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 Pacific Ocean off Costa Rica, April–May 2011

submitted by

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to

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15 November 2010

LGL Report TA4926-2

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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 eastern tropical Pacific Ocean (ETP) off Costa Rica during April–May 2011. The survey will take place in the Exclusive Economic Zone (EEZ) of Costa Rica in water depths from <100 m to >2500 m. The airgun array will consist of two towed subarrays of 18 airguns firing alternately, each with a total volume of ~3300 in^3. L-DEO requests that it be issued an Incidental Harassment Authorization (IHA) allowing non-lethal takes of marine mammals incidental to the planned seismic survey. This request is submitted pursuant to Section 101 (a) (5) (D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371 (a) (5).

Numerous species of cetaceans and pinnipeds inhabit the ETP. Several of these species are listed as ***endangered*** under the ESA, including the humpback, sei, fin, blue, and sperm whales. Other ESA-listed species that could occur in the study area include the ***endangered*** hawksbill and leatherback turtles, the ***threatened*** green, loggerhead, and olive ridley turtles, and the ***endangered*** California least tern.

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

I. OPERATIONS TO BE CONDUCTED

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

Overview of the Activity

L-DEO plans to conduct a seismic survey in the eastern tropical Pacific Ocean (ETP) off Costa Rica. The survey will encompass the area 8.5–9°N, 83.75–84.25°W (Fig. 1). Water depths in the survey area range from <100 m to >2500 m. The project is scheduled to occur ~7 April–9 May 2011. Some minor deviation from these dates is possible, depending on logistics and weather.

L-DEO plans to use 3D seismic reflection techniques to image the structures along a major plate-boundary fault off Costa Rica that has a history of generating large earthquakes and tsunamis. The 3D seismic reflection data will be used to determine the fault structure and the properties of the rocks that lie along the fault zone. These properties evolve with depth into the subduction zone and change the earthquake behavior of the fault. The main goal is to map the down dip variation in the properties to assess the property changes along the fault and determine where the large stress accumulations that lead to large earthquakes occur along the fault zone.

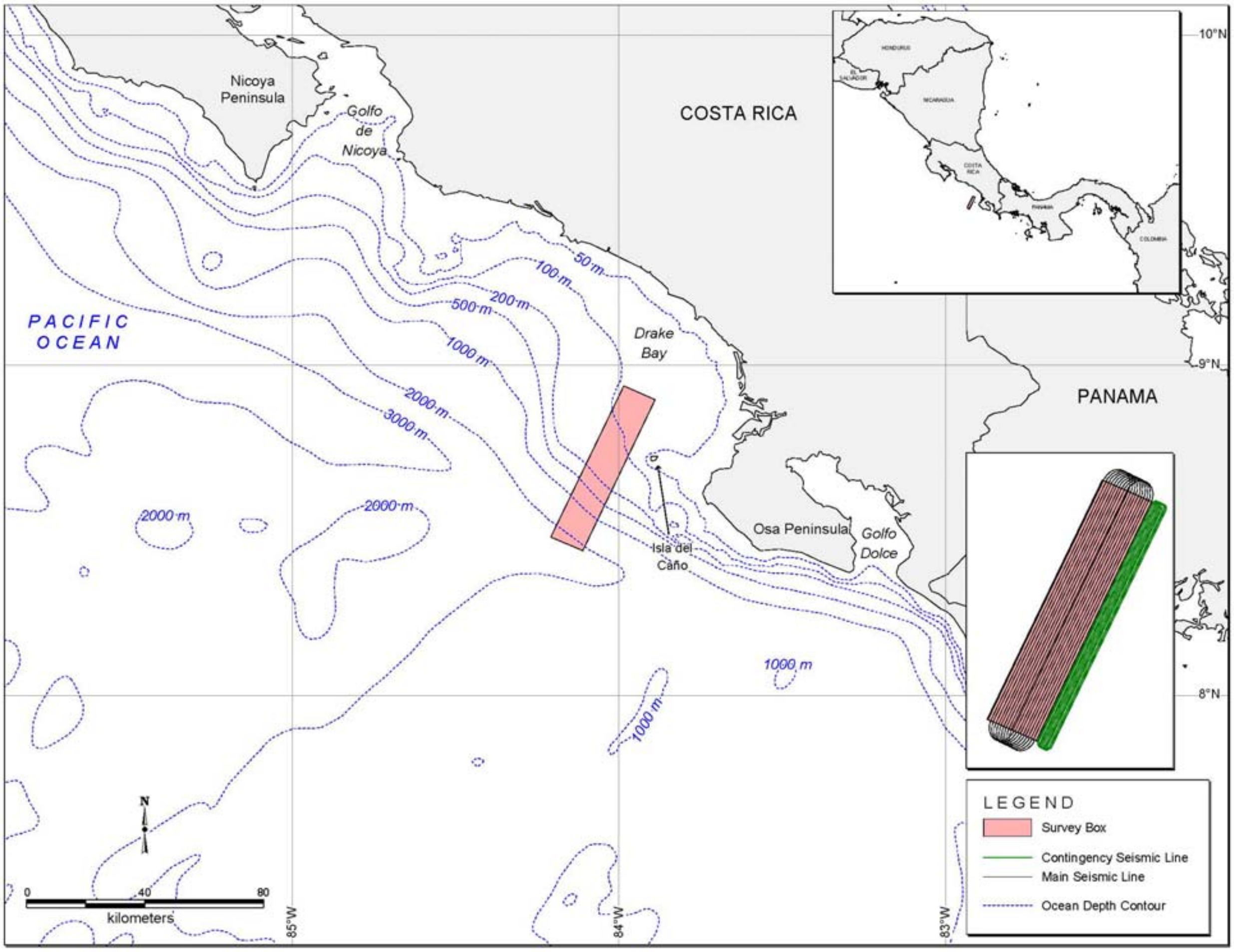

FIGURE 1. Study area and proposed seismic transect lines for the L-DEO survey planned for April–May 2011 in the ETP off Costa Rica.

The survey will involve one source vessel, the R/V *Marcus G. Langseth*. The *Langseth* will deploy a 36-airgun array as an energy source. However, two identical two-string sources will be firing alternately, so that no more than 18 airguns will be firing at any time. The maximum discharge volume will be 3300 in^3. The receiving system will consist of four 6-km long hydrophone streamers. As the airgun array is towed along the survey lines, the hydrophone streamer will receive the returning acoustic signals and transfer the data to the on-board processing system. Two or three small fishing vessels will be in the water in front of and behind the *Langseth* to ensure that other vessels do not entangle the streamers.

The survey is a multichannel seismic (MCS) reflection survey in a 3D configuration. The survey will consist of a racetrack configuration with a total of 19 loops that will cover an area of ~57 x 12 km (Fig. 1). The lines will be spaced 300 m apart. The planned seismic survey will consist of ~2145 km of transect lines, with an additional 365 km of turns. The array will be powered down to one 40-in^3 airgun during turns. 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 § IV(3)), 25% has been added for those additional operations. If the planned contingency time is not used up, an additional 12 lines 300 m apart will be surveyed to the southeast side of the original survey area. These contingency lines will consist of ~675 km of transect lines, with an additional 30 km of turns.

Survey effort including turns and contingency will be 835, 1360, and 1020 km in water depths >1000 m, 100–1000 m, and <100 m, respectively, for a total of 3215 km.

All planned geophysical data acquisition activities will be conducted by L-DEO with on-board assistance by the scientists who have proposed the study. The Principal Investigators are Drs. Nathan Bangs and Kirk McIntosh (Institute for Geophysics, University of Texas) and Dr. Eli Silver (University of California at Santa Cruz). The vessel will be self-contained, and the crew will live aboard the vessel for the entire cruise. As noted above, small vessels will accompany the *Langseth* to protect the streamers.

Vessel Specifications

The R/V *Marcus G. Langseth* will be used as the source vessel. The *Langseth* will tow the 18-airgun subarrays and four streamers along predetermined lines (Fig. 1). When the *Langseth* is towing the airgun array as well as the hydrophone streamer, the turning rate of the vessel while the gear is deployed is limited to five degrees per minute. Thus, the maneuverability of the vessel is limited during operations with the streamer.

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

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

Other details of the *Langseth* include the following:

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

Airgun Description

During the survey, the airgun array to be used will consist of two subarrays of 18 airguns, each with a total volume of ~3300 in^3. The airgun array will consist of a mixture of Bolt 1500LL and Bolt 1900LLX airguns. The airguns in each subarray will be configured as two 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 subarrays will be fired alternately during the survey. Each of the two subarrays will be towed ~140 m behind the vessel and will be distributed across an area of ~12×16 m behind the *Langseth*, offset by 75 m. The shot interval will be 25 m during the study. The firing pressure of the subarrays is 1900 psi. During firing, a brief (~0.1 s) pulse of sound is emitted. The airguns will be silent during the intervening periods.

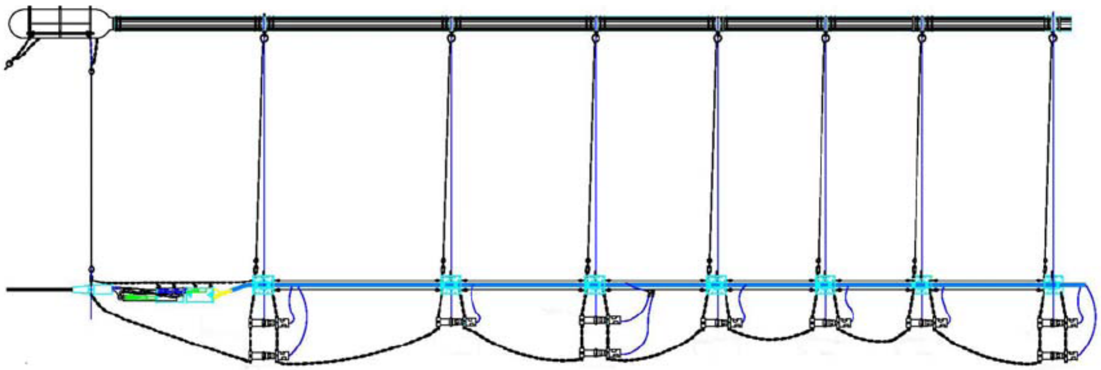

FIGURE 2. One linear airgun array or string with ten airguns, nine of which would be operating.

The tow depth of the array will be ~7 m. Because the actual source is a distributed sound source (18 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.

18-Airgun Array (2 Strings) Specifications

Energy Source	Eighteen 2000 psi Bolt airguns of 40–360 in^3
Source output (downward)	0-pk is 42 bar-m (252 dB re 1 μPa·m); pk-pk is 87 bar-m (259 dB)
Towing depth of energy source	~7 m
Air discharge volume	~3300 in^3
Dominant frequency components	0–188 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 with 18 airguns firing (Fig. 3) and for a single 1900LL 40-in^3 airgun, which will be used during power downs (Fig. 4). The maximum relevant depth (2000 m) applicable to marine mammals was used for predicting exclusion zones (see below). A detailed description of the modeling effort is provided in Appendix A of the Environmental Assessment (EA).

The predicted sound contours are shown as sound exposure levels (SEL) in decibels (dB) re 1 $\mu Pa^2 \cdot s$. SEL is a measure of the received energy in the pulse and represents the sound pressure level (SPL) that would be measured if the pulse energy were spread evenly across a 1-s period. Because actual seismic pulses are less than 1 s in duration in most situations, this means that the SEL value for a given pulse is usually lower than the SPL calculated for the actual duration of the pulse (see Appendix B of 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

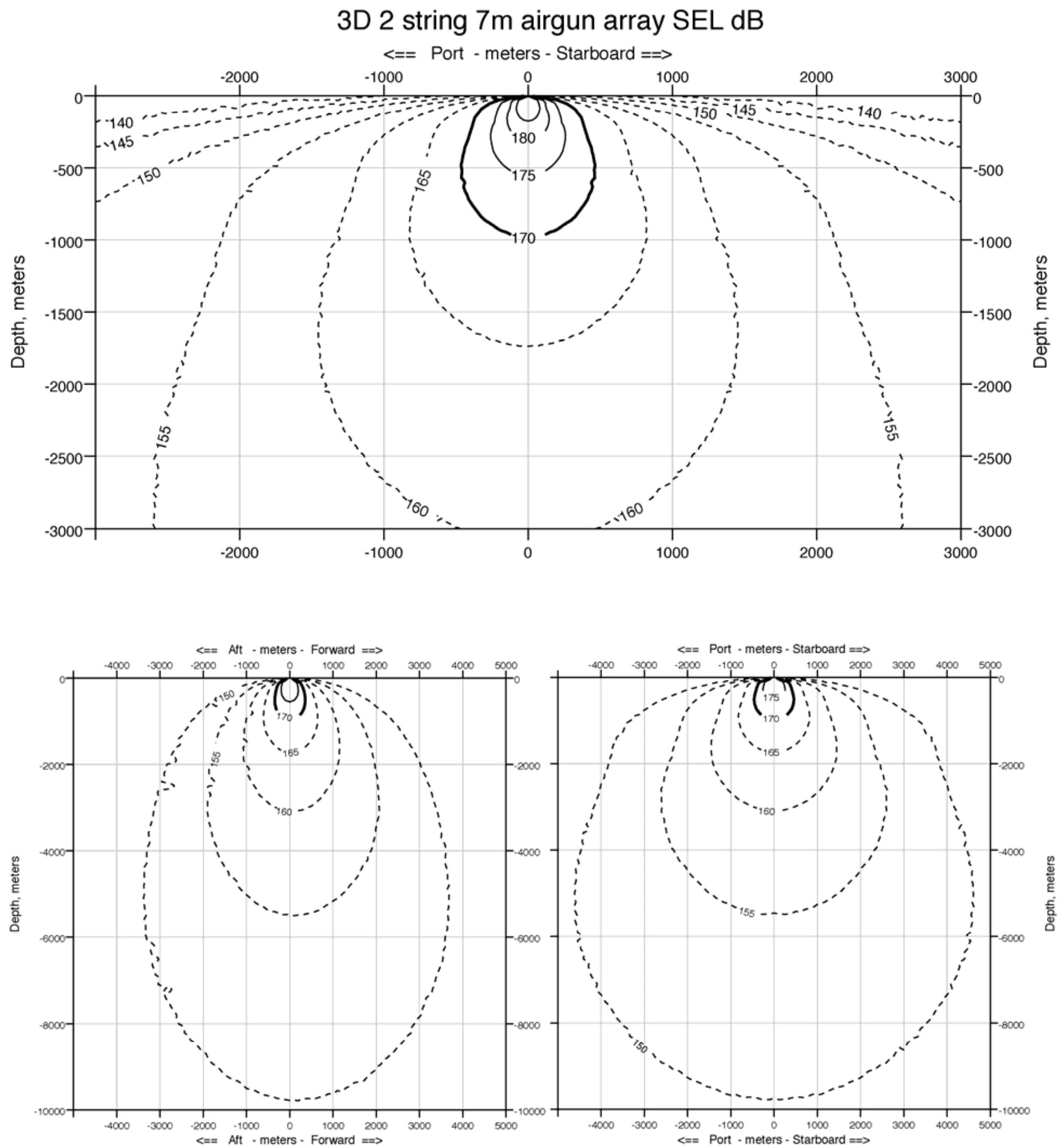

FIGURE 3. Modeled received sound levels (SELs) from the 18-airgun subarray planned for use during the survey in the ETP during April–May 2011. Received rms levels (SPLs) are expected to be ~10 dB higher.

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 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

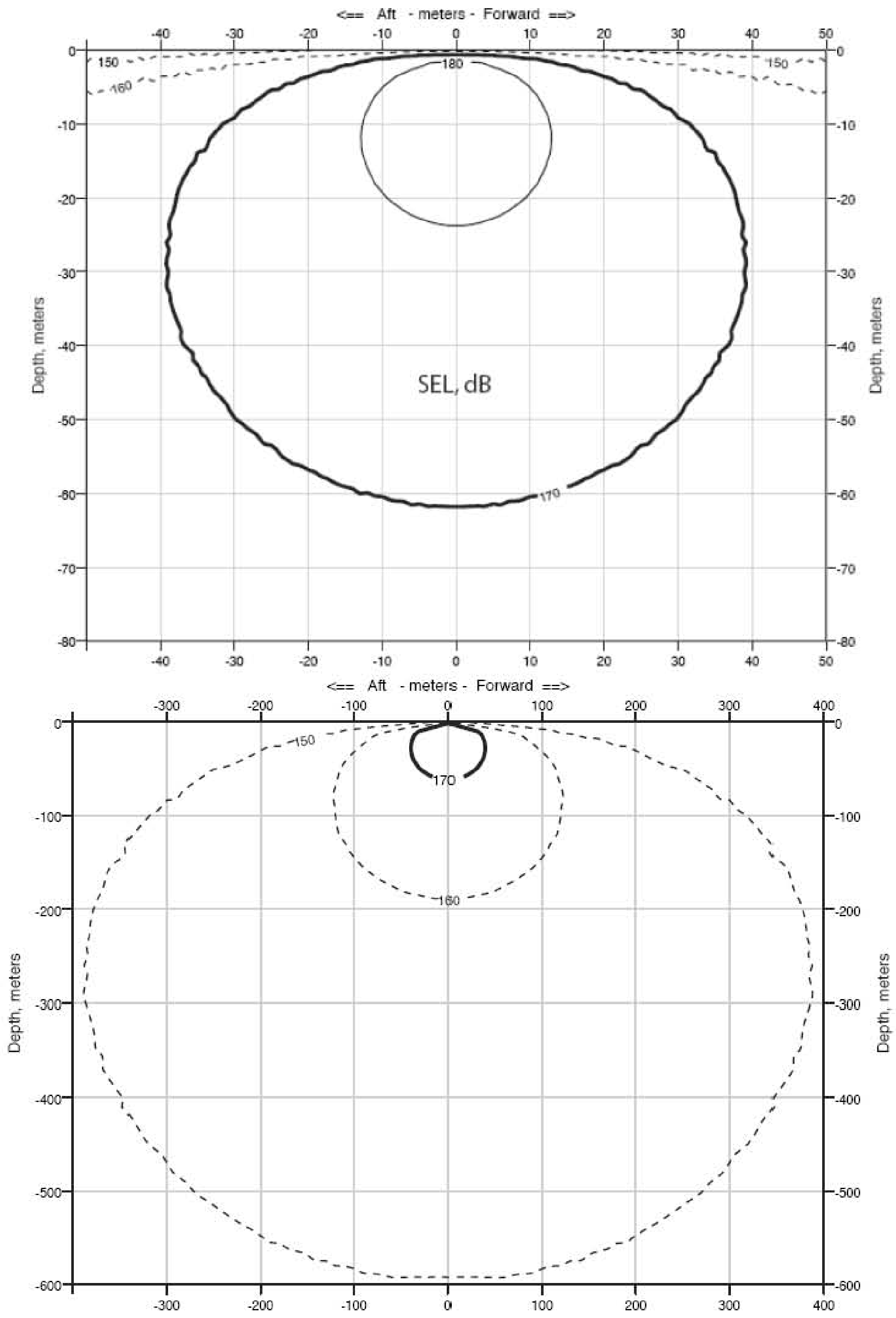

FIGURE 4. Modeled received sound levels (SELs) from a single 40-in^3 airgun operating in deep water, which is planned for use during the survey in the ETP during April–May 2011. Received rms levels (SPLs) are expected to be ~10 dB higher.

re 1 μPa_{rms}. It should be noted that neither the SEL nor the SPL (=rms) measure is directly comparable to the peak or peak-to-peak pressure levels normally used by geophysicists to characterize source levels of airguns. Peak and peak-to-peak pressure levels for airgun pulses are always higher than the rms dB referred to in much of the biological literature (Greene 1997; McCauley et al. 1998, 2000a). For example, a measured received level of 160 dB re 1 μPa_{rms} in the far field typically would correspond to a peak measurement of ~170–172 dB re 1 μPa, and to a peak-to-peak measurement of ~176–178 dB re 1 μPa, as measured for the same pulse received at the same location (Greene 1997; McCauley et al. 1998, 2000a). (The SEL value for the same pulse would normally be 145–150 dB re 1 μ$Pa^2 \cdot s$). The precise difference between rms and peak or peak-to-peak values for a given pulse depends on the frequency content and duration of the pulse, among other factors. However, the rms level is always lower than the peak or peak-to-peak level and (for an airgun-type source at the ranges relevant here) higher than the SEL value.

Predicted Sound Levels

Empirical data concerning propagation distances in deep (~1600 m) and shallow (~50 m) water were acquired for the 36-airgun, 6600-in^3 array during the acoustic calibration study of the R/V *Marcus G. Langseth* in the Gulf of Mexico in 2007–2008 (Tolstoy et al. 2009). The results showed that radii around the array where the received levels were 190, 180, 170, and 160 dB re 1 μPa_{rms} varied with water depth. The L-DEO model does not allow for bottom interactions, and thus is most directly applicable to deep water and to relatively short ranges. During the proposed study, survey effort including contingency will be 835, 1360, and 1020 km in water depths >1000 m, 100–1000 m, and <100 m, respectively.

- The empirical data indicated that, for ***deep water*** (>1000 m), the L-DEO model (as applied to the *Langseth*'s 36-airgun array) ***overestimated*** the measured received sound levels at a given distance (Tolstoy et al. 2009). However, to be conservative, the modeled distances shown in Figure 3 for the *Langseth's* 18-airgun subarray will be applied to deep-water areas during the proposed study (Table 1). As very few, if any, mammals are expected to occur below 2000 m, this depth was used as the maximum relevant depth.

- Empirical measurements for the *Langseth* indicated that in ***shallow water*** (<100 m), the L-DEO model ***underestimates*** actual levels. For the 36-airgun array, the distances measured in shallow-water to the 160–190 dB isopleths ranged from 1.7 to 5.2× higher than the distances in deep-water (Tolstoy et al. 2009). During the proposed cruise, the same factors will be applied to derive appropriate shallow-water radii from the modeled deep-water radii for the *Langseth*'s 18-airgun subarray (Table 1).

- Empirical measurements of sounds from the *Langseth*'s airgun array were not acquired for ***intermediate depths*** (100–1000 m). On the expectation that results will be intermediate between those from shallow and deep water, a correction factor of 1.5× will be applied to the estimates provided by the model for the 18-airgun subarray operating in deep-water situations to obtain estimates for intermediate-depth sites (Table 1).

Modeling conducted for a previous L-DEO survey off Costa Rica using site-specific data on sound velocity profiles in the water column and bottom composition at a depth of 65 m in Drake Bay (at the proposed survey area) and a depth of 340 m ~100 km north of there resulted in much smaller radii than those in Table 1 (288–2121 m and 295–4511 m, respectively). This suggests that the radii estimated in Table 1 for shallow and intermediate depth ranges are overestimates, and thus precautionary. Also, the estimated 160-dB distance for the 18-gun subarray in water depths <100 m (Table 1) is higher than the measured distance for the 36-gun array (17.5 km; Tolstoy et al. 2009), again suggesting that the estimates are precautionary.

TABLE 1. Predicted distances to which sound levels ≥190, 180, 170, and 160 dB re 1 μPa_{rms} could be received during the proposed survey during April–May 2011 using an 18-airgun, 3300-in^3 subarray towed at a depth of 7 m. Radii are based on Figures 3 and 4, assuming that received levels on an RMS basis are, numerically, 10 dB higher than the SEL values shown in Figures 3 and 4.

		Predicted RMS Radii (m)			
Source and Volume	**Water Depth**	**190 dB**	**180 dB**	**170 dB**	**160 dB**
Single Bolt airgun (40 $in^{3)}$	>1000 m	12	40	120	385
	100–1000 m	18	60	180	578
	<100 m	150	296	500	1050
18-airgun subarray (3300 in^3)	>1000 m	140	450	1400	3800
	100–1000 m	210	675	2100	5700
	<100 m	235	1030	4550	19,500[1]

[1] This is likely an overestimate, as the measured distance for the 36-gun array operating in shallow waters of the northern Gulf of Mexico was 17.5 km .

Table 1 shows the distances at which four rms sound levels are expected to be received from the 18-airgun subarray and a single airgun. The 180- and 190-dB re 1 μPa_{rms} distances are the safety criteria as specified by NMFS (2000) and are applicable to cetaceans and pinnipeds, respectively. The 180-dB distance will also be used as the exclusion zone for sea turtles, as required by NMFS in most other recent seismic projects (e.g., Smultea et al. 2004; Holst et al. 2005a,b; Holst and Beland 2008; Holst and Smultea 2008). If marine mammals or turtles are detected within or about to enter the appropriate exclusion zone, the airguns will be powered down (or shut down if necessary) immediately.

Southall et al. (2007) made detailed recommendations for new science-based noise exposure criteria. L-DEO will be prepared to revise its procedures for estimating numbers of mammals “taken”, EZs, etc., as may be required by any new guidelines established by NMFS as a result of these recommendations. However, currently the procedures are based on best practices noted by Pierson et al. (1998) and Weir and Dolman (2007) as NMFS has not yet specified a new procedure for determining 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 tow depth of ~7 m. Two identical two-string subarrays will be firing alternately, so that no more than 18 airguns will be firing at any time. The maximum discharge volume will be 3300 in^3. The receiving system will consist of four 6-km long hydrophone streamers. As the airgun array is towed along the survey lines, the hydrophone streamer will receive the returning acoustic signals and transfer the data to the on-board processing system.

The planned seismic survey will consist of ~2510 km of transect lines (including turns), plus a contingency of 705 km of transect lines (including turns) if time permits (Fig. 1). Survey effort including turns and contingency will be 835, 1360, and 1020 km in water depths >1000 m, 100–1000 m, and <100 m, respectively, for a total of 3215 km. In addition to the operations of the airgun array, a Kongsberg EM 122 multibeam echosounder (MBES) and a Knudsen 320B sub-bottom profiler (SBP) will also be operated from the *Langseth* continuously throughout the cruise.

Multibeam Echosounder and Sub-bottom Profiler

Along with the airgun operations, two additional acoustical data acquisition systems will be operated during the survey. The ocean floor will be mapped with the Kongsberg EM 122 MBES and a Knudsen 320B SBP. These sound sources will be operated from the *Langseth* continuously throughout the cruise.

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

The Knudsen 320B SBP is normally operated to provide information about the sedimentary features and the bottom topography that is being mapped simultaneously by the MBES. The beam is transmitted as a 27º cone, which is directed downward by a 3.5-kHz transducer in the hull of the *Langseth*. The maximum output is 1000 watts (204 dB), but in practice, the output varies with water depth. 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.

***Langseth* Sub-bottom Profiler Specifications**

Maximum source output (downward)	204 dB re 1 μPa·m; 800 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 survey will encompass the area 8.5–9°N, 83.75–84.25°W in the EEZ of Costa Rica (Fig. 1). Water depths in the survey area range from <100 m to >2500 m. The closest that the vessel will approach to the coast is ~30 km. The exact dates of the activities depend on logistics and weather conditions. The Langseth will depart from Puerto Caldera on 7 April and return there on 9 May 2011. Seismic operations will be carried out for an estimated 25–26 (maximum 28) days.

III. Species and Numbers of Marine Mammals in Area

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

Twenty-eight species of marine mammals, including 20 odontocetes, 6 mysticetes, and 2 pinnipeds are known to occur in Costa Rican Pacific waters (May-Collado 2009). Two pinniped species could potentially occur in the proposed survey area on rare occasions (Table 2). Information on the occurrence, distribution, population size, and conservation status for each of the 28 marine mammal species that may occur in the proposed study area is presented in Table 2. The status of these species is based on the ESA, the IUCN Red List of Threatened Species, the Convention on International Trade in Endangered Species (CITES), and NatureServe (an international network of biological inventories that provides conservation status ranks for Latin America). Several of these species are listed under the ESA as endangered, including the sperm, humpback, fin, sei, and blue whales.

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.

Mysticetes

Humpback Whale

The humpback whale is listed as ***Endangered*** under the U.S. ESA and ***Least Concern*** on the 2010 IUCN Red List of Threatened Species (IUCN 2010), and is listed in CITES Appendix I (UNEP-WCMC 2010). The worldwide population of humpback whales is divided into various northern and southern ocean populations (Mackintosh 1965). Geographical overlap of these populations has been documented only off Central America (Acevedo and Smultea 1995; Rasmussen et al. 2004, 2007; Rasmussen 2006). The humpback whale is one of the most abundant cetaceans off the Pacific coast of Costa Rica during the winter breeding season of northern hemisphere humpbacks. Humpbacks are also observed off the coast of Costa Rica during the winter breeding period for southern hemisphere humpbacks (e.g., Rasmussen et al. 2004; Rasmussen 2006). The estimate of abundance for the California/Oregon/Washington humpback whale stock is 1392 (Carretta et al. 2010), and the estimated abundance for the southeast Pacific stock is ~2900 (Félix et al. 2005)

Humpback whales occur worldwide, migrating from tropical breeding areas to polar or sub-polar feeding areas (Jefferson et al. 2008). Although the humpback whale is considered mainly a coastal species, it often traverses deep pelagic areas while migrating (Clapham and Mattila 1990; Norris et al. 1999; Calambokidis et al. 2001). Some males occur in waters >3000 m deep and up to 57 km from the coast in the Caribbean Sea (Swartz et al. 2003). Humpbacks were found primarily in water depths ≤50 m in the Pacific Ocean off southern Costa Rica during 1996–2004 surveys (Rasmussen et al. 2004).

Humpback whales are often sighted singly or in groups of two or three, but while on breeding and feeding grounds they may occur in groups of >20 (Leatherwood and Reeves 1983; Jefferson et al. 2008). Rasmussen (2006) reported a group size of 1.7 for coastal surveys conducted off the northwest side of the Osa Peninsula between 1996 and 2004. Based on NMFS vessel-based surveys in the ETP in July–December 2006, Jackson et al. (2008) reported a mean group size of 1.5 (n = 11). The diving behavior of humpback whales is related to time of year and whale activity (Clapham and Mead 1999). In summer feeding areas, humpbacks typically forage in the upper 120 m of the water column, with a maximum recorded dive depth of 500 m (Dolphin 1987; Dietz et al. 2002). On winter breeding grounds, humpback dives have been recorded at depths >100 m (Baird et al. 2000).

TABLE 2. The habitat, regional abundance, and conservation status of marine mammals that could occur in or near the proposed seismic survey areas in the ETP.

Species	Occurrence in survey area during April–May	Habitat	Abundance in the ETP[1]	ESA[2]	IUCN[3]	CITES[4]	Nature Serve[5]
Mysticetes							
Humpback whale	Very rare	Mainly nearshore waters and banks	NE Pacific 1392[6]; SE Pacific 2900[7]	EN	LC	I	G4
Common minke whale	Very rare	Coastal	N.A.	NL	LC	I	G5
Bryde's whale	Uncommon	Pelagic and coastal	13,000[8]	NL	DD	I	G4
Sei whale	Very rare	Mostly pelagic	N.A.	EN	EN	I	G3
Fin whale	Very rare	Slope, mostly pelagic	2636[6]	EN	EN	I	G3G4
Blue whale	Rare	Pelagic and coastal	1415[9]	EN	EN	I	G3G4
Odontocetes							
Sperm whale	Uncommon	Usually deep pelagic, steep topography	26,053[10]	EN	VU	I	G3G4
Pygmy sperm whale	Very rare	Deep waters off shelf	N.A.[11]	NL	DD	II	G4
Dwarf sperm whale	Rare	Deep waters off shelf	11,200[12]	NL	DD	II	G4
Cuvier's beaked whale	Uncommon	Slope and pelagic	20,000[9]	NL	LC	II	G4
Pygmy beaked whale	Very rare	Pelagic	25,300[13]	NL	DD	II	GNR
Ginkgo-toothed beaked whale	Very rare	Pelagic	25,300[13]	NL	DD	II	G3
Blainville's beaked whale	Rare	Pelagic	25,300[13]	NL	DD	II	G4
Rough-toothed dolphin	Common	Mainly pelagic	107,633	NL	LC	II	G4
Bottlenose dolphin	Very common	Coastal, shelf, pelagic	335,834	NL	LC	II	G5
Pantropical spotted dolphin	Very common	Coastal and pelagic	1,575,247[14]	NL	LC	II	G5
Spinner dolphin	Common	Coastal and pelagic	1,797,716[14]	NL	DD	II	G5
Striped dolphin	Uncommon	Off continental shelf	964,362	NL	LC	II	G5
Fraser's dolphin	Rare	Pelagic	289,300[9]	NL	LC	II	G4
Short-beaked common dolphin	Common	Shelf, pelagic, high relief	3,127,203	NL	LC	II	G5
Risso's dolphin	Common	Shelf, slope, seamounts	110,457	NL	LC	II	G5
Melon-headed whale	Rare	Pelagic	45,400[9]	NL	LC	II	G4
Pygmy killer whale	Rare	Pelagic	38,900[9]	NL	DD	II	G4
False killer whale	Uncommon	Pelagic	39,800[9]	NL	DD	II	G4
Killer whale	Rare	Widely distributed	8500[15]	NL	DD	II	G4G5
Short-finned pilot whale	Common	Mostly pelagic, high-relief	589,315[16]	NL	DD	II	G5
Pinnipeds							
California sea lion	Very rare	Coastal, shelf	238,000[17]	NL	LC	NL	G5
Galápagos sea lion	Very rare	Coastal	14,000-16,000[18]	NL	EN	NL	GNR

N.A. Not available or not assessed.
[1] Abundance from Gerrodette et al. (2008) unless otherwise stated.
[2] U.S. Endangered Species Act: EN = Endangered, T = Threatened, NL = Not listed
[3] Codes for IUCN classifications: EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient. Classifications are from the 2010 IUCN *Red List of Threatened Species* (IUCN 2010).
[4] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2010); NL = Not listed.
[5] NatureServe Status (NatureServe 2009); GNR = unranked, G2 = Imperiled, G3 = Vulnerable, G4 = Apparently secure; G5 = Secure.
[6] U.S. west coast (Carretta et al. 2010).
[7] Southeast Pacific; Félix et al. (2005).
[8] This estimate is mainly for *Balaenoptera edeni* but may include some *B. borealis* (Wade and Gerrodette 1993).
[9] ETP (Wade and Gerrodette 1993).
[10] Eastern temperate North Pacific (Whitehead 2002).
[11] California/Oregon/Washington (Carretta et al. 2010).
[12] This abundance estimate is mostly for *K. sima* but may also include some *K. breviceps* (Wade and Gerrodette 1993).
[13] This estimate includes all species of the genus *Mesoplodon* in the ETP (Wade and Gerrodette 1993).
[14] For all stocks in ETP.
[15] ETP (Ford 2002).
[16] This estimate is for *G. macrorhynchus* and *G. melas* in the ETP (Gerrodette and Forcada 2002).
[17] U.S. stock (Carretta et al. 2010).
[18] Galapagos Islands (Alava and Salazar 2006).

Humpback whales are seasonally abundant in Costa Rica Pacific waters (May-Collado 2009). Northern hemisphere humpback whales are commonly observed from January to April, and southern hemisphere humpbacks are observed from July to October (Rasmussen 2006; May-Collado 2009). By spring, most of the northeast Pacific humpbacks have migrated north to summer feeding grounds off the coast of California (Steiger et al. 1991; Urbán et al. 2000; Rasmussen et al. 2004; May-Collado et al. 2005). By late fall, most of the southern hemisphere humpback whales in Costa Rica have migrated south to feeding grounds off the Antarctic Peninsula (Rasmussen 2006). However, humpback whale sightings in Costa Rica waters have been reported in all months of the year (T. Gerrodette, pers. comm. *in* Rasmussen 2006).

Rasmussen et al. (2004) reported 40 humpback whale sightings around the Osa Peninsula based on survey effort from January to mid March 2001–2003. Whales were most often found around the north-western edge of the Peninsula. Calambokidis et al. (2010) recorded 56 humpback whale sightings during a two-week survey along the Osa Peninsula in January–February 2010. May-Collado et al. (2005) reported 186 sightings of 246 humpbacks in 1979–2001 off Costa Rica, primarily during January–March, all close to shore and concentrated in Drake Bay and the northern Osa Peninsula.

Two sightings of individual humpback whales were observed ~100 km northeast of the proposed survey area along the 50-m depth contour during an L-DEO seismic program off Costa Rica and Nicaragua in February–March 2008 (Holst and Smultea 2008).

Humpback whales are likely to be very rare in the proposed survey area at the time of the survey (mid April to mid May).

Minke Whale

The minke whale inhabits all oceans of the world from the high latitudes to near the equator (Jefferson et al. 2008). In the Northern Hemisphere, minke whales are usually seen in coastal areas but can be seen in pelagic waters during northward migrations in spring and summer and southward migration in autumn (Stewart and Leatherwood 1985). There is no estimate of abundance available for the ETP.

Minke whales are relatively solitary, but may occur in aggregations of up to 100 where food resources are concentrated (Jefferson et al. 2008). Based on SWFSC vessel surveys from 1991 to 2005, Barlow and Forney (2007) reported a mean group size of 1.6 (n = 4) off southern California. No mean group size information is available for the ETP. Little is known about the diving behavior of minke whales, but they are not known to make prolonged deep dives (Leatherwood and Reeves 1983).

The general distribution of minke whales includes the offshore and coastal waters of the study area (e.g., Reeves et al. 2002), and the species has been found off the coast of Costa Rica on occasion (Rodríguez-Herrera et al. 2002). However, minke whales are likely to be rare in the survey area. Rasmussen et al. (2004) did not report any minke whale sightings in annual winter surveys (1996–2003) off Costa Rica. May-Collado et al. (2005) also did not report any minkes in Costa Rica waters based on surveys from 1979–2001, nor have minkes been reported among compiled strandings off Costa Rica (Rodríguez-Fonseca and Cubero-Pardo 2001).

Neither Jackson et al. (2004) nor Jackson et al. (2008) positively identified minke whales in or near the proposed survey area during surveys conducted during July–December. No minke whales were observed during L-DEO seismic surveys off Costa Rica or Nicaragua in November–December 2004 or February–March 2008 (Holst et al. 2005a; Holst and Smultea 2008). Minke whales are unlikely to occur in the proposed survey area, thus no encounters are expected and no takes are requested.

Bryde's Whale

Bryde's whale occurs in tropical and subtropical waters, generally between 40°N and 40°S (Jefferson et al. 2008). Long confused with sei whales (*Balaenoptera borealis*), *B. edeni* was named in 1913 and *B. brydei* was named in 1950, although it is still uncertain whether the two are distinct species or subspecies. Here, we follow Kato (2002) in recognizing the uncertainty and using *B. edeni/brydei*.

Bryde's whale is common throughout the ETP, with a concentration near the equator east of 110ºW, decreasing west of 140ºW (Lee 1993; Wade and Gerrodette 1993). Wade and Gerrodette (1993) estimated Bryde's whale population size in the ETP at 13,000, based on data collected during 1986–1990. This species has also been sighted off Columbia and Ecuador (Gallardo et al. 1983), and may occur around the Galápagos Islands (Clarke and Aguayo 1965 *in* Gallardo et al. 1983). The International Whaling Commission (IWC) recognizes a cross-equatorial or Peruvian stock of Bryde's whale (Donovan 1991).

Bryde's whale is known to occur in both shallow coastal and deeper offshore waters (Jefferson et al. 2008). It does not undertake long migrations, although there is a general pattern of movement toward the equator in winter and toward higher latitudes in summer (Kato 2002). Bryde's whales are usually solitary or in pairs, although groups of 10–20 are known from feeding grounds (Jefferson et al. 2008). Romero et al. (2001) reported that 78% of all sightings off Venezuela were of single animals. Wade and Gerrodette (1993) reported a mean group size of 1.7 (n = 109) for the ETP. The durations of Bryde's whale dives are 1–20 min (Cummings 1985).

Based on the SWFSC surveys and model used to calculate densities in the project area in § IV(3), Bryde's whale is the most common mysticete in the survey area. Off Costa Rica, May-Collado et al. (2005) reported at least 16 and possibly up to 24 sightings of at least 32 (possibly up to 43) Bryde's whales in 1979–2001; these numbers are uncertain because it is now surmised that early reports of Bryde's/sei whales in this region were most likely Bryde's whales. Both Bryde's whale and Bryde's/sei whale sightings occurred from coastal to oceanic waters off Costa Rica. Rasmussen et al. (2004) reported one sighting of a Bryde's whale in January–March in annual surveys (1996–2003) off Costa Rica and from 2001 to 2003 off Panama. Jackson et al. (2008) did not encounter Bryde's whales near the project area during July–December 2006 surveys. One Bryde's whale stranding on the central Pacific coast at Playa Bandera was reported during 1966–1999 (Rodríguez-Fonseca and Cubero-Pardo 2001).

No Bryde's whales were sighted during L-DEO seismic surveys off Costa Rica or Nicaragua in November–December 2004 or February–March 2008 (Holst et al. 2005a; Holst and Smultea 2008).

Sei Whale

The sei whale is listed as ***Endangered*** under the U.S. ESA and on the 2010 IUCN Red List of Threatened Species (IUCN 2010), and is listed in CITES Appendix I (UNEP-WCMC 2010). Sei whale populations were depleted by whaling, and the current status is generally uncertain (Horwood 1987). The global population size is unknown but thought to be small.

The sei whale has a nearly cosmopolitan distribution, with a marked preference for temperate oceanic waters, and is rarely seen in coastal waters (Gambell 1985a). 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). Sei whales appear to prefer regions of steep bathymetric relief such as the continental shelf break, seamounts, and canyons (Kenney and Winn 1987; Gregr and Trites 2001). On feeding grounds, they associate with oceanic frontal systems (Horwood 1987) such as the cold eastern currents in the North Pacific (Perry et al. 1999).

Sei whales are frequently seen in groups of 2–5 (Leatherwood et al. 1988; Jefferson et al. 2008), although larger groups sometimes form on feeding grounds (Gambell 1985a). Based on NMFS vessel surveys in the ETP during July–December 2006, Jackson et al. (2008) reported mean group sizes for tentative sei whale sightings (may have been Bryde's whales, see above) of 1.3 (n = 21). Sei whales generally do not dive deeply, and dive durations are 15 min or longer (Gambell 1985a).

Sei whales may have been sighted during surveys in the ETP (Wade and Gerrodette 1993; Kinzey et al. 1999, 2000, 2001); however, it is difficult to distinguish sei whales from Bryde's whales at sea. Because sei whales generally have a more northerly and temperate distribution (Leatherwood et al. 1988), Wade and Gerrodette (1993) classified any tentative sei whale observations in the ETP as Bryde's whale sightings. Sei whales may also have been sighted near the Galápagos Islands (Clarke 1962 *in* Gallardo et al. 1983), although Clarke and Aguayo (1965 *in* Gallardo et al. 1983) suggested that those sightings could have been Bryde's whales. Although the occurrence of sei whale is documented off Costa Rica (Rodríguez-Herrera et al. 2002), the reliability of the identification is uncertain.

Sei whales are likely to be very rare in the survey area. Neither Ferguson and Barlow (2001) nor Jackson et al. (2004, 2008) positively identified sei whales in or near the proposed survey area during surveys conducted during July–December. Similarly, Rasmussen et al. (2004) did not report sei whales in annual surveys off Costa Rica. No sei whales were detected during L-DEO seismic surveys off Costa Rica in November–December 2004 or February–March 2008 (Holst et al. 2005a; Holst and Smultea 2008).

Fin Whale

The fin whale is listed as ***Endangered*** under the U.S. ESA and on the 2010 IUCN Red List of Threatened Species (IUCN 2010), and is listed in CITES Appendix I (UNEP-WCMC 2010). Based on 2001 and 2005 surveys, the California/Oregon/Washington Stock of fin whales was estimated at 2636 (Carretta et al. 2010).

Fin whales are widely distributed in all the world's oceans in coastal, shelf, and oceanic waters, but typically occur in temperate and polar regions (Gambell 1985b; Perry et al. 1999; Gregr and Trites 2001; Jefferson et al. 2008). The North Pacific population summers from the Chukchi Sea to California, and winters from California southward (Gambell 1985b). Fin whales from the Southern Hemisphere are usually distributed south of 50ºS in the austral summer (Gambell 1985b). The Chile–Peruvian stock of the Southern Hemisphere fin whale population winters west of northern Chile and Peru from 110ºW to 60ºW (Gambell 1985b). If fin whales occur in the project area, they would probably be from the North Pacific population.

The species appears to have complex seasonal movements and is likely a seasonal migrant. Mating and calving occurs in temperate waters during winter, followed by migration to northern latitudes to feed during the summer (Mackintosh 1966; Gambell 1985b; Jefferson et al. 2008). However, some evidence suggests that there is a resident population of fin whales in the Gulf of California (Tershy et al. 1993). Thus, some individuals or populations may not undertake the typical long-distance migrations that characterize this species. Sergeant (1977) suggested that fin whales tend to follow steep slope contours, either because they detect them readily or because biological productivity is high along steep contours because of tidal mixing and perhaps current mixing.

Fin whales are typically observed alone or in pairs, but also in groups of up to seven or more, with the largest aggregations occurring on feeding grounds (Jefferson et al. 2008). Based on NMFS vessel-based surveys in the ETP in July–December 2006, Jackson et al. (2008) reported a mean group size of 1.2 (n = 8); all sightings were near Baja California. Croll et al. (2001) reported a mean dive depths and times of 98 m and 6.3 min for foraging fin whales, and 59 m and 4.2 min for non-foraging individuals. Dive depths of >150 m coinciding with the diel migration of krill were reported by Panigada et al. (1999).

Fin whales are considered very rare in the proposed survey area. No confirmed fin whale sightings were made near the proposed survey area during 10 years of survey effort in July–December by Ferguson and Barlow (2001) or by Jackson et al. (2008) during July–December surveys in 2006. Despite >30 years of SWFSC other surveys and stranding records from the Pacific coast of Costa Rica, there have been no confirmed records of fin whales (May-Collado et al. 2005). A possible sighting of a fin whale in this region occurred off the Osa Peninsula in 1997; however, the species was not confirmed (May-Collado et al. 2005). Rodríguez-Herrera et al. (2002) list the fin whale as having been documented off Costa Rica.

No fin whales were detected during L-DEO seismic surveys off Costa Rica or Nicaragua in November–December 2004 or February–March 2008 (Holst et al. 2005a; Holst and Smultea 2008).

Blue Whale

The blue whale is listed as ***Endangered*** under the U.S. ESA and on the 2010 IUCN Red List of Threatened Species (IUCN 2010), and is listed in CITES Appendix I (UNEP-WCMC 2010). Blue whale abundance has been estimated at 2300 for the Southern Hemisphere (IWC 2010), up to 1000 in the central and northeast Atlantic (Pike et al. 2009), and ~2842 for the eastern North Pacific (Carretta et al. 2010). 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,b, 2001, 2007; Watkins et al. 2000; Stafford 2003). The blue whale population in the ETP in the summer/fall was estimated at 1415 (Wade and Gerrodette 1993).

The blue whale is widely distributed throughout most of the world's oceans, occurring in coastal, shelf, and pelagic waters (Jefferson et al. 2008), and is most often found in cool, productive waters where upwelling occurs (Reilly and Thayer 1990). 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). Little is known about the movements and wintering grounds of the stocks (Mizroch et al. 1984). Some individuals may stay in low or high latitudes throughout the year (Reilly and Thayer 1990; Watkins et al. 2000). Broad-scale acoustic monitoring indicates that blue whales of the Eastern North Pacific Stock may range from the ETP along the coast of North America to Canada, and offshore at least 500 km (Stafford et al. 2001).

Blue whales are typically found singly or in groups of two or three (Yochem and Leatherwood 1985; Jefferson et al. 2008). They commonly form scattered aggregations on feeding grounds (Jefferson et al. 2008), and apparently single whales are likely part of a large, dispersed group (Wade and Friedrichsen 1979). Based on NMFS vessel surveys in the ETP in July–December 2006, Jackson et al. (2008) reported a mean group size of 1.9 (n = 57). Four satellite-radio-tagged blue whales in the northeast Pacific Ocean spent 94% of their time underwater, 72% of dives were <1 min long, and "true" dives (>1 min) were 4.2–7.2 min long. Shallow (<16-m) dives were most common (75%), and the average depth of deep (>16-m) dives was 105 m (Lagerquist et al. 2000). Croll et al. (2001) reported mean dive depths and times of 140 m and 7.8 min for foraging blue whales, and 68 m and 4.9 min for non-foraging individuals. Dives of up to 300 m were recorded for tagged blue whales (Calambokidis et al. 2003).

In the ETP, blue whales have been sighted offshore from Costa Rica, particularly the CRD, throughout the year (Wade and Friedrichsen 1979; Reilly and Thayer 1990; Mate et al. 1999; Chandler and Calambokidis 2004; Branch et al. 2006). The CRD is centered at 9ºN, 90ºW, ~630 km west of the northern offshore boundary of the proposed survey area. Reilly and Thayer (1990) suggested that blue whales that occur in the CRD may be migrant animals from the northern or southern hemispheres or they may be a resident population. Reilly and Thayer (1990) also suggested that the whales seen along the equator are likely part of the southeast Pacific population, which occupies the coastal shelf of South America and the Antarctic (Mackintosh 1966). However, the whales could also be resident in the area, exploiting food resources in the CRD and near the South American coastline (Mate et al. 1999; Palacios 1999). Based on call similarities, Stafford et al. (1999b) linked the whales near the CRD to the population that feeds off California at the same time of year. A recent satellite-tagging study confirmed that some blue whales off California migrate south in the fall to an area west of the CRD at 9ºN; the area is considered an important winter feeding area for blue whales (Bailey et al. 2009).

Sightings of blue whales in the ETP, including equatorial waters, may include the pygmy blue whale (Berzin 1978; Donovan 1984). Berzin (1978) reported that the distribution of the pygmy blue whale is much wider than previously thought; however, this subspecies is difficult to distinguish from the larger blue whale (Donovan 1984).

Blue whales are rare in the proposed survey area. May-Collado et al. (2005) reported three groups of four blue whales off Costa Rica based on compiled sightings from 1979 to 2001. One sighting was in deep oceanic waters ~200 km west of the proposed survey area. Jackson et al. (2008) also sighted one blue whale ~250 km northwest of the Nicoya Peninsula during surveys in July–December 2006. No blue whales were detected during L-DEO seismic surveys off Costa Rica or Nicaragua in November–December 2004 or February–March 2008 (Holst et al. 2005a; Holst and Smultea 2008).

Odontocetes

Sperm Whale

The sperm whale is listed as ***Endangered*** under the U.S. ESA and ***Vulnerable*** on the 2010 IUCN Red List of Threatened Species (IUCN 2010), and is listed in CITES Appendix I (UNEP-WCMC 2010). Wade and Gerrodette (1993) estimated sperm whale abundance in the ETP at 22,666. Whitehead (2002) updated that estimate to 26,053.

It is not clear whether sperm whales seen in the ETP are part of the Northern or Southern Hemisphere stocks, or whether they should be considered a separate stock (Rice 1998). Sperm whales occurring off the Galápagos Islands and near the coast of Ecuador are thought to belong to two different populations (Dufault and Whitehead 1995). Whitehead and Waters (1990) suggested that those in the Galápagos may be part of the Northern Hemisphere stock, and those off Ecuador part of the Southern Hemisphere stock, based on the timing of their breeding seasons. Both populations are considered part of the Southern Hemisphere stock for management purposes (Donovan 1991).

Sperm whales range between the northern and southern edges of the polar pack ice, although they are most abundant in tropical and temperate waters >1000 m deep over the continental shelf edge and slope and in pelagic waters (e.g., Rice 1989; Gregr and Trites 2001; Waring et al. 2001). Adult females and juveniles generally occur year-round in tropical and subtropical waters, whereas males often move to higher latitudes outside the breeding season to forage (Best 1979; Watkins and Moore 1982; Arnbom and Whitehead 1989; Whitehead and Waters 1990). Sperm whales often associate with areas of high secondary productivity and steep underwater topography, such as volcanic islands (Jacquet and Whitehead 1996). Adult males may occur in water depths <100 m and as shallow as 40 m (Whitehead et al. 1992; Scott and Sadove 1997). Females almost always occur in water depths >1000 m (Whitehead 2002).

Sperm whales undertake some of the deepest-known dives for the longest durations among cetaceans. They can dive as deep as ~2 km and possibly deeper on rare occasions, for periods of over 1 h; however, most of their foraging occurs at depths of ~300–800 m for 30–45 min (Whitehead 2003). A recent study of tagged male sperm whales off Norway found that foraging dives extended to highly variable maximum depths, ranging from 14 to 1860 m and with median 175 m (Teloni et al. 2008). During a foraging dive, sperm whales typically travel ~3 km horizontally and 0.5 km vertically (Whitehead 2003). At the Galápagos Islands, sperm whales typically forage at depths of ~400 m (Papastavrou et al. 1989; Whitehead 1989; Smith and Whitehead 2000). Whales typically dove for ~40 min and then spent 10 min at the surface (Papastavrou et al. 1989).

Sperm whales occur singly (older males) or in groups, with mean group sizes of 20–30 but as many as 50 (Whitehead 2003; Jefferson et al. 2008). May-Collado et al. (2005) reported a mean group size of 9.9 off Costa Rica. Based on NMFS vessel surveys in the ETP in 2006, Jackson et al. (2008) reported a mean group size of 6.1 (n = 24).

Sperm whales are uncommon in the proposed survey area. May-Collado et al. (2005) reported 35 sightings of 348 sperm whales in Costa Rica waters from 1979–2001, primarily concentrated in deep offshore waters off southeast Costa Rica, including waters near Isla del Cocos, although four sightings were reported within ~200 km of the proposed survey area. Rasmussen et al. (2004) reported one sperm whale sighting in deep offshore waters in annual surveys (1996–2003) off Costa Rica and Panama. Jackson et al. (2004) also recorded one sperm whale >200 km southeast of the proposed survey area during surveys in July–December 2003.

Polacheck (1987) and Wade and Gerrodette (1993) reported that during surveys in the summer and fall, sperm whales were widely distributed in the ETP, although they were generally more abundant in deep "nearshore" waters than far offshore. Rodríguez-Fonseca and Cubero-Pardo (2001) reported that the sperm whale is the cetacean species with the highest frequency of strandings in Costa Rica, with a reported seven strandings on the Pacific coast during a 33-year period. Twenty sperm whale strandings were also reported off the coast of Ecuador between 1987 and 1994 (Haase and Félix 1994).

No sperm whales were detected in or near the proposed survey area during an L-DEO seismic survey in November–December 2004, during which >3500 km of daytime visual effort and 5200 km of 24-h PAM effort took place (Holst et al. 2005a). Similarly, no sperm whales were detected during L-DEO seismic surveys off Costa Rica or Nicaragua in February–March 2008 (Holst and Smultea 2008).

Dwarf and Pygmy Sperm Whales

Dwarf sperm whales (*Kogia sima*) and pygmy sperm whales (*K. breviceps*) are distributed widely throughout tropical and temperate seas, but their precise distributions are unknown. Much of what we know of the species comes from strandings (McAlpine 2002). They are difficult to sight at sea, because of their dive behavior and perhaps because of their avoidance reactions to ships and behavior changes in relation to survey aircraft (Würsig et al. 1998). The two species are often difficult to distinguish from one another when sighted (McAlpine 2002). Wade and Gerrodette (1993) estimated that the population of dwarf sperm whales in the ETP was 11,200.

Both *Kogia* species are sighted primarily along the continental shelf edge and slope and over deeper waters off the shelf (Hansen et al. 1994; Davis et al. 1998; Jefferson et al. 2008). Several studies have suggested that pygmy sperm whales live mostly beyond the continental shelf edge, whereas dwarf sperm whales tend to occur closer to shore, often over the continental shelf (Rice 1998; Wang et al. 2002; MacLeod et al. 2004). Barros et al. (1998), on the other hand, suggested that dwarf sperm whales might be more pelagic and dive deeper than pygmy sperm whales. Another suggestion is that the pygmy sperm whale is more temperate, and the dwarf sperm whale more tropical, based at least partially on live sightings at sea from a large database from the ETP (Wade and Gerrodette 1993). This idea is also supported by the distribution of strandings in South American waters (Muñioz-Hincapié et al. 1998).

Pygmy and dwarf sperm whales are usually found singly or in groups of less than six (Jefferson et al. 2008). May-Collado et al. (2005) reported a mean group size of 1.9 dwarf sperm whales off Costa

Rica. Based on NMFS vessel-based surveys in the ETP, Jackson et al. (2008) reported a mean group size of 1.6 (n = 31) for dwarf sperm whales. In the Gulf of California, median dive and surface times for dwarf or unidentified *Kogia* sp. were 8.6 min and 1.2 min, and dives of up to 25 min and surface times up to 3 min were common (J. Barlow, pers. comm. *in* Willis and Baird 1998). Little is known about dive depths of *Kogia* spp. A satellite-tagged pygmy sperm whale released off Florida made longer dives (> 8 min and up to ~18 min) at night and on overcast days, and shorter dives (usually 2–5 min) on clear days, probably because of the distribution of their prey, vertically-migrating squid (Scott et al. 2001).

Both *Kogia* species distributions overlap with the proposed survey area, although dwarf sperm whales are likely to be rare and pygmy sperm whales are likely to be very rare. Rodríguez-Fonseca (2001) reported the presence of *Kogia* sp. off Costa Rica, but only the dwarf sperm whale has been positively identified as occurring in that area (Ferguson and Barlow 2001). Similarly, the dwarf sperm whale was the only confirmed *Kogia* species off Costa Rica based on sightings compiled from 1979 to 2001 by May-Collado et al. (2005). Most of the 32 groups of *Kogia sima* occurred in offshore waters, with frequent sightings ~100–150 km northeast of the Osa Peninsula. Jackson et al. (2008) reported one dwarf sperm whale ~200 km west of the proposed survey area and one *Kogia* sp. sighting off the Nicoya Peninsula during July–December surveys in 2006. Rodríguez-Fonseca and Cubero-Pardo (2001) reported a stranding of six *K. sima* in 1993 on the Pacific coast.

No *Kogia* sp. were detected during L-DEO seismic surveys off Costa Rica and Nicaragua in November–December 2004 (Holst et al. 2005a). During an L-DEO seismic survey off Costa Rica and Nicaragua in February–March 2008, one sighting of a dwarf sperm whale was made within 50 km of the proposed survey area in water ~2000 m deep, and a sighting of two *Kogia* sp. was made ~150 km west of the proposed survey area in waters 3500 m deep (Holst and Smultea 2008). The latter sighting was reported as probable pygmy sperm whales, but the sighting distance was 5.7 km (Holst and Smultea 2008).

Cuvier's Beaked Whale

Cuvier's beaked whale is probably the most widespread of the beaked whales, although it is not found in high-latitude polar waters (Heyning 1989). There are an estimated 20,000 Cuvier's beaked whales in the ETP (Wade and Gerrodette 1993).

Cuvier's beaked whale is found in deep water, but it appears to prefer steep continental slope waters (Jefferson et al. 2008), and is most common in water depths >1000 m (Heyning 1989). Ferguson et al. (2006a) reported that in the ETP, the mean water depth where Cuvier's beaked whales were sighted was ~3.4 km. It is most commonly seen in groups of 2–7 but also up to 15, with a reported mean group size of 2.3 (MacLeod and D'Amico 2006; Jefferson et al. 2008). May-Collado et al. (2005) reported a mean group size of 2.6 off Costa Rica. In the ETP, group sizes range from one to seven (Heyning 1989). Wade and Gerrodette (1993) reported a mean group size of 2.2 (n = 91) and Jackson et al. (2008) reported a mean group size of 1.8 (n = 16). Cuvier's beaked whales make long (30–60 min), deep dives with reported maximum depths of 1267 m (Johnson et al. 2004) and 1450 m (Baird et al. 2006).

Cuvier's beaked was the most frequent beaked whale identified to species level (14 of 47 beaked whale sightings) in or near the proposed study area based on surveys in Costa Rica waters during 1979–2001; an additional 15 groups were recorded as unidentified beaked whales (May-Collado et al. 2005). Beaked whales occurred primarily in offshore deep waters (May-Collado et al. 2005). Rodríguez-Fonseca (2001) identified the waters by Isla del Cocos, and Isla del Caño and the outer part of the Osa Peninsula, as two important areas off western Costa Rica for the species, although the study of May-Collado et al. (2005) "did not show patterns to support" the importance of Isla del Cocos for Cuvier's beaked whale. Jackson et al. (2004) reported one Cuvier's beaked whale sighting off the Nicoya Peninsula during surveys in July–December 2003. Jackson et al. (2008) also encountered beaked whales within ~200 km of the proposed survey area during surveys in July–December 2006.

No Cuvier's beaked whales or other beaked whales were detected during L-DEO seismic surveys off Costa Rica or Nicaragua in November–December 2004 or February–March 2008 (Holst et al. 2005a; Holst and Smultea 2008).

Mesoplodont Beaked Whales

Mesoplodont beaked whales (*Mesoplodon* spp.) are difficult to distinguish in the field, and confirmed at-sea sightings are rare (Mead 1989; Carretta et al. 2010; Jefferson et al. 2008). Until better methods are developed for distinguishing the different *Mesoplodon* species from one another, the management unit for the U.S. west coast is defined to include all *Mesoplodon* populations (Carretta et al. 2010). Wade and Gerrodette (1993) estimated a population size of mesoplodont beaked whales at 25,300 for the ETP.

Mesoplodonts are distributed primarily in deep waters (>2000 m) and along continental slopes at depths 200–2000 m; they are rarely found in continental shelf waters (Pitman 2002). Most mesoplodonts identified to species are known from strandings involving single individuals (Jefferson et al. 2008), thus it is not possible to identify spatial or seasonal patterns in their distribution (Caretta et al. 2010). Dive depths of most of these species are undocumented.

Mean group sizes are unknown for many of the *Mesoplodon* spp. For the genus, May-Collado et al. (2005) reported a mean group size of 2.4 off Costa Rica, Wade and Gerrodette (1993) reported a mean group size of 3.0 (n = 128) for the ETP, and Jackson et al. (2008) reported a mean group size of 2.4 (n = 30) for the ETP during July–December surveys in 2006.

Mesoplodonts are uncommon in the proposed survey area based on 1979–2001 surveys in Costa Rica waters (May-Collado et al. 2005). May-Collado et al. (2005) reported five mesoplodont sightings, and Jackson et al. (2008) reported one mesoplodont sighting within ~200 km of the proposed survey area.

MacLeod and Mitchell (2006) identified the ETP as a key area for beaked whales. Three species are known to occur in or near the survey area: the pygmy, gingko-toothed, and Blainville's beaked whale.

***Pygmy Beaked Whale* (*M. peruvianus*)**.—Information on the pygmy beaked whale is based on scattered sightings in the ETP and a small number of strandings (Jefferson et al. 2008). The pygmy beaked whale is thought to occur between latitudes of ~28°N and 30°S, from Baja California to Peru and Chile (Urbán-Ramírez and Aurioles-Gamboa 1992; Pitman and Lynn 2001; Jefferson et al. 2008). Reyes et al. (1991) reported 10 records of this species in south-central Peru. Pitman and Lynn (2001) reported that the species may have been known previously as *Mesoplodon* sp. "A". The pygmy beaked whale is now believed to be widespread in the ETP, concentrated off central Mexico (Pitman and Lynn 2001). Wade and Gerrodette (1993) reported several sightings of *M. peruvianus* and *Mesoplodon* sp. "A" in the ETP.

This species is known to inhabit deep warm temperate waters beyond the continental shelf (Jefferson et al. 2008). Most sightings have consisted of two but as many as five have been sighted, with a mean group size of 2.3 (Jefferson et al. 2008).

Ferguson and Barlow (2003) reported no pygmy beaked whale sightings and one *Mesoplodon* sp. "A" sighting in the survey block (138) that includes the proposed survey area during 10 years of surveys conducted in July–December. No pygmy (or *M.* sp "A") beaked whales were reported off Costa Rica by May-Collado et al. (2005) or Rodríguez-Fonseca and Cubero-Pardo (2001) based on compiled sightings from 1979–2001 and strandings from 1966–1999, respectively. Jackson et al. (2004) reported two sightings of *M. peruvianus* in offshore waters west of Nicoya Peninsula. Jackson et al. (2008) reported one sighting of *M. peruvianus* within ~200 km of the proposed project area during July–December surveys in 2006. Pygmy beaked whales are unlikely to occur in the proposed survey area.

***Ginkgo-toothed Beaked Whale* (*M. ginkgodens*)**.—The ginkgo-toothed beaked whale is only known from stranding records (Mead 1989). Strandings have been reported for the western and eastern North Pacific, South Pacific, and Indian oceans, and from the Galápagos Islands (Palacios 1996a). Two of the total 13 records reported by Mead (1989) were from the eastern North Pacific, one from Del Mar, California, and one from Baja California. The species is hypothesized to occupy relatively cool areas in the temperate and tropical Pacific, where upwelling is known to occur, such as in the California and Peru Currents and the equatorial front (Palacios 1996a).

No ginkgo-toothed beaked whales were reported off Costa Rica by May-Collado et al. (2005) based on compiled sightings from 1979–2001, or by Rodríguez-Fonseca and Cubero-Pardo (2001) using 1966–1999 stranding records.

***Blainville's Beaked Whale* (*M. densirostris*).**—Blainville's beaked whale is the most widely distributed *Mesoplodon* species (Mead 1989), although it is generally limited to pelagic tropical and warmer temperate waters (Jefferson et al. 2008). Occasional occurrences in cooler, higher-latitude waters are presumably related to warm-water incursions (Reeves et al. 2002). Long-term habitat studies in the northern Bahamas found that Blainville's beaked whales preferred continental slope waters 200–1000 m deep characterized by intermediate depth gradients (MacLeod and Zuur 2005), where they spent most of their time along a canyon wall in waters <800 m deep (Claridge 2003; MacLeod et al. 2004; MacLeod and Zuur 2005). Studies elsewhere indicate that Blainville's beaked whales most frequently occurred in waters 300–1400 m deep (Society Islands, Gannier 2000) and 100–500 m deep (Canary Islands, Ritter and Brederlau 1999). This species may also occur in coastal areas, particularly where deep water gullies come close to shore (Jefferson et al. 2008).

The most commonly observed group size for this species is 1–2, with a maximum of 9 off Hawaii (Baird et al. 2006; Jefferson et al. 2008). MacLeod and D'Amico (2006) reported a mean group size of 3.5 (n = 31), and Ritter and Brederlau (1999) reported a mean group size of 3.4. The maximum known dive depth of tagged Blainville's beaked whales is 1408 m off Hawaii (Baird et al. 2006).

In the ETP, Blainville's beaked whales have been sighted in offshore as well as nearshore areas of Central and South America (Pitman et al. 1987; Pitman and Lynn 2001). The species was not sighted in the survey block (138) that includes the proposed study area but was sighted in survey blocks immediately to the south of it during 10 years of surveys conducted in July–December (Ferguson and Barlow (2003). Off Costa Rica, May-Collado et al. (2005) reported one sighting of three Blainville's beaked whales in deep offshore waters based on sightings during 1979–2001.

Rough-toothed Dolphin

The rough-toothed dolphin is distributed worldwide in tropical, subtropical, and warm temperate waters (Miyazaki and Perrin 1994). Wade and Gerrodette (1993) estimated rough-toothed dolphin abundance in the ETP at 145,900 based on data collected during 1986–1990. For 2006, the abundance estimate was 107,633 (Gerrodette et al. 2008).

Rough-toothed dolphins are generally seen in deep water and in shallower waters around islands. They are typically found in groups of 10–20, but groups of up to 300 have been seen (Jefferson 2002). May-Collado et al. (2005) reported a mean group size of 19.3 off Costa Rica based on sightings during 1979–2001. The mean group size in the ETP is 15.5 (Ferguson et al. 2006b). Rough-toothed dolphins are deep divers and can dive for up to 15 min (Reeves et al. 2002).

In the ETP, sightings of rough-toothed dolphins have been reported by Perrin and Walker (1975), Pitman and Ballance (1992), Wade and Gerrodette (1993), Kinzey et al. (1999, 2000, 2001), Ferguson and Barlow (2001), May-Collado et al. (2005), and Jackson et al. (2008).

Rough-toothed dolphins are common in the proposed survey area. May-Collado et al. (2005) documented 28 sightings of 513 individuals based on surveys in Costa Rica waters during 1979–2001. These sightings were distributed from nearshore to far offshore, with several occurring in the proposed survey area. Jackson et al. (2004, 2008) also reported rough-toothed dolphin sightings in or near the proposed survey area. No rough-toothed dolphins were detected during L-DEO seismic surveys off Costa Rica or Nicaragua in November–December 2004 or February–March 2008 (Holst et al. 2005a; Holst and Smultea 2008).

Common Bottlenose Dolphin

The bottlenose dolphin occurs throughout the world's tropical, subtropical, and temperate waters, most commonly in coastal and continental shelf waters (Jefferson et al. 2008). Gerrodette et al. (2008) estimated the abundance of bottlenose dolphins in the ETP at 335,834 for 2006.

There are two distinct bottlenose dolphin types: a shallow water type mainly found in coastal waters and a deepwater type mainly found in oceanic waters (Duffield et al. 1983; Hoelzel et al. 1998; Walker et al. 1999). The nearshore dolphins usually inhabit shallow waters along the continental shelf and upper slope, at depths <200 m (Davis et al. 1998), whereas offshore dolphins show a preference for water <2000 m deep (Klatsky et al. 2007). Bottlenose dolphins are reported to regularly dive to depths >450 m for periods of >5 min, and even down to depths of 600–700 m for up to 12 min (Klatsky et al. 2007). They usually occur in groups of 2–20, although groups of >100 are occasionally seen in offshore areas (Shane et al. 1986; Jefferson et al. 2008). Off Costa Rica, May-Collado et al. (2005) reported a mean group size of 21.5 based on sightings during 1979–2001. For the ETP, Ferguson et al. (2006b) reported a mean group size of 24.1 and Jackson et al. (2008) reported a mean group size of 24.2 (n = 149).

In the ETP, bottlenose dolphins tend to be more abundant close to the coasts and islands (Scott and Chivers 1990); they also seem to occur more inshore than other dolphin species (Wade and Gerrodette 1993). Polacheck (1987) reported that the highest encounter rates for bottlenose dolphins in the ETP tended to be in nearshore areas.

Bottlenose dolphins are relatively common in the proposed survey area. Based on the SWFSC surveys and model used to calculate densities in the proposed survey area in § IV(3), they are the fifth-ranked species there. May-Collado et al. (2005) compiled 176 sightings of 3584 individuals in Costa Rica waters during 1979–2001. These sightings were distributed primarily in coastal waters but also in offshore oceanic waters; numerous sightings occurred in the proposed survey area. Jackson et al. (2004, 2008) reported sightings of bottlenose dolphins in the proposed survey area. Rasmussen et al. (2004) reported 49 sightings of bottlenose dolphins in annual surveys (1996–2003) off Costa Rica. Three sightings of bottlenose whales were reported during a two-week survey off Costa Rica in January–February 2010 (Calambokidis et al. 2010).

One group of bottlenose dolphins were identified near the proposed survey area in waters 1000 m deep during L-DEO seismic surveys off Costa Rica and Nicaragua in November–December 2004 (Holst et al. 2005a). Two groups of bottlenose dolphins were observed in the proposed survey area in waters 100 m deep during L-DEO seismic surveys in February–March 2008 (Holst and Smultea 2008).

Pantropical Spotted Dolphin

In the eastern Pacific, the pantropical spotted dolphin ranges from 25ºN off Baja California, Mexico, to 17ºS off southern Peru (Perrin and Hohn 1994). Au and Perryman (1985) reported that the species occurs primarily north of the equator, off southern Mexico, and westward along 10ºN. They also reported its occurrence in seasonal tropical waters south of the Galápagos Islands.

Dizon et al. (1994) identified three stocks of spotted dolphins in the ETP: the coastal stock (*S. a. grafmani*) and two offshore (*S. a. attenuata*) stocks (the northeast and the west/south stock). However, recent genetic evidence suggests that there may be nine genetically distinct stocks of this species in coastal areas from Baja California south to Ecuador (Rosales and Escorza-Trefiño 2005). The coastal stock occurs within ~200 km of the coastline (Dizon et al. 1994) and is the stock most likely to occur in the proposed survey area.

There was an overall stock decline of spotted dolphins in the ETP during 1960–1980 because of the purse-seine tuna fishery (Allen 1985). Gerrodette and Forcada (2005) reported that the population of offshore northeastern spotted dolphins has not yet recovered from the earlier population declines. For 1986–1990, Wade and Gerrodette (1993) reported a population estimate of 2.1 million for all three stocks based on data collected during 1986–1990. The abundance estimate of all spotted dolphin stocks in the ETP for 2006 was 1.6 million (Gerrodette et al. 2008). Off Costa Rica, May-Collado et al. (2005) reported a mean group size of 29.4 based on sightings during 1979–2001. For the ETP, Gerrodette et al. (2008) estimated a mean group size of 223.4 for coastal pantropical spotted dolphins.

Pantropical spotted dolphins are very common in the proposed survey area. Based on the SWFSC surveys and model used to calculate densities in the project area (see § IV[3]), they are the second-ranked species there. May-Collado et al. (2005) reported 525 sightings of 1311 pantropical spotted dolphins during 1979–2001. The majority of sightings were primarily in coastal waters around Osa Peninsula with numerous sightings occurring in the proposed survey area (May-Collado et al. 2005). Jackson et al. (2008) reported three sightings of pantropical spotted dolphins near the proposed survey area during July–December surveys in 2006. Rodríguez-Fonseca (2001) noted that the oceanic spotted dolphin was less common than the coastal spotted dolphin in Costa Rican waters. Rasmussen et al. (2004) reported 381 sightings of spotted dolphins in annual surveys during 1996–2003 off Costa Rica and during 2001–2003 off Panama. Thirty-one sightings of spotted dolphins were also recorded by Calambokidis et al. (2010) during a two-week survey off Costa Rica in January–February 2010. Two spotted dolphin strandings on the Pacific coast were included in a list of strandings for Costa Rica during 1966–1999 (Rodríguez-Fonseca and Cubero-Pardo 2001).

One group of pantropical spotted dolphins was observed in water depth ~1000 m near the proposed survey area and three additional groups were observed within ~100 km of the proposed survey area in water depth 2000 m during L-DEO seismic surveys off Costa Rica and Nicaragua in November–December 2004 (Holst et al. 2005a). One group of 40 pantropical spotted dolphins was identified ~90 km of the proposed survey area in water depth 70 m during L-DEO seismic surveys in February–March 2008 (Holst and Smultea 2008).

Spinner Dolphin

The spinner dolphin is distributed in oceanic and coastal waters and is associated with warm tropical surface water (Au and Perryman 1985; Reilly 1990; Reilly and Fiedler 1994). The total population of spinner dolphins in the ETP in 1979 was estimated at 0.8–0.9 million (Allen 1985). Wade and Gerrodette (1993) reported an abundance estimate of 1.7 million for spinner dolphins in the ETP based on data collected during 1986–1990. Gerrodette et al. (2008) estimated the abundance for spinner dolphins in the ETP for 2006 at 1,797,716.

In the ETP, three types of spinner dolphins have been identified and two of those are recognized as subspecies: the eastern spinner dolphin, *S. l. orientalis,* considered an offshore species, the Central American spinner, *S. l. centroamericana* (also known as the Costa Rican spinner), considered a coastal species in Costa Rica (Perrin 1990; Dizon et al. 1991), and the 'whitebelly' spinner, which is thought to be a hybrid of the eastern spinner and Gray's spinner (*S. l. longirostris*). Although there is a great deal of overlap between the ranges of eastern and whitebelly spinner dolphins, the eastern form generally occurs in the northeastern portion of the ETP, whereas the whitebelly spinner occurs in the southern portion of the ETP, ranging farther offshore (Wade and Gerrodette 1993; Reilly and Fiedler 1994). The Costa Rican spinner dolphin is typically seen within 150 km from shore (ACS 2005). The eastern spinner dolphin and the Costa Rica spinner dolphin subspecies are likely to occur in the proposed survey area.

Spinner dolphins tend to occur in large groups compared to most other cetaceans. May-Collado et al. (2005) reported a mean group size of 97 based on sightings during 1979–2001. Ferguson et al. (2006b) reported mean group sizes of 108.8 and 147.7 for eastern and unidentified spinner dolphins in the ETP, respectively, and Gerrodette and Forcada (2005) reported a mean group size of 112 for the eastern stock. Spinner dolphins usually dive to 600 m or deeper to feed (Perrin and Gilpatrick 1994).

Rasmussen et al. (2004) reported only one sighting of spinner dolphins in annual surveys from 1996 to 2003 off Costa Rica. May-Collado et al. (2005) reported spinner dolphins primarily in oceanic waters off Costa Rica during 1979–2001, with small numbers in coastal waters. Both *S. l. orientalis* and *S. l. centroamericana* sightings were reported once each in the proposed survey area (May-Collado et al. 2005). No sightings of eastern spinner dolphins were reported in or near the proposed survey area during July–December surveys in 2003 or in 2006 (Jackson et al. 2004, 2008).

During L-DEO seismic surveys off Costa Rica and Nicaragua in November–December 2004 and February–March 2008, one group of spinner dolphins was identified <50 km west of the Nicoya Peninsula in waters <1000 m deep, and one group of spinner dolphins was identified ~100 km southwest of the Nicoya Peninsula in waters ~3500 m deep (Holst et al. 2005a; Holst and Smultea 2008).

Striped Dolphin

The striped dolphin has a cosmopolitan distribution in tropical to warm temperate waters from ~50°N to 40°S (Perrin et al. 1994a; Jefferson et al. 2008). Wade and Gerrodette (1993) estimated that the population in the ETP numbered 1.9 million based on data collected during 1986–1990. The population has declined; Gerrodette et al. (2008) estimated the abundance of striped dolphins in the ETP at 964,362 for 2006.

The striped dolphin's preferred habitat seems to be cool, deep, oceanic waters (Davis et al. 1998) along the edge and seaward of the continental shelf, particularly convergence zones and upwelling areas (Au and Perryman 1985). Striped dolphin group sizes are typically several dozen to 500, although groups of thousands sometimes form (Jefferson et al. 2008). Off Costa Rica, May-Collado et al. (2005) reported a mean group size of 48.9 based on sightings during 1979–2001. For the ETP, Wade and Gerrodette (1993) reported a mean group size of 61, and Jackson et al. (2008) reported a mean group size of 51.8 (n = 137). Striped dolphins are believed to be capable of diving to depths of 200–700 m based on stomach content analyses (Archer and Perrin 1999).

The striped dolphin is very common in the proposed survey area. Based on the SWFSC surveys and model used to calculate densities in the project area (see § IV[3]), it is the third-ranked species there. The striped dolphin was also the third most sighted species in Costa Rica waters during 1979–2000, although the species was reported nearly exclusively from oceanic waters (May-Collado et al. 2005). All sightings reported occurred >150 km of the proposed survey area (Jackson et al. 2004, 2008; May-Collado et al. 2005).

During L-DEO seismic surveys off Costa Rica and Nicaragua in February–March 2008, one sighting of 40 striped dolphins was made in waters ~2000 m deep and ~25 km from the proposed survey area (Holst and Smultea 2008). None were observed in November–December 2004 (Holst et al. 2005a).

Fraser's Dolphin

Fraser's dolphin is a tropical species that rarely occurs in temperate regions, and then only in relation to temporary oceanographic anomalies such as El Niño events (Perrin et al. 1994b). Wade and Gerrodette (1993) reported a mainly equatorial distribution in the ETP, and estimated its abundance in the area at 289,300 based on data collected during 1986–1990.

Fraser's dolphins typically occur in water at least 1000 m deep. They dive to depths of at least 250–500 m to feed (Dolar 2002). They travel in groups ranging from just a few animals to hundreds or even thousands (Perrin et al. 1994b), often mixed with other species (Culik 2002). For the ETP, Wade and Gerrodette (1993) reported a mean group size of 395, and Ferguson et al. (2006b) reported a mean group size of 440.

Fraser's dolphin are rare in the proposed survey area. May-Collado et al. (2005) reported only one sighting of 158 Fraser's dolphins in deep oceanic waters during SWFSC, CRC, and PCC surveys in Costa Rica waters during 1979–2001. No Fraser's dolphins were reported in the ETP during July–December surveys in 2003 or in 2006 (Jackson et al. 2004, 2008). Similarly, no Fraser's dolphins were detected during L-DEO seismic surveys off Costa Rica or Nicaragua in November–December 2004 or February–March 2008 (Holst et al. 2005a; Holst and Smultea 2008). No encounters are expected during the proposed survey and no takes are requested

Short-beaked Common Dolphin

Common dolphins are found in tropical and temperate oceans around the world (Evans 1994). There are two species of common dolphin, the more coastal long-beaked dolphin (*Delphinus capensis*) and the more offshore short-beaked dolphin (*D. delphis*). The short-beaked common dolphin is widely distributed compared to the long-beaked common dolphin (Heyning and Perrin 1994). Only the short-beaked common dolphin is expected to occur in the ETP. Three stocks of *D. delphis* are recognized in the ETP: northern, central, and southern (Dizon et al. 1994). Individuals present in the proposed survey area would be from the central stock.

Gerrodette et al. (2005) reported an abundance estimate for short-beaked common dolphins of 1.1 million for 2003. However, abundance estimates of common dolphins have fluctuated from <1 million to >3 million from 1986 to 2000 (Gerrodette and Forcada 2002). The abundance estimate for 2006 was ~3,130,000 (Gerrodette et al. 2008).

The common dolphin's distribution is associated with prominent underwater topography, such as seamounts (Evans 1994). Short-beaked common dolphins are widely distributed from the coast to at least 550 km from shore (Carretta et al. 2010). In the ETP, common dolphin distribution is associated with cool, upwelling areas along the equator and off Baja California, Central America, and Peru (Au and Perryman 1985; Reilly 1990; Reilly and Fiedler 1994). Reilly (1990) reported no seasonal changes in common dolphin distribution, although Reilly and Fiedler (1994) observed interannual changes in distribution that were likely attributable to El Niño events.

Common dolphins travel in groups of ~10 to >10,000 (Jefferson et al. 2008). Off Costa Rica, May-Collado et al. (2005) reported a mean group size of 220.7 based on sightings during 1979–2001. For the ETP, Ferguson et al. (2006b) reported a mean group size of 230, and Jackson et al. (2008) reported a mean group size of 217 (n = 123). Most dives of a radio-tagged common dolphin off southern California were to depths 9–50 m, and the maximum reported depth was ~200 m (Evans 1994).

This species is abundant in the proposed survey area. May-Collado et al. (2005) reported 82 sightings of 17,875 individuals during 1979–2001 off Costa Rica, mostly in oceanic waters; numerous sightings occurred in and near the proposed survey area. Based on the SWFSC surveys and model used to calculate densities in the proposed survey area (see § IV[3]), they are the first-ranked species there. Jackson et al. (2004, 2008) reported 2 and 3 sightings of common dolphins within ~200 km of the proposed survey area during July–December surveys in 2003 and 2008, respectively. Rasmussen et al. (2004) reported one sighting of common dolphins in annual surveys from 1996 to 2003 off Costa.

During L-DEO seismic surveys off Costa Rica and Nicaragua in November–December 2004, one group of 45 short-beaked common dolphins was identified and one group of 15 common dolphins (species unidentified) was sighted <150 km and ~25 km, respectively, from the proposed survey area (Holst et al. 2005a). Two groups of common dolphins were identified <50 km from the proposed survey area in waters ≥2000 m deep in February–March 2008 (Holst and Smultea 2008).

Risso's Dolphin

Risso's dolphin is primarily a tropical and mid-temperate species distributed worldwide between 60ºN and 60ºS, where surface water temperatures are ~10ºC (Kruse et al. 1999). Gerrodette et al. (2008) reported an abundance estimate of 110,457 Risso's dolphins for the ETP.

Risso's dolphins usually occur over steeper sections of the upper continental slope in waters 400–1000 m deep (Baumgartner 1997; Davis et al. 1998), and are known to frequent seamounts and escarpments (Kruse et al. 1999; Baird 2002a). Risso's dolphins occur individually or in small- to moderate-sized groups, normally ranging in numbers from 10 to 100 but up to as many as 4000 (Jefferson et al. 2008). May-Collado et al. (2005) reported a mean group size of 11.6 off Costa Rica. For the ETP, Ferguson et al. (2006b) reported a mean group size of 18.64, and Jackson et al. (2008) reported a mean group size of 18.5 (n = 48). Risso's dolphin can remain underwater up to 30 min (Kruse et al. 1999).

Risso's dolphins are relatively common in the proposed survey area; based on the SWFSC surveys and model used to calculate densities in the proposed survey area (see § IV[3]), they are the sixth-ranked species there. May-Collado et al. (2005) documented 76 sightings of 880 individuals based on surveys in Costa Rica waters during 1979–2001, several occurring in within ~200 km of the proposed survey area. No Risso's dolphin sightings were reported near the proposed survey area during July–December surveys in 2003 or in 2006 (Jackson et al. 2004, 2008) or during annual surveys from 1996 to 2003 off Costa Rica (Rasmussen et al. 2004).

During L-DEO seismic surveys off Costa Rica and Nicaragua, one sighting of 25 Risso's dolphins in waters ~2000 m deep was made ~ 25 km from the proposed survey area in November–December 2004 (Holst et al. 2005a), but none were observed in February–March 2008 (Holst and Smultea 2008).

Melon-headed Whale

The melon-headed whale is a pantropical and pelagic species (Perryman 2002). It occurs mainly between 20ºN and 20ºS; occasional occurrences in temperate regions are likely associated with warm currents (Perryman 2002; Reeves et al. 2002). Au and Perryman (1985) and Perryman et al. (1994) reported that the melon-headed whale occurs primarily in equatorial waters, although Wade and Gerrodette (1993) reported its occurrence in non-equatorial waters. Wade and Gerrodette (1993) estimated the abundance of this species in the ETP at 45,400 based on data collected during 1986–1990.

Melon-headed whales are oceanic, occurring in offshore areas or nearshore areas where deep water occurs near the coast (Perryman 2002). Mullin et al. (1994) reported that they are usually sighted in water >500 m deep, and away from the continental shelf. Melon-headed whales tend to travel in groups of 100–500, but have also been seen in groups of 1500–2000. Ferguson et al. (2006b) reported a mean group size of 258 in the ETP.

Melon-headed whales are rare in the proposed survey area. May-Collado et al. (2005) reported two sightings of 445 animals during 1979–2001, one of which was ~170 km southwest of the Osa Peninsula.

Three melon-headed whale strandings occurred on the Pacific coast of Costa Rica during 1966–1999; >200 individuals stranded on the Nicoya Peninsula in 1976, and two individual strandings occurred on the northern coast in 1970 (Rodríguez-Fonseca and Cubero-Pardo 2001). No melon-headed whales were reported near the proposed survey area during July–December surveys in 2003 or 2006 (Jackson et al. 2004, 2008) or during annual surveys from 1996 to 2003 off Costa Rica (Rasmussen et al. 2004).

During L-DEO seismic surveys off Costa Rica and Nicaragua, two sightings of 55 'blackfish' were made ~120 km west of the proposed survey area in waters >3000 m deep in February–March 2008 (Holst and Smultea 2008). These animals were reported as probable melon-headed whales, although the sighting distances were >1800 m. No melon-headed whales were observed in November–December 2004 (Holst et al. 2005a).

Pygmy Killer Whale

The pygmy killer whale is pantropical (Ross and Leatherwood 1994; Rice 1998). The species has been sighted in the ETP (Van Waerebeek and Reyes 1988; Pitman and Ballance 1992; Wade and Gerrodette 1993) and appears to occur sporadically along the equator and the coast of Central America (Wade and Gerrodette 1993). Wade and Gerrodette (1993) estimated the abundance of this species in the ETP at 39,800 based on data collected during 1986–1990.

Pygmy killer whales tend to travel in groups of 15–50, although groups of a few hundred have been sighted (Ross and Leatherwood 1994). In the ETP, Wade and Gerrodette (1993) reported a mean group size of 28, and Ferguson et al. (2006b) reported a mean group size of 30. In warmer water, they are usually seen close to the coast (Wade and Gerrodette 1993), but they are also found in deep waters.

Pygmy killer whales are rare off Costa Rica. May-Collado et al. (2005) reported no sightings of this species based on surveys during 1979–2001, and none were reported during annual surveys from 1996 to 2003 (Rasmussen et al. 2004). No pygmy killer whales were reported near the proposed study area during July–December surveys in 2006 in the ETP (Jackson et al. 2008).

No pygmy killer whales were observed during L-DEO seismic surveys off Costa Rica in November–December 2004 (Holst et al. 2005a). However, during L-DEO seismic surveys off Costa Rica and Nicaragua in February–March 2008, a sighting of 10 'blackfish' was made ~150 km from the proposed survey area in water depths >3000 m (Holst and Smultea 2008). This sighting was made at a distance of 1.6 km and was reported as probable pygmy killer whales (Holst and Smultea 2008).

False Killer Whale

The false killer whale is widely distributed, though not abundant anywhere (Jefferson et al. 2008). It is found in all tropical and warmer temperate oceans, especially in deep offshore waters (Odell and McClune 1999). Wade and Gerrodette (1993) estimated their abundance in the ETP at 39,800 based on data collected during 1986–1990.

False killer whales have been sighted in the ETP, where they chase or attack *Stenella* and *Delphinus* dolphins during tuna fishing operations (Perryman and Foster 1980). They travel in groups of 20–100 (Baird 2002b), although groups of several hundred are sometimes observed. Off Costa Rica, May-Collado et al. (2005) reported a mean group size of 36.2, and Martínez-Fernandez et al. (2005) reported a mean group size of 13.2. For the ETP, Wade and Gerrodette (1993) and Ferguson et al. (2006b) reported a mean group size of 11, and Jackson et al. (2008) reported a mean group size of 11.8 (n = 16). False killer whales are usually seen far offshore, although sightings have been reported for both shallow (<200 m) and deep (>2000 m) waters (Wade and Gerrodette 1983).

False killer whales are uncommon in the proposed survey area. May-Collado et al. (2005) compiled nine sightings of 253 animals during 1979–2001; one sighting occurred in the proposed survey area, four other sightings occurred nearshore off the west coast of Osa Peninsula. Martínez-Fernandez et al. (2005) observed four groups off Costa Rica during monthly strip-transect surveys during December 2004–June 2005. None were reported in the ETP during July–December surveys in 2006 (Jackson et al. 2008). Rasmussen et al. (2004) reported eight sightings of false killer whales in annual surveys (1996–2003) off Costa Rica.

No false killer whales were reported off Costa Rica during L-DEO seismic surveys in November–December 2004 or in February–March 2008 (Holst et al. 2005a; Holst and Smultea 2008).

Killer Whale

The killer whale is cosmopolitan and widely distributed; it has been observed in all oceans of the world (Ford 2009). Killer whales are segregated socially, genetically, and ecologically into three distinct groups: resident, transient, and offshore animals. Offshore whales do not appear to mix with the other types of killer whales (Black et al. 1997; Dahlheim and Heyning 1999). The abundance of killer whales in the ETP was estimated at 8500 (Wade and Gerrodette 1993), and the minimum global abundance is 50,000 (Ford 2009).

Groups sizes of killer whales are 1–75, though offshore transient groups generally contain <10 (Dahlheim et al. 1982; Jefferson et al. 2008). Off Costa Rica, May-Collado et al. (2005) reported that the mean group size (3.5) was the smallest among the delphinids seen, based on sightings during 1979–2001. For the ETP, Ferguson et al. (2006b) reported a mean group size of 5.5, and Jackson et al. (2008) reported a mean group size of 8.1 (n = 15). The maximum depth to which seven tagged free-ranging killer whales dove off B.C. was 228 m, but only an average of 2.4 % of their time was spent below 30 m (Baird et al. 2003).

Killer whales are found throughout the ETP (Pitman and Ballance 1992; Wade and Gerrodette 1993), but are most densely distributed near the coast from 35ºN to 5ºS (Dahlheim et al. 1982). Dahlheim et al. (1982) reported the occurrence of a cluster of sightings at two offshore locations in the ETP. One location was bounded by 7–14ºN and 127–139ºW, and the other was within a band between the equator and 5ºN and from the Galápagos Islands to 115ºW; both are well to the west of the proposed survey area.

Killer whales are rare in the proposed survey area. May-Collado et al. (2005) reported seven sightings of 25 animals in Costa Rica waters in 1979–2001; two of the seven sightings occurred nearshore of the west coast of Osa Peninsula. Jackson et al. (2008) reported one sighting of killer whales in the proposed survey area during surveys in July–December 2006. None were reported near the proposed survey area during surveys in 2003 (Jackson et al. 2004). Rasmussen et al. (2004) reported three sightings in annual surveys (1996–2003) off Costa Rica.

No killer whales were detected during L-DEO seismic surveys off Costa Rica or Nicaragua in November–December 2004 or February–March 2008 (Holst et al. 2005a; Holst and Smultea 2008).

Short-finned Pilot Whales

The short-finned pilot whale typically inhabits pelagic tropical and warm temperate waters of ~1000-m depth near the continental shelf edge but also slope waters (Davis et al. 1998; Jefferson et al. 2008). It is generally nomadic, but resident populations have been reported in certain locations, including Hawaii and California (Olson and Reilly 2002). The abundance of pilot whales in the ETP for 1998–2000 was estimated at 589,315 (Gerrodette and Forcada 2002).

Pilot whales have a wide distribution throughout the ETP, but are most abundant in cold waters where upwelling occurs (Wade and Gerrodette 1993). Polacheck (1987) reported that encounter rates for pilot whales in the ETP were highest inshore; offshore concentrations may also occur, but at lower densities. Pilot whales are usually seen in groups of 20–90, although groups of several hundred are also seen (Olson and Reilly 2002; Jefferson et al. 2008). May-Collado et al. (2005) reported a mean group size of 14.2 in Costa Rica based on sightings during 1979–2001. For the ETP, Wade and Gerrodette (1993) and Ferguson et al. (2006b) reported a mean group size of 18, and Jackson et al. (2008) reported a mean group size of 18.0 (n = 57). 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 (Heide-Jørgensen et al. 2002). The species' maximum recorded dive depth is 971 m (Baird pers. comm. *in* DoN 2005).

Short-finned pilot whales are common in the proposed survey area. May-Collado et al. (2005) reported 68 sightings of 967 animals off Costa Rica in 1979–2001. Numerous sightings were made within ~200 km and least 2 sightings were within ~50 km of the proposed survey area (May-Collado et al. 2005). Jackson et al. (2004, 2008) reported one and three sightings of short-finned pilot whales within ~200 km of the proposed survey area during July–December surveys in 2003 and 2006, respectively.

During L-DEO seismic surveys off Costa Rica and Nicaragua, one group of short-finned pilot whales was identified near proposed survey area in waters ~1000 m deep, and one group was identified near the project area in waters <2000 m deep in November–December 2004 and February–March 2008, respectively (Holst et al. 2005a; Holst and Smultea 2008).

Pinnipeds

Six species of pinnipeds are known to occur in the ETP: the California sea lion (*Zalophus californianus*), South American sea lion (*Otaria flavescens*), Galápagos sea lion (*Zalophus wollebaeki*), Galápagos fur seal (*Arctocephalus galapagoensis*), Guadalupe fur seal (*A. townsendi*), and South American fur seal (*A. australis*). Of the six species, two have the potential to occur within the survey area, although any occurrence would be rare as they are vagrants to the area.

The California sea lion is listed as ***Least Concern*** on the 2010 IUCN Red List of Threatened Species (IUCN 2010) and listed in CITES Appendix II (UNEP-WCMC 2010). Its normal southernmost range is considerably north of the proposed survey area. However, the California sea lion has been documented off western Costa Rica on at least seven occasions including, from north to south, on the Nicoya and Osa peninsulas, in Golfo Dulce, and at Isla del Cocos (Acevedo-Gutierrez 1994, 1996; Cubero-Pardo and Rodríguez 1999; Rodríguez-Herrera et al. 2002; May-Collado 2009).

The California sea lion is normally distributed from southern Mexico north to southwestern Canada The breeding areas of the California sea lion are on islands located in southern California, western Baja California, and the Gulf of California. Although encounters with the species are possible in the proposed survey area, it is unlikely that it would be seen there. No pinnipeds were observed off Costa Rica during L-DEO seismic surveys in the ETP in November–December 2004 or February–March 2008 (Holst et al. 2005a; Holst and Smultea 2008). Similarly, Jackson et al. (2004, 2008) did not encounter any pinnipeds in the proposed survey area during surveys in the ETP.

The Galápagos sea lion, listed as ***Endangered*** on the 2010 IUCN Red List of Threatened Species (IUCN 2010) and listed in CITES Appendix II (UNEP-WCMC 2010), generally occurs around the Galápagos Islands. Galápagos sea lions are seen occasionally at Isla del Coco, an island 500 km southwest of Costa Rica (Acevedo-Gutiérrez 1994; Capella et al. 2002; Palacios 1996b; Palacios et al. 1997). Based on available survey data, it is unlikely that this species would occur in the proposed survey area.

No encounters with pinnipeds are expected during the proposed survey and no takes are requested.

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 ETP during April–May 2011.

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

VI. Numbers of Marine Mammals That Could be Taken

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

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

VII. Anticipated Impact on Species or Stocks

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

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

- First we summarize the potential impacts on marine mammals of airgun operations, as called for in § VII. A more comprehensive review of the relevant background information appears in Appendix B of the E
- Then we discuss the potential impacts of operations by the echosounders.
- Finally, we estimate the numbers of marine mammals that could be affected by the proposed survey in the ETP during April–May 2011. This section includes a description of the rationale for the estimates of the potential numbers of harassment "takes" during the planned survey, as called for in § VI.

Summary of Potential Effects of Airgun Sounds

The effects of sounds from airguns could include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and at least in theory, temporary or permanent hearing impairment, or non-auditory physical or physiological effects (Richardson et al. 1995; Gordon et al. 2004; Nowacek et al. 2007; Southall et al. 2007). Permanent hearing impairment, in the unlikely event that it occurred, would constitute injury, but temporary threshold shift (TTS) is not an injury (Southall et al.

2007). Although the possibility cannot be entirely excluded, it is unlikely that the project would result in any cases of temporary or especially permanent hearing impairment, or any significant non-auditory physical or physiological effects. Some behavioral disturbance is expected, but this would be localized and short-term.

Tolerance

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

Masking

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

Disturbance Reactions

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

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

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

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

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

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

However, some individual humpback whales, especially males, approached within distances of 100–400 m, where the maximum received level was 179 dB re 1 μPa$_{rms}$.

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) of the EA]. However, more recent research on bowhead whales (Miller et al. 2005; Harris et al. 2007) corroborates earlier evidence that, during the summer feeding season, bowheads are not as sensitive to seismic sources. Nonetheless, subtle but statistically significant changes in surfacing–respiration–dive cycles were evident upon statistical analysis (Richardson et al. 1986). In summer, bowheads typically begin to show avoidance reactions at received levels of about 152–178 dB re 1 μPa$_{rms}$ (Richardson et al. 1986, 1995; Ljungblad et al. 1988; Miller et al. 2005).

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

Various species of *Balaenoptera* (blue, sei, fin, and minke whales) have occasionally been seen in areas ensonified by airgun pulses (Stone 2003; MacLean and Haley 2004; Stone and Tasker 2006), and calls from blue and fin whales have been localized in areas with airgun operations (e.g., McDonald et al. 1995; Dunn and Hernandez 2009). 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; Allen and Angliss 2010). The western Pacific gray whale population did not seem affected by a seismic survey in its feeding ground during a previous year (Johnson et al. 2007). Similarly, bowhead whales have continued to travel to the eastern Beaufort Sea each summer, and their numbers have increased notably, despite seismic exploration in their summer and autumn range for many years (Richardson et al. 1987; Allen and Angliss 2010).

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

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; Richardson et al. 2009; see also Barkaszi et al. 2009). 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. 2008; Miller et al. 2009; Tyack 2009).

There are almost no specific data on the behavioral reactions of beaked whales to seismic surveys. However, some northern bottlenose whales remained in the general area and continued to produce high-frequency clicks when exposed to sound pulses from distant seismic surveys (Gosselin and Lawson 2004; Laurinolli and Cochrane 2005; Simard et al. 2005). Most beaked whales tend to avoid approaching vessels of other types (e.g., Würsig et al. 1998). They may also dive for an extended period when approached by a vessel (e.g., Kasuya 1986), although it is uncertain how much longer such dives may be as compared to dives by undisturbed beaked whales, which also are often quite long (Baird et al. 2006; Tyack et al. 2006). Based on a single observation, Aguilar-Soto et al. (2006) suggested that foraging efficiency of Cuvier's beaked whales may be reduced by close approach of vessels. In any event, it is likely that most beaked whales would also show strong avoidance of an approaching seismic vessel, although this has not been documented explicitly.

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

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

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

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

Hearing Impairment and Other Physical Effects

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

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

Recommendations for new science-based noise exposure criteria for marine mammals, frequency-weighting procedures, and related matters were published recently (Southall et al. 2007). Those recommendations have not, as of late 2010, been formally adopted by NMFS for use in regulatory processes and during mitigation programs associated with seismic surveys. However, some aspects of the recommendations have been taken into account in certain environmental impact statements and small-take authorizations. NMFS has indicated that it may issue new noise exposure criteria for marine mammals that account for the now-available scientific data on TTS, the expected offset between the TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive (e.g., M-weighting or generalized frequency weightings for various groups of marine mammals, allowing for their functional bandwidths), and other relevant factors. Preliminary information about possible changes in the regulatory and mitigation requirements, and about the possible structure of new criteria, was given by Wieting (2004) and NMFS (2005).

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

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

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

For toothed whales exposed to single short pulses, the TTS threshold appears to be, to a first approximation, a function of the energy content of the pulse (Finneran et al. 2002, 2005). Based on these data, the received energy level of a single seismic pulse (with no frequency weighting) might need to be ~186 dB re 1 $\mu Pa^2 \cdot s$ (i.e., 186 dB SEL or ~196–201 dB re 1 μPa_{rms}) in order to produce brief, mild TTS[1]. Exposure to several strong seismic pulses that each have received levels near 190 dB re 1 μPa_{rms} might result in cumulative exposure of ~186 dB SEL and thus slight TTS in a small odontocete assuming the TTS threshold is (to a first approximation) a function of the total received pulse energy; however, this 'equal-energy' concept is an oversimplification. The distances from the *Langseth*'s airguns at which the received energy level (per pulse, flat-weighted) would be expected to be ≥190 dB re 1 μPa_{rms} are estimated in Table 1. Levels ≥190 dB re 1 μPa_{rms} are expected to be restricted to radii no more than 235 m (Table 1). For an odontocete closer to the surface, the maximum radius with ≥190 dB re 1 μPa_{rms} would be smaller.

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

For baleen whales, there are no data, direct or indirect, on levels or properties of sound that are required to induce TTS. The frequencies to which baleen whales are most sensitive are assumed to be lower than those to which odontocetes are most sensitive, and natural background noise levels at those low frequencies tend to be higher. As a result, auditory thresholds of baleen whales within their frequency band of best hearing are believed to be higher (less sensitive) than are those of odontocetes at their best frequencies (Clark and Ellison 2004). From this, it is suspected that received levels causing

[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).

TTS onset may also be higher in baleen whales (Southall et al. 2007). In any event, no cases of TTS are expected given three considerations: (1) the low abundance of baleen whales in the planned study area at the time of the survey; (2) the strong likelihood that baleen whales would avoid the approaching airguns (or vessel) before being exposed to levels high enough for TTS to occur; and (3) the mitigation measures that are planned.

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

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

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

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

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

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

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

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

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

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

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

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

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

Possible Effects of Multibeam Echosounder Signals

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

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

Masking

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

Behavioral Responses

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

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

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

Hearing Impairment and Other Physical Effects

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

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

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

Possible Effects of the Sub-bottom Profiler Signals

An SBP will also be operated from the source vessel during the planned study. Details about this equipment were provided in § I. Sounds from the SBP 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 SBP signals given the directionality of the signal and the brief period when an individual mammal is likely to be within its beam. Furthermore, in the case of most baleen whales, the SBP signals do not overlap with the predominant frequencies in the calls, which would avoid significant masking.

Behavioral Responses

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

Hearing Impairment and Other Physical Effects

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

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

All anticipated takes would be "takes by harassment", involving temporary changes in behavior. The mitigation measures to be applied will minimize the possibility of injurious takes. (However, as noted earlier, there is no specific information demonstrating that injurious "takes" would occur even in the absence of the planned mitigation measures.) In the sections below, we describe methods to estimate the number of potential exposures to various received sound levels and present estimates of the numbers of marine mammals that could be affected during the proposed seismic program. The estimates are based on a consideration of the number of marine mammals that could be disturbed appreciably by operations with the 18-airgun subarray to be used during ~3200 km of seismic surveys in the ETP. The sources of distributional and numerical data used in deriving the estimates are described in the next subsection.

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

Basis for Estimating "Take by Harassment"

Extensive systematic ship-based surveys have been conducted by NMFS SWFSC for marine mammals in the ETP. We used densities from two sources: (1) SWFSC has recently developed habitat modeling as a method to estimate cetacean densities on a finer spatial scale than traditional line-transect analyses by using a continuous function of habitat variables, e.g., sea surface temperature, depth, distance from shore, and prey density (Barlow et al. 2009). For the ETP, the models are based on data from 12 SWFSC ship-based cetacean and ecosystem assessment surveys conducted during July–December from 1986 to 2006. The models have been incorporated into a web-based Geographic Information System (GIS) developed by Duke University's Department of Defense Strategic Environmental Research and Development Program (SERDP) team in close collaboration with the SWFSC SERDP team (Read et al. 2009). We used the GIS to obtain mean and maximum densities for the 11 cetacean species in the model in the proposed survey area. (2) For species sighted in SWFSC surveys whose sample sizes were too small to model density, we used densities from the surveys conducted during summer and fall 1986–1996, as summarized by Ferguson and Barlow (2001, 2003). Densities were calculated from Ferguson and Barlow (2003) for 5° x 5° blocks that include the proposed survey area (Block 138) and blocks adjacent to 138 that include coastal waters: Blocks 119, 137, 138, 139, 158, and 159. Those blocks included 18,385 km of survey effort in Beaufort sea states 0–5, and 3899 km[2] of survey effort in Beaufort sea states 0–2. Densities were obtained for an additional seven species that were sighted in one or more of those blocks.

For two endangered species for which there are only unconfirmed sightings in the region, the sei and fin whales, arbitrary low densities (equal to the density of the species with the lowest calculated density) were assigned. The false killer whale has been sighted near the survey area but not in the 7 blocks of Ferguson and Barlow (2003), so it was also assigned the same arbitrary low density.

Oceanographic conditions, including occasional El Niño and La Niña events, influence the distribution and numbers of marine mammals present in the ETP, resulting in considerable year-to-year variation in the distribution and abundance of many marine mammal species (e.g., Escorza-Treviño 2009). 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 estimated densities for each cetacean species likely to occur in the study area, i.e., species for which we obtained or assigned densities. The densities have been corrected for both detectability and availability bias by the authors. 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 $g(0)$.

There is some uncertainty about the representativeness of the data and the assumptions used in the calculations below. However, the approach used here is believed to be the best available approach. Also, to provide some allowance for these uncertainties, "maximum estimates" as well as "best estimates" of the densities present and numbers potentially affected have been derived. For the modeled species, best estimates and maximum estimates of density in the survey area are the mean and maximum densities given in Read et al. (2009). For the other species, best estimates of density are the effort-weighted mean densities in the seven 5° x 5° blocks from Ferguson and Barlow (2001, 2003), and maximum estimates of density are the highest densities in any of the blocks.

[2] Includes other blocks pooled with the blocks of interest to provide sufficient effort to allow a density estimate.

TABLE 3. Densities of marine mammals in the ETP near the proposed survey area. Cetacean densities are based on NMFS SWFSC ship transect surveys conducted in 1986–2006 from predictive modeling (Barlow et al. 2009; Read et al. 2009) or in 1986–1996 from Ferguson and Barlow (2003). See text for details. Densities are corrected for *f*(0) and *g*(0). Species listed as "Endangered" under the ESA are in italics.

	Density (#/1000 km^2)		
Species[1]	**Best (mean)**	**Maximum**	**Source**
Mysticetes			
Humpback whale	*0.25*	*4.40*	Ferguson and Barlow (2003)
Bryde's whale	0.96	2.52	Read et al. (2009)
Sei whale	*0.01*	*0.01*	Arbitrary low
Fin whale	*0.01*	*0.01*	Arbitrary low
Blue whale	*0.13*	*1.86*	Read et al. (2009)
Odontocetes			
Sperm whale	*4.19*	*9.80*	Ferguson and Barlow (2003)
Pygmy and dwarf sperm whales	0.03	0.05	Read et al. (2009)
Cuvier's beaked whale	2.47	3.70	Ferguson and Barlow (2003)
Mesoplodon spp.[2]	0.36	1.00	Read et al. (2009)
Rough-toothed dolphin	4.19	11.19	Read et al. (2009)
Bottlenose dolphin	17.06	90.91	Read et al. (2009)
Pantropical spotted dolphin	76.96	236.66	Read et al. (2009)
Spinner dolphin	58.43	364.26	Read et al. (2009)
Striped dolphin	67.75	154.21	Read et al. (2009)
Short-beaked common dolphin	110.89	763.50	Read et al. (2009)
Risso's dolphin	12.76	22.60	Ferguson and Barlow (2003)
Melon-headed Whale	11.06	57.70	Ferguson and Barlow (2003)
Pygmy killer whale	1.25	2.30	Ferguson and Barlow (2003)
False killer whale	0.01	0.01	Arbitrary low
Killer whale	0.19	0.40	Ferguson and Barlow (2003)
Short-finned pilot whale	11.88	28.22	Read et al. (2009)

[1] With the exception of sei, fin, and false killer whales, includes only species for which density estimates are available. Densities of other species included in Table 2 (minke whale, Fraser's dolphin, and the sea lions) presumably would be lower than the lowest density in this table.

[2] Includes pygmy, ginkgo-toothed, and Blainville's beaked whales.

The estimated numbers of individuals potentially exposed are based on the 160-dB re 1 μPa_{rms} criterion for all cetaceans and the 170-dB re 1 μPa_{rms} criterion for delphinids. It is assumed that marine mammals exposed to airgun sounds that strong might change their behavior sufficiently to be considered "taken by harassment".

It should be noted that the following estimates of exposures to various sound levels assume that the surveys will be fully completed; in fact, the ensonified areas calculated using the planned number of line-kilometers ***have been increased by 25%*** to accommodate lines that may need to be repeated, equipment testing, etc. As is typical during ship surveys, inclement weather and equipment malfunctions are likely to cause delays and may limit the number of useful line-kilometers of seismic operations that can be undertaken. Furthermore, any marine mammal sightings within or near the designated exclusion zone will result in the shut down of seismic operations as a mitigation measure. Thus, the following estimates of the numbers of marine mammals potentially exposed to 160- or 170-dB re 1 μPa_{rms} sounds are precautionary, and probably overestimate the actual numbers of marine mammals that might be involved. These estimates assume that there will be no weather, equipment, or mitigation delays, which is highly unlikely. Furthermore, the radii and therefore exposures may be overestimated, possibly considerably (see § I).

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

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 expected density of animals in the area along with the total marine area that would be within the 160-dB radius around the operating airgun array on at least one occasion. The number of possible exposures (including repeated exposures of the same individuals) can be estimated by considering the total marine area that would be within the 160-dB radius around the operating airguns, including areas of overlap. In the proposed survey, the seismic lines are parallel and in close proximity, so individuals could be exposed on two or more occasions. The 160-dB area including overlap is 31.9 x the area excluding overlap (13.7 x the area excluding overlap for the 170-dB radius), so a marine mammal that stayed in the survey area during the entire survey could be exposed 32 times (14 times), on average. Given the pattern of the seismic lines, the interval between exposures of a stationary animal would be ~18 h. However, it is unlikely that a particular animal would stay in the area during the entire survey. The numbers of different individuals potentially exposed to ≥160 dB re 1 μPa_{rms} were calculated by multiplying

- the expected species density, either "mean" (i.e., best estimate) or "maximum", times
- the anticipated 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 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 of overlap were included only once when estimating the number of individuals exposed. Before calculating numbers of individuals exposed, the areas were increased by 25% as a precautionary measure.

Table 4 shows the best and maximum estimates of the number of different individual marine mammals that potentially could be exposed to ≥160 dB re 1 μPa_{rms} during the seismic survey if no animals moved away from the survey vessel. The ***Requested Take Authorization***, given in the far right column of Table 4, is based on the maximum estimates rather than the best estimates of the numbers exposed, because the density estimates their are based on SWFSC marine mammal surveys conducted during July–November, whereas the proposed seismic survey is scheduled during April–May. For ***endangered*** species, the ***Requested Take Authorization*** has been increased to the mean group size in the ETP (Jackson et al. 2008) for the particular species in cases where the calculated number of individuals exposed was between 0.05 and the mean group size (i.e., for sei and fin whales). For non-listed species, the ***Requested Take Authorization*** has been increased to the mean group size in the ETP (Ferguson et al. 2006) for the particular species in cases where the calculated number of individuals exposed was between 1 and the mean group size.

Applying the approach described above, ~3225 km^2 (~4030 km^2 including the 25% contingency) would be within the 160-dB isopleth during the survey assuming that all contingency lines are completed. 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 could be underestimated. However, the approach assumes that no cetaceans will move away from or toward the trackline as the *Langseth* approaches in response to increasing sound levels prior to the time the levels reach 160 dB, which will result in overestimates for those species known to avoid seismic vessels (see § IV a).

TABLE 4. Estimates of the possible numbers of different individuals that might be exposed, during L-DEO's proposed seismic survey in ETP in April–May 2011. The proposed sound source consists of an 18-airgun subarray with a total discharge volume of 3300 in^3. Received levels of seismic sounds are expressed in dB re 1 µPa (rms, averaged over pulse duration), consistent with NMFS' practice. Not all marine mammals will change their behavior when exposed to these sound levels, but some may alter their behavior when levels are lower (see text). Delphinids 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.

	Number of Individuals Exposed to Sound Levels >160 dB (>170 dB, Delphinids)					
	Best Estimate[1]					
Species	**Number**		**% of Regional Pop'n**[2]	**Maximum Estimate**[1]		**Requested Take Authorization**
Balaenopteridae						
Humpback whale	*1*		*0.07*	*18*		***18***
Bryde's whale	4		0.03	10		**10**
Sei whale	*0*		*NA*	*0*		***1***[3]
Fin whale	*0*		*<0.01*	*0*		***1***[3]
Blue whale	*1*		*0.04*	*8*		***8***
Physeteridae						
Sperm whale	*17*		*0.06*	*40*		***40***
Pygmy/dwarf sperm whales	0		<0.01	0		**0**
Ziphiidae						
Cuvier's beaked whale	10		0.05	15		**15**
Mesoplodon sp. (unidentified)	1		0.01	4		**4**
Delphinidae						
Rough-toothed dolphin	17	(7)	0.02	45	(18)	45
Bottlenose dolphin	69	(27)	0.02	366	(146)	366
Pantropical spotted dolphin	310	(124)	0.02	954	(380)	954
Spinner dolphin	236	(94)	0.01	1468	(585)	1468
Striped dolphin	273	(109)	0.03	622	(248)	622
Short-beaked common dolphin	447	(178)	0.01	3077	(1226)	3077
Risso's dolphin	51	(20)	0.05	91	(36)	91
Melon-headed whale	45	(18)	0.10	233	(93)	**258**[3]
Pygmy killer whale	5	(2)	0.01	9	(4)	**30**[3]
False killer whale	0	(0)	<0.01	0	(0)	**0**
Killer whale	1	(0)	0.01	2	(1)	**5**[3]
Short-finned pilot whale	48	(19)	0.01	114	(45)	**114**

[1] Best and maximum estimates are based on densities from Table 3 and ensonified areas (including 25% contingency) of 4030.63 for 160 dB and 1605.71 km^2 for 170 dB (identified in parentheses). Takes are not anticipated for the minke whale and Fraser's dolphin.
[2] Regional population size estimates are from Table 2; NA means not available.
[3] Requested Take Authorization increased to mean group size in the ETP for baleen whales (Jackson et al. 2008) and delphinids (Ferguson et al. 2006).

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 1536 (Table 4). That total includes 17 sperm whales (listed as ***endangered under*** the ESA) or 0.06% of the regional population.

In addition, 11 beaked whales (10 Cuvier's and 1 Mesoplodont beaked whales) could be exposed during the survey (Table 4). Most (97.8%) of the cetaceans potentially exposed are delphinids; short-beaked common, pantropical spotted, striped, and spinner dolphins are estimated to be the most common species in the area, with best estimates of 447, 310, 273, and 236 (each representing 0.01%–0.03% of the regional population) exposed to ≥160 dB re 1 μPa$_{rms}$, respectively. However, a more meaningful estimate is the one for sound levels ≥170 dB (see below). The 'Maximum Estimate' column in Table 4 shows an estimated total of 7076 cetaceans. Again, most of these consist of dolphins.

Number of Delphinids 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 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 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 ~1285 km^2 (~1605 km^2 including the 25% contingency). The best and maximum estimates of the numbers of individual delphinids that could be exposed to ≥170 dB during the survey are 598 and 2782, respectively (Table 4). These values are based on the predicted 170-dB radius around the airgun array to be used during the study, and are considered to be more realistic estimates of the number of individual delphinids that could be affected.

Number of Pinnipeds that might be Exposed to ≥160 dB and ≥170 dB.—No pinnipeds are expected to occur in the survey area, so no exposures are expected and no take authorization is requested.

Conclusions

The proposed seismic survey will involve towing an airgun array that introduces pulsed sounds into the ocean, along with simultaneous operation of an MBES and SBP. The survey will employ a 18-airgun subarray similar to the airgun arrays used for typical high-energy seismic surveys. The total airgun discharge volume is ~3300 in^3. Routine vessel operations, other than the proposed airgun operations, are conventionally assumed not to affect marine mammals sufficiently to constitute "taking". No "taking" of marine mammals is expected in association with echosounder operations given the considerations discussed in § I, i.e., sounds are beamed downward, the beam is narrow, and the pulses are extremely short.

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

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

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

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) and density criterion used. The requested "take authorization" for each species is based on the maximum estimate of the number of individuals that could be exposed to ≥160 dB re 1 μPa_{rms}. Those figures likely overestimate the actual number of animals that will be exposed to and react to the seismic sounds. The reasons for that conclusion are outlined above. The relatively short-term exposures are unlikely to result in any long-term negative consequences for the individuals or their populations.

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

Pinnipeds.— No pinnipeds are expected to occur in the survey area, so no exposures are expected and no take authorization is requested.

VIII. ANTICIPATED IMPACT ON SUBSISTENCE

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

There is no subsistence hunting off Costa Rica, 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 of the EA, respectively.

Effects on Fish

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

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

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

Pathological Effects

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

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

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

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

Physiological Effects

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

Behavioral Effects

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

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

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

Effects on Invertebrates

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

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

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

Pathological Effects

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

Some studies have suggested that seismic survey sound has a limited pathological impact on early developmental stages of crustaceans (Pearson et al. 1994; Christian et al. 2003; DFO 2004). However, the impacts appear to be either temporary or insignificant compared to what occurs under natural conditions. Controlled field experiments on adult crustaceans (Christian et al. 2003, 2004; DFO 2004) and adult cephalopods (McCauley et al. 2000a,b) exposed to seismic survey sound have not resulted in any significant pathological impacts on the animals. It has been suggested that 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. Primary and secondary stress responses (i.e., changes in haemolymph levels of enzymes, proteins, etc.) of crustaceans have been noted several days or months after exposure to seismic survey sounds (Payne et al. 2007). The periods necessary for these biochemical changes to return to normal are variable and depend on numerous aspects of the biology of the species and of the sound stimulus.

Behavioral Effects

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

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

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

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

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

XI. Mitigation Measures

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

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

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

Planning Phase

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 (6, 10, 12, and 20 airguns) during the acoustic calibration study of the R/V *Ewing*'s 20-airgun, 8600-in^3 array in 2003 (Tolstoy et al. 2004a,b) and for the 36-airgun, 6600-in^3 array during the acoustic calibration study of the R/V *Marcus G. Langseth* in 2007–2008 (Tolstoy et al. 2009). 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.

Received sound levels have been predicted by L-DEO in relation to distance and direction from the airguns for the 36-airgun array with 18 airguns firing (Fig. 3) and for a single 1900LL 40 in^3 airgun, which will be used during power downs (Fig. 4). A detailed description of the modeling effort is provided in Appendix A of the EA. The L-DEO model does not allow for bottom interactions, and thus is most directly applicable to deep water and to relatively short ranges. During the proposed study, survey effort including contingency will be 835, 1360, and 1020 km in water depths >1000 m, 100–1000 m, and <100 m, respectively. Based on the modeling for deep water and using correction factors for shallow water derived from the acoustic calibration studies, 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 and water depth and range up to 1030 m and 235 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 exclusion zones (EZs). If the protected species observer (PSO) 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 survey off Costa Rica include (1) power-down procedures, (2) shut-down procedures, and (3) ramp-up procedures.

Power-down Procedures

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

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

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

- it is visually observed to have left the EZ, or
- it has not been seen within the zone for 15 min in the case of small odontocetes (or pinnipeds), or
- it has not been seen within the zone for 30 min in the case of mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, and beaked whales, or
- the vessel has moved outside the EZ for turtles, e.g., if a turtle is sighted close to the vessel and the ship speed is 8.5 km/h, it would take the vessel from ~3 min in deep water to ~7.5 min in shallow water to leave the turtle behind.

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

Shut-down Procedures

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

Ramp-up Procedures

A ramp-up procedure will be followed when the airgun array begins operating after a specified period without airgun operations or when a power down has exceeded that period. It is proposed that, for the present cruise, this period would be ~3 min. This period is based on the deep-water 180-dB radius for the 18-airgun subarray (450 m) in relation to the planned speed of the *Langseth* while shooting (8.5 km/h). Similar periods were used during previous L-DEO surveys.

Ramp up will begin with the smallest airgun in the array (40 in^3). Airguns will be added in a sequence such that the source level of the array will increase in steps not exceeding 6 dB per 5-min period over a total duration of ~30 min. During ramp up, the PSOs will monitor the EZ, and if marine mammals or turtles are sighted, a power down or shut down will be implemented as though the full array were operational.

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

XII. Plan of Cooperation

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

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

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

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

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

Not applicable. The proposed activity will take place off Costa Rica, 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

PSOs 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. PSOs will also watch for marine mammals and turtles near the seismic vessel for at least 30 minutes prior to the start of airgun operations after an extended shut down. When feasible, PSOs 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 PSO observations, the airguns will be powered down 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 off Costa Rica, at least three visual PSOs will be based aboard the *Langseth*. PSOs will be appointed by L-DEO with NMFS concurrence. At least one PSO, and when practical two PSOs, 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 effectiveness of detecting animals near the source vessel. PSO(s) will be on duty in shifts of duration no longer than 4 h. Other crew will also be instructed to assist in detecting marine mammals and turtles and implementing mitigation requirements (if practical). Before the start of the seismic survey the crew will be given additional instruction regarding how to do so.

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

Passive Acoustic Monitoring

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

The PAM system consists of hardware (i.e., hydrophones) and software. The "wet end" of the system consists of a towed four-hydrophone array, two of which are monitored simultaneously; the active section of the array is ~30 m long. The array is attached to the vessel by a 250-m electromechanical lead-in cable and a 50-m long deck lead-in cable. However, not the entire length of lead-in cable is used; thus, the hydrophones are typically located 120 m behind the stern of the ship. The deck cable is connected from the array to a computer in the laboratory where signal conditioning and processing takes place. The digitized signal is then sent to the main laboratory, where the acoustic PSO monitors the system. The hydrophone array is typically towed at depths <20 m.

The towed hydrophones will ideally be monitored 24 h per day while at the seismic survey area during airgun operations, and during most periods when the *Langseth* is underway while the airguns are not operating. However, PAM may not be possible if damage occurs to the array during operations. One PSO will monitor the acoustic detection system at any one time, by listening to the signals from two channels via headphones and/or speakers and watching the real-time spectrographic display for frequency ranges produced by cetaceans. PSOs monitoring the acoustical data will be on shift for 1–6 h at a time. Besides the visual PSOs, an additional PSO with primary responsibility for PAM will also be aboard. All PSOs 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 PSO will contact the visual PSO immediately, to alert him/her to the presence of cetaceans (if they have not already been seen), and to allow a power down or shut down to be initiated, if required. The information regarding the call will be entered into a database. The data to be entered include an acoustic encounter identification number, whether it was linked with a visual sighting, date, time when first and last heard and whenever any additional information was recorded, position and water depth when first detected, species or species group (e.g., unidentified dolphin, sperm whale), types and nature of sounds heard (e.g., clicks, continuous, sporadic, whistles, creaks, burst pulses, strength of signal, etc.), and any other notable information. The acoustic detection can also be recorded for further analysis.

PSO Data and Documentation

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

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

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

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

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

Results from the vessel-based observations will provide

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

5. Data on the behavior and movement patterns of marine mammals and turtles seen at times with and without seismic activity.

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

XIV. Coordinating Research to Reduce and Evaluate Incidental Take

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

L-DEO will coordinate the planned marine mammal monitoring program associated with the seismic survey off Costa Rica (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. L-DEO and NSF will coordinate with applicable U.S. agencies (e.g., NMFS), and will comply with their requirements.

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