposures to various sound levels are based on the average densities presented in Table 3.

It should be noted that the estimates of exposures to various sound levels assume that the surveys will be completed; in fact, the planned number of line-kilometers has been increased by 25% to accommodate lines that may need to be repeated, equipment testing, etc. As is typical during offshore 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 EZ will result in the power or shut down of seismic operations as a mitigation measure. Thus, the following estimates of the numbers of marine mammals potentially exposed to 160- or 170-dB 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.

Potential Number of Marine Mammals Exposed to ≥160 and ≥170 dB

Table 4 shows the estimated number of exposures and the number of different individuals potentially exposed during the seismic survey if no animals moved away from the survey vessel. The estimates are based on the 160 dB re 1 μPa$_{rms}$ criterion for all cetaceans and pinnipeds, and the 170 dB re 1 μPa$_{rms}$

TABLE 3. Densities of marine mammals sighted during surveys off Oregon/Washington, with their approximate coefficients of variation (CV). Cetacean densities are from Barlow and Forney (2007) and are based on ship transect surveys conducted up to 550 km offshore during summer–autumn of 1991, 2001, and 2005. Northern fur seal densities are from at-sea surveys during spring–autumn by Bonnell et al. (1992). Densities are corrected for *f*(0) and *g*(0). Species listed as *endangered* or *threatened* under the ESA are in italics.

	Average Density (#/1000 km^2)		**Maximum Density (#/1000 km^2)**	
Species	**Density**	**CV [a]**	**Density**	**CV [a]**
Mysticetes [b]				
North Pacific right whale	*0*	-	*0*	-
Humpback whale	*0.80*	0.42	*1.71*	0.48
Minke whale	0.71	0.76	1.17	0.83
Sei whale	*0.14*	*0.83*	*0.54*	*0.83*
Fin whale	*1.07*	*0.40*	*1.58*	*0.57*
Blue whale	*0.22*	0.62	*0.46*	0.72
Odontocetes				
Sperm whale	*1.43*	*0.58*	*3.52*	*0.72*
Pygmy sperm whale	1.30	0.94	2.93	0.94
Dwarf sperm whale	0	-	0	-
Cuvier’s beaked whale	0	-	0	-
Baird's beaked whale	1.72	0.60	4.28	0.76
Blainville’s beaked whale	0	-	0	-
Hubb's beaked whale	0	-	0	-
Stejneger's beaked whale	0	-	0	-
Mesoplodon sp. (unidentified)	0.70	0.83	2.97	0.94
Bottlenose dolphin	0	-	0	-
Striped dolphin	0.04	0.94	0.10	0.94
Short-beaked common dolphin	14.18	0.76	35.06	0.94
Pacific white-sided dolphin	24.84	0.46	33.20	0.62
Northern right-whale dolphin	19.40	0.47	26.70	0.57
Risso’s dolphin	12.95	0.45	17.35	0.55
False killer whale	0	-	0	-
Killer whale	1.70	0.57	2.88	0.72
Short-finned pilot whale	0	-	0	-
Phocoenidae				
Dall's porpoise	148.09	0.26	247.31	0.32
Pinnipeds[c]				
Northern fur seal	10	N.A.	100	N.A.

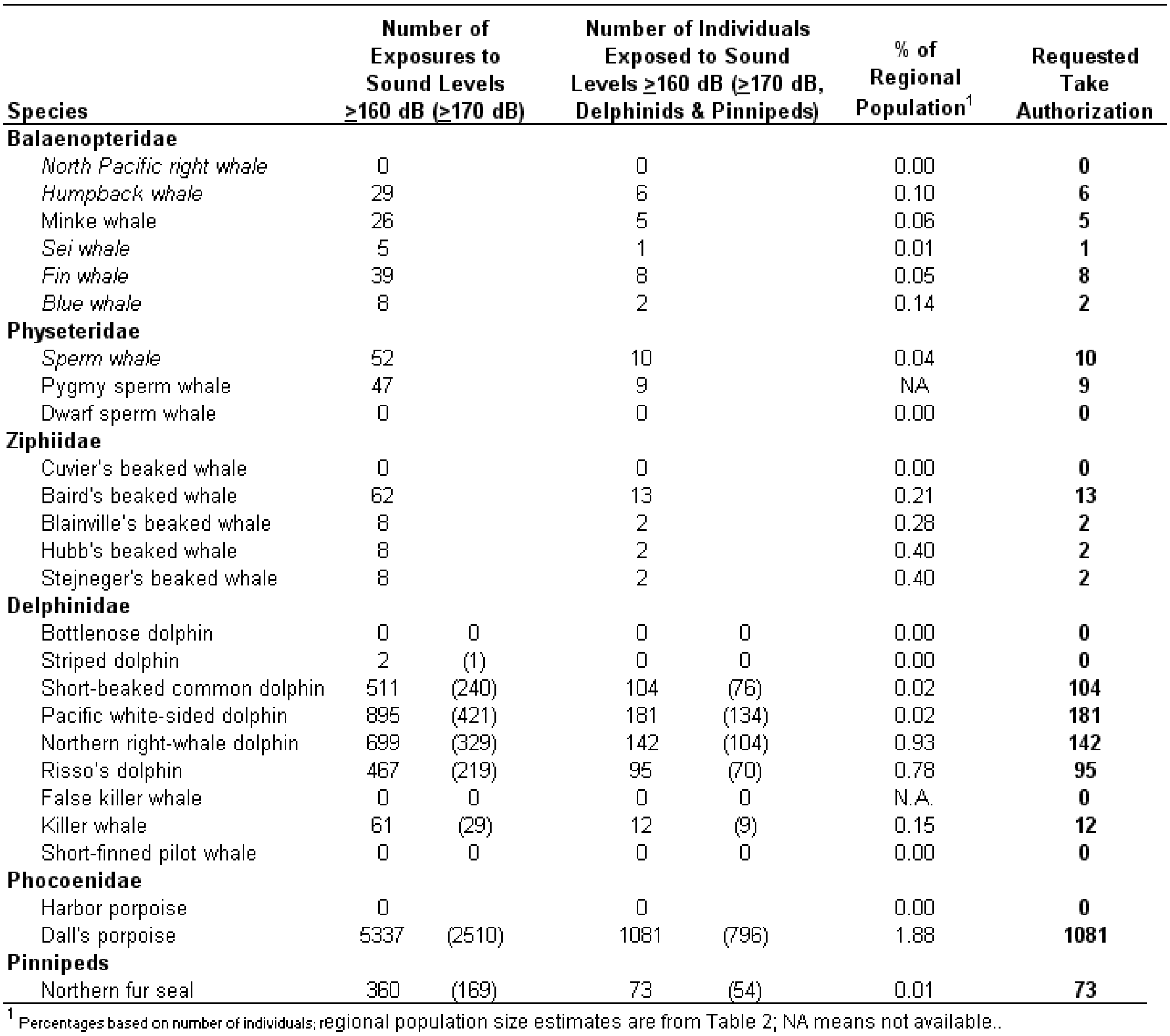
N.A. = data not available.ons

[a] CV (Coefficient of Variation) is a measure of a number's variability. The larger the CV, the higher the variability. It is estimated by $0.94 - 0.162\log_e n$ from Koski et al. (1998), but likely underestimates true variability.

[c] Gray whales and harbor porpoise are not included, as they only occur in coastal waters and would not be encountered in the offshore study area (see Barlow and Forney 2007).

[c] California sea lions, Steller sea lions, and harbor seals are not included, as they are not expected to be encountered in the offshore study. The number of at-sea sightings of northern elephant seals was too small to provide meaningful density estimates (Bonnell et al. 1992).

TABLE 4. Estimates of the possible numbers of marine mammal exposures to the different sound levels, and the numbers of different individuals that might be exposed, during L-DEO's proposed seismic survey off British Columbia in August–September 2009. Received levels of airgun 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). Delphinids, Dall's porpoise, and pinnipeds are unlikely to react to levels below 170 dB. 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 of Exposures to Sound Levels ≥160 dB (≥170 dB)**		**Number of Individuals Exposed to Sound Levels ≥160 dB (≥170 dB, Delphinids & Pinnipeds)**		**% of Regional Population[1]**	**Requested Take Authorization**
Balaenopteridae						
North Pacific right whale	0		0		0.00	**0**
Humpback whale	29		6		0.10	**6**
Minke whale	26		5		0.06	**5**
Sei whale	5		1		0.01	**1**
Fin whale	39		8		0.05	**8**
Blue whale	8		2		0.14	**2**
Physeteridae						
Sperm whale	52		10		0.04	**10**
Pygmy sperm whale	47		9		NA	**9**
Dwarf sperm whale	0		0		0.00	**0**
Ziphiidae						
Cuvier's beaked whale	0		0		0.00	**0**
Baird's beaked whale	62		13		0.21	**13**
Blainville's beaked whale	8		2		0.28	**2**
Hubb's beaked whale	8		2		0.40	**2**
Stejneger's beaked whale	8		2		0.40	**2**
Delphinidae						
Bottlenose dolphin	0	0	0	0	0.00	**0**
Striped dolphin	2	(1)	0	0	0.00	**0**
Short-beaked common dolphin	511	(240)	104	(76)	0.02	**104**
Pacific white-sided dolphin	895	(421)	181	(134)	0.02	**181**
Northern right-whale dolphin	699	(329)	142	(104)	0.93	**142**
Risso's dolphin	467	(219)	95	(70)	0.78	**95**
False killer whale	0	0	0	0	N.A.	**0**
Killer whale	61	(29)	12	(9)	0.15	**12**
Short-finned pilot whale	0	0	0	0	0.00	**0**
Phocoenidae						
Harbor porpoise	0		0		0.00	**0**
Dall's porpoise	5337	(2510)	1081	(796)	1.88	**1081**
Pinnipeds						
Northern fur seal	360	(169)	73	(54)	0.01	**73**

[1] Percentages based on number of individuals; regional population size estimates are from Table 2; NA means not available..

criterion for delphinids, Dall's porpoise, and pinnipeds. It is assumed that marine mammals exposed to airgun sounds this strong might change their behavior sufficiently to be considered "taken by harassment". The ***Requested Take Authorization***, given in the far right column of Table 4, is based on the best estimates of the numbers of individuals exposed.

***Number of Cetaceans that could be 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 total marine area that would be within the 160-dB radii around the operating airgun array on at least one occasion along with the expected density of animals in the area. The proposed seismic lines run parallel to each other in close proximity; thus, an individual mammal may be exposed numerous times during the survey. The number of possible exposures to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} (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. However, it is unlikely that a particular animal would stay in the area during the entire survey. The best estimates in this section are based on the averages of the densities from the 1996, 2001, and 2005 NMFS surveys.

The number of potential exposures and the number of different individuals potentially exposed to ≥160 dB re 1 μPa_{rms} were calculated by multiplying

- the expected average species density, times
- the anticipated minimum area to be ensonified to that level during airgun operations including overlap (exposures), or
- the anticipated area to be ensonified to that level during airgun operations excluding overlap (individuals).

The area expected to be ensonified was determined by entering the planned survey lines into a MapInfo Geographic Information System (GIS), using the GIS to identify the relevant areas by "drawing" the applicable 160-dB (or, in the next subsection, 170-dB) buffer (see Table 1) around each seismic line, and then calculating the total area within the buffers. Areas where overlap occurred (because of closely-spaced lines) were included when estimating the number of exposures; areas of overlap were included only once when estimating the number of individuals exposed.

Applying the approach described above, ~7302 km^2 (including 25% contingency) would be within the 160-dB isopleth on one or more occasions during the survey, whereas 36,039 km^2 is the area ensonified to ≥160 dB when overlap is included. Thus, it is possible that an average individual marine mammal may be exposed up to five times during the survey. Because this approach does not allow for turnover in the mammal populations in the study area during the course of the survey, the actual number of individuals exposed may be underestimated, although the conservative (i.e., probably overestimated) line-kilometer distances used to calculate the area may offset this. Also, the approach assumes that no cetaceans will move away or toward the trackline as the *Langseth* approaches in response to increasing sound levels prior to the time the levels reach 160 dB.

The best 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 1674 (Table 4). That total includes 22 baleen whales (17 if which are considered ***endangered*** under the ESA: 8 fin, 6 humpback, 2 blue, and 1 sei whale), which would represent 0.05%, 0.1%, 0.14%, 0.01%, respectively, of the regional populations (Table 4). However, the numbers of humpback whales exposed are overestimated, because the densities used are overestimates for offshore waters.

In addition, 10 sperm whales (also listed as ***endangered*** under the ESA) or 0.04% of the regional population could be exposed during the survey, as well as 19 beaked whales (Table 4). Dall's porpoise is estimated to be the most common species in the area, with a best estimate of 1081 or <2% of the regional population exposed to ≥160 dB re 1 µPa$_{rms}$. However, a more meaningful estimate is the one for sound levels ≥170 dB (see below). Also, both estimates for Dall's porpoise are likely overestimates, as Green et al. (1992) noted lower offshore densities during summer and fall compared to spring and winter. The best estimate of the number of exposures of cetaceans to seismic sounds with received levels ≥160 dB re 1 µPa$_{rms}$ during the survey is 8263 (Table 4).

Number of Delphinids and Dall's Porpoises that could be Exposed to ≥170 dB.—The 160-dB criterion, on which the preceding estimates are based, was derived from studies of baleen whales. Odontocete hearing at low frequencies is relatively insensitive, and delphinids generally appear to be more tolerant of strong low-frequency sounds than are many baleen whales. As summarized in Appendix B (5), delphinids and Dall's porpoises commonly occur within distances where received levels would be expected to exceed 160 dB re 1 µPa$_{rms}$. There is no generally accepted alternative "take" criterion for delphinids and Dall's porpoises exposed to airgun sounds. However, the estimates in this subsection assume that only those delphinids exposed to ≥170 dB re 1 µPa$_{rms}$, on average, would be affected sufficiently to be considered "taken by harassment". ("On average" means that some individuals might react significantly upon exposure to levels somewhat <170 dB, but others would not do so even upon exposure to levels somewhat >170 dB.)

The area ensonified by levels ≥170 dB was estimated to be 5374 km^2 (as described above for levels ≥160 dB), and the estimated area, including overlap, is 16,946 km^2. Thus, an average individual marine mammal may be exposed to ≥170 dB three times during the survey. The best estimate of the number of individual delphinids that could be exposed to ≥170 dB for all delphinids during the survey is 393, and the corresponding estimate for Dall's porpoise is 796 (Table 4). These values are based on the predicted 170-dB radii around the airgun array to be used during the study, and are considered to be more realistic estimates of the number of individual delphinids and Dall's porpoises that could be affected.

Number of Pinnipeds that could be Exposed to ≥160 dB and ≥170 dB.—Two of the five pinniped species discussed in § III/IV—the northern fur seal and the northern elephant seal—occur in offshore waters; the other three—the California sea lion, harbor seal, and Steller sea lion—are infrequent there. This conclusion is based on results of extensive aerial surveys conducted from the coast to offshore waters of Oregon and Washington (Bonnell et al. 1992; Green et al. 1993; Buchanan et al. 2001; Carretta et al. 2007). However, the available density data are probably not truly representative of densities that could be encountered during the surveys, as the data were averaged over a umber of months and over coastal, shelf, slope, and offshore waters.

As summarized earlier and in Appendix B, most pinnipeds seem to be less responsive to airgun sounds than are some mysticetes. Thus, the numbers of pinnipeds that could be exposed to received levels ≥170 dB re 1 µPa$_{rms}$ were also calculated, based on the estimated 170-dB radii (Table 1). For operations in deep water, the estimated 160- and 170-dB radii are very likely over-estimates of the actual 160- and 170-dB distances (Tolstoy et al. 2004a,b). Thus, the resulting estimates of the numbers of pinnipeds exposed to such levels may be overestimated.

The methods described previously for cetaceans were also used to calculate exposure numbers for the one pinniped species likely to be in the survey area and whose densities were estimated by Bonnell et al. (1992). Based on the mean densities, 73 northern fur seals could be exposed to airgun sounds ≥160 dB re 1 µPa$_{rms}$; the corresponding numbers that could be exposed to airgun sounds ≥170 dB re 1 µPa$_{rms}$ are 54 northern fur seals. We have not included any estimates for the northern elephant seal, as density estimates were unavailable because of the small number of sightings on systematic transect surveys. However, it is unlikely that any northern elephant seals would be encountered that far offshore.

Conclusions

The proposed seismic project will involve towing an airgun array that introduces pulsed sounds into the ocean, along with, at times, simultaneous operation of an MBES and a SBP. The survey will employ 36-airgun array similar to the airgun arrays used for typical high-energy seismic surveys, but shot intervals will be long (~105 s or 210 s). 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.

Odontocete reactions to seismic pulses, or at least the reactions of delphinids and Dall's porpoises, are expected to extend to lesser distances than are those of mysticetes. Odontocete low-frequency hearing is less sensitive than that of mysticetes, and delphinids and Dall's porpoises are often seen from seismic vessels. In fact, there are documented instances of dolphins and Dall's porpoises approaching active seismic vessels. However, delphinids as well as some other types of odontocetes sometimes show avoidance responses and/or other changes in behavior 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". Furthermore, the estimated numbers of animals potentially exposed to sound levels sufficient to cause appreciable disturbance are generally low percentages of the regional population sizes. The best estimate of the number of individuals that would be exposed to sounds ≥160 dB re 1 μPa_{rms} represent, for most species, <1% of the regional population. For Dall's porpoise, >1% of the regional populations were estimated to be exposed (Table 4).

Varying estimates of the numbers of marine mammals that might be exposed to strong airgun sounds during the proposed program have been presented, depending on the specific exposure criteria (≥160 or ≥170 dB). The requested "take authorization" for each species is based on the estimated number of individuals that could be exposed to ≥160 dB re 1 μPa_{rms}. That figure likely overestimates 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 controlled speed, look outs, non-pursuit, ramp ups, power downs or shut downs when marine mammals are seen within defined ranges, and special measures for species of particular concern, should further reduce short-term reactions, and avoid or minimize any auditory effects. In all cases, the effects are expected to be short-term, with no lasting biological consequence.

Pinnipeds.—A best estimates of 73 northern fur seals could be exposed to airgun sounds with received levels ≥160 dB re 1 μPa$_{\mathrm{rms}}$. This estimate represents 0.01% of the regional population. 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.

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 legal subsistence hunting for marine mammals off the coast of B.C., 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 C and D, 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 very limited (see Appendix D). 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.

The following sections provide a general synopsis of 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 (*Coreogonus 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; Hassel et al. 2003; Popper et al. 2005).

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. 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; 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 (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. Benthic invertebrates in the Endeavour MPA are not expected to be affected by seismic operations, as sound levels from the airguns will diminish dramatically by the time the sound reaches the ocean floor at a depth of ~2250 m.

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 could 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; 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 exposure to commercial seismic survey activities has injured giant squid (Guerra et al. 2004), but there is no evidence to support such claims.

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. Any primary and secondary stress responses (i.e., changes in haemolymph levels of enzymes, proteins, etc.) of crustaceans after exposure to seismic survey sounds appear to be temporary (hours to days) in studies done to date (J. Payne, Department of Fisheries and Oceans [DFO] research scientist, St. John's, NL, Canada, pers. comm.). 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). 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, because operations will be limited in duration (~20 days). 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. Concentrations of marine mammals and/or marine mammal prey species are not expected to occur in or near the proposed study area; the area does not appear to constitute an area of localized or critical feeding, breeding, or migration for any marine mammal species.

A total of 64 OBSs will be deployed during the ETOMO study. Sixteen OBSs will be deployed in the vent field grid (OBSs will be deployed between the vent fields; Fig. 1), and another 48 OBSs will be deployed throughout the remaining study area in the Endeavour MPA. Two different types of OBSs will be used. The WHOI "D2" OBS has an anchor made of hot-rolled steel with dimensions 2.5 x 30.5 x 38.1 cm. The anchor of the LC4x4 OBS consists of a 1 m^2 piece of steel grating. OBS anchors will be left behind upon equipment recovery. Although OBS placement will disrupt a very small area of seafloor habitat and may disturb benthic invertebrates, the impacts are expected to be localized and transitory. Care will be taken to deploy the OBSs in such a way that creates the least disturbance to the area. The vent area is dynamic, and the natural variability within the system is high; toppling and regrowth of sulphide structures, and death of assemblages are common (Tunnicliffe and Thomson 1999). Thus, it is not expected that the placement of OBSs would have adverse effects beyond naturally occurring changes in this environment, and any effects of the planned activity on marine mammal habitats and food resources are expected to be negligible.

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 all applicable Canadian and U.S. federal regulations, including obtaining permission for incidental harassment or incidental 'take' of marine mammals and other endangered species. The proposed activities will take place in the EEZ of 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), Weir and Dolman (2007), and the Statement of Canadian Practice (available at http://www.dfo-mpo.gc.ca/oceans-habitat/oceans/im-gi/seismic-sismique/index_e.asp).

Planning Phase

In designing the proposed seismic survey, L-DEO and NSF have considered potential environmental impacts including seasonal, biological, and weather factors; ship schedules; and equipment availability during a preliminary assessment carried out when ship schedules were still flexible. Part of the considerations was whether the research objectives could be met with a smaller source or with a different survey design that involves less prolonged seismic operations.

Proposed Exclusion Zones

Empirical data concerning 180, 170, and 160 dB re 1 μPa_{rms} distances were acquired for various airgun configurations during the acoustic calibration study of the R/V *Maurice Ewing*'s 20-airgun 8600 in^3 array in 2003 (Tolstoy et al. 2004a,b). The results showed that distances around the airgun array where the received level was 160 dB re 1 μPa_{rms} varied with water depth. Distances around the airgun array where the received levels were 180 and 190 dB re 1 μPa_{rms} were not measured, but similar depth-related variation is likely for those levels.

Received sound levels have been modeled by L-DEO for the 36-airgun array (Fig. 3–6) and for a single 1900LL 40-in^3 airgun (which will be used during power downs; Fig. 7), in relation to distance and direction from the airguns. Based on the modeling for deep water, the distances from the source where sound levels are predicted to be 190, 180, 170, and 160 dB re 1 μPa_{rms} were determined (see Table 1 in § I). The 180- and 190-dB radii vary with tow depth of the airgun array and range up to 1220 m and 380 m, respectively. The 180- and 190-dB levels are shut-down criteria applicable to cetaceans and pinnipeds, respectively, as specified by NMFS (2000); these levels were used to establish the EZs. If the MMO detects marine mammal(s) or turtle(s) within or about to enter the appropriate EZ, 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 ETOMO survey include (1) power-down procedures, (2) shut-down procedures, (3) ramp-up procedures, and (4) special procedures for species of particular concern.

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 can also occur when the vessel is moving from one seismic line to another. During a power down for mitigation, 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, and if the vessel's speed and/or course cannot be changed to avoid having the animal 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 EZ. The animal will be considered to have cleared the EZ if it

- is visually observed to have left the EZ, or
- has not been seen within the zone for 15 min in the case of small odontocetes, or
- 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, i.e., ~5 to 20 min, depending on the sighting distance, vessel speed, and tow-depth [based on the length of time it will take the vessel to leave behind the turtle, so that it is outside the EZ; e.g., if a turtle is sighted close to the vessel, the ship speed is 9.3 km/h, and the tow-depth is 15 m, it would take the vessel ~8 min to leave the turtle behind].

During airgun operations following a power down (or shut down) whose duration has exceeded the limits specified above, the airgun array will be ramped up gradually (see below).

Shut-down Procedures

During a power down, the operating airgun will be shut down if a marine mammal or turtle is seen within or approaching the EZ for the then-operating source, typically a single gun of 40 in^3 (Table 1). The airguns will be shut down if a North Pacific right whale is sighted from the vessel, even if it is located outside the EZ, because of the rarity and sensitive status of this species. Airgun activity will not resume until the marine mammal or turtle has cleared the EZ, or until the visual marine mammal observer (MMVO) is confident that the animal has left the vicinity of the vessel. Criteria for judging that the animal has cleared the EZ 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 cruise, this period would be ~9 min. This period is based on the largest modeled 180-dB radius for the 36-airgun array (see Table 1) in relation to the planned speed of the *Langseth* while shooting (see above). Similar periods (~8–10 min) were used during previous L-DEO surveys.

Ramp up will begin with the smallest gun 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 ~30–40 min. During ramp-up, the MMVOs will monitor the EZ, and if marine mammals or turtles are sighted, a course/speed change, 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 if they choose. 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 close to the vessel at night.

Special Procedures for Species of Particular Concern

The airguns will be shut down if a North Pacific right whale is sighted at any distance from the vessel.

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 NEPO, 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

MMVOs will be based aboard the seismic source vessel and will watch for marine mammals and turtles near the vessel during daytime airgun operations and during any start-ups at night. MMVOs will also watch for marine mammals and turtles near the seismic vessel for at least 30 min. prior to the start of airgun operations after an extended shut down. When feasible, MMVOs will also observe during daytime periods when the seismic system is not operating for comparison of sighting rates and behavior with vs. without airgun operations. Based on MMVO observations, the airguns will be powered or shut down when marine mammals are observed within or about to enter a designated EZ [see § XI above]. The EZ is a region in which a possibility exists of adverse effects on animal hearing or other physical effects.

During seismic operations in the Endeavour MPA, at least three MMVOs will be based aboard the *Langseth*. MMVOs will be appointed by L-DEO with NMFS concurrence. At least one MMVO, and when practical two MMVOs, will monitor marine mammals and turtles near the seismic vessel during ongoing daytime operations and nighttime start ups of the airguns. Use of two simultaneous observers will increase the proportion of the animals present near the source vessel that are detected. MMVO(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 ~18 m above sea level, and the observer will have a good view around the entire vessel. During daytime, the MMO(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 bad weather 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, localization, and tracking 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. When bearings (primary and mirror-image) to calling cetacean(s) are determined, the bearings will be relayed to the visual observer to help him/her sight the calling animal(s).

The PAM system consists of hardware (i.e., hydrophones) and software. The "wet end" of the system consists of a low-noise, towed hydrophone array that is connected to the vessel by a 50- to 100-m long cable. The array will be deployed from a winch located on the back deck. A deck cable will connect from the winch to the main computer lab where the acoustic station and signal conditioning and processing system will be located. The lead-in from the hydrophone array is ~400 m long, and the active part of the hydrophone array is ~50 m long. The hydrophone array is typically towed at depths of 20 to 30 m.

The towed hydrophones will 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. One MMO 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. MMOs monitoring the acoustical data will be on shift for 1–6 h at a time. Besides the visual MMOs, an additional MMO with primary responsibility for PAM will also be aboard. All MMOs 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 acoustic MMO will contact the visual MMO 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.

MMVO Data and Documentation

MMVOs 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 a custom 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. Preliminary reports will be prepared during the field program and summaries forwarded to the operating institution's shore facility and to NSF weekly or more frequently. MMVO observations will provide the following information:

1. The basis for decisions about powering down or shutting down the airguns.
2. Information needed to estimate the number of marine mammals potentially 'taken by harassment'. These data will be reported to NMFS per terms of MMPA authorizations or regulations.
3. Data on the occurrence, distribution, and activities of marine mammals and turtles in the area where the seismic study is conducted.
4. 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, DFO, 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 will coordinate the planned marine mammal monitoring program associated with the ETOMO seismic survey (as summarized in § XI and XIII) with other parties that may have interest in the area and/or be conducting marine mammal studies in the same region during the proposed seismic survey. During the summer of 2009, NEPTUNE Canada will deploy an instrument platform at the Endeavour ridge. This platform will include an acoustic doppler current pofiler, current meter, hydrophone, rotary sonar, bottom pressure recorder, video camera, temperature probe, oxygen sensor, and LED lights. L-DEO and NSF have coordinated, and will continue to coordinate, with applicable Canadian (e.g., DFO) and U.S. agencies (e.g., NMFS), and will comply with their requirements.

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