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 Central Pacific Ocean, November–December 2011

submitted by

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

to

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

Application Prepared by

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

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SUMMARY

Lamont-Doherty Earth Observatory (L-DEO), with research funding from the National Science Foundation (NSF), plans to conduct a marine seismic survey ~1300 km south of Hawaii in the central Pacific Ocean during November–December 2011. The survey will take place in international waters with a depth of ~5000 m. The airgun array will consist of 36 airguns with a total volume of ~6600 in^3. L-DEO requests that it be issued an Incidental Harassment Authorization (IHA) allowing non-lethal takes of marine mammals incidental to the planned seismic survey. This request is submitted pursuant to Section 101 (a)(5)(D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371 (a) (5).

Numerous species of cetaceans and pinnipeds inhabit the proposed survey area in the central Pacific. Several of these species are listed as ***endangered*** under the ESA, including the humpback, sei, fin, blue, and sperm whales, and the Hawaiian monk seal. ESA-listed sea turtle species that could occur in the survey area include the ***endangered*** hawksbill and leatherback turtles, and the ***threatened*** green, loggerhead, and olive ridley turtles. Listed seabirds that could be encountered in the area include the ***endangered*** Hawaiian petrel and short-tailed albatross, and the ***threatened*** Newell's shearwater; the black-footed albatross is a candidate species for listing.

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 ~1300 km south of Hawaii in the central Pacific Ocean. The survey will encompass the area 5–10°N and 150–156°W (Fig. 1). Water depth in the survey area is ~5000 m. The project is scheduled to occur ~26 November–29 December 2011. Some minor deviation from these dates is possible, depending on logistics and weather.

L-DEO plans to use conventional seismic methodology to collect a suite of observations that will unambiguously characterize the detailed structure of oceanic lithosphere in an uncomplicated spreading segment far removed from the influence of asthenospheric melt. With these observations and associated

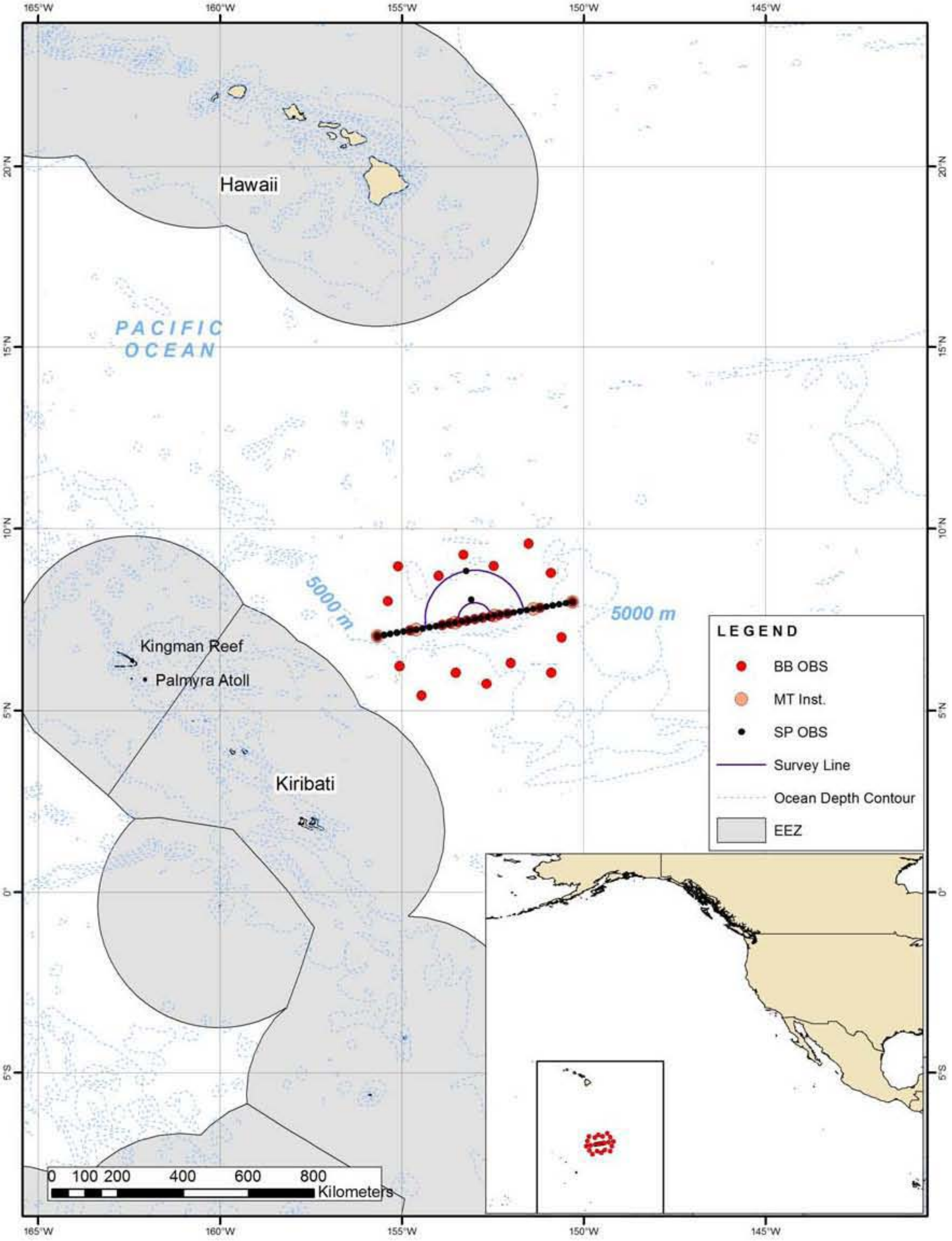

FIGURE 1. Study area and proposed survey design for the seismic survey in the central Pacific Ocean planned for 26 November–29 December 2011 with OBS and MT instrument placements and seismic tracklines. SP = short-period; BB = broad band; MT inst = magneto-telluric instrument; EEZ = exclusive economic zone.

analyses we aim to define the detailed structure of oceanic lithosphere and develop a comprehensive theory for its formation and evolution.

The survey will involve one source vessel, the R/V *Marcus G. Langseth*. The *Langseth* will deploy a 36-airgun array as an energy source. The receiving system will consist of one 6-km long hydrophone streamer and/or ocean bottom seismometers (OBSs). As the airgun array is towed along the survey lines, the hydrophone streamer will receive the returning acoustic signals and transfer the data to the on-board processing system. The OBSs record the returning acoustic signals internally for later analysis. Upon arrival at the survey area, ~34 short-period (SP) OBSs will be deployed. The streamer and airgun array will then be deployed, and seismic operations will commence. After completion of seismic operations, the SP OBSs will be recovered and 27 broad-band (BB) OBSs and 5 magneto-telluric (MT) instruments will be deployed. These instruments will remain in the survey area for 1 year.

The total survey effort will consist of ~2120 km of transect lines. A 600-km long transect line will be shot twice: once using the streamer as the receiver and once again using the OBSs. Subsequent seismic operations will occur along two semi-circular arcs (180°) centered at the mid-point of the 600-km long transect line with radii of 50 and 150 km, respectively (Fig. 1). There will be additional seismic operations in the survey area associated with turns, airgun testing, and repeat coverage of any areas where initial data quality is sub-standard. In our calculations (see § IV(3)), 25% has been added for those additional operations.

In addition to the operations of the airgun array, a multibeam echosounder (MBES) and a sub-bottom profiler (SBP) will also be operated from the *Langseth* continuously throughout the cruise. All planned geophysical data acquisition activities will be conducted by L-DEO with on-board assistance by the scientists who have proposed the study. The Principal Investigators (PIs) are Dr. J.B. Gaherty (L DEO); Drs. D. Lizarralde, J.A. Collins, and R. Evans (all of Woods Hole Oceanographic Institution, WHOI); and Dr. G. Hirth (Brown University). The vessel will be self-contained, and the crew will live aboard the vessel for the entire cruise.

Vessel Specifications

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

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

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

Other details of the *Langseth* include the following:

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

Airgun Description

During the survey, the airgun array to be used will consist of 36 airguns, with a total volume of ~6600 in^3. The airgun array will consist of a mixture of Bolt 1500LL and Bolt 1900LLX airguns. The airguns will be configured as four identical linear arrays or "strings" (Fig. 2). Each string will have ten airguns; the first and last airguns in the strings are spaced 16 m apart. Nine airguns in each string will be fired simultaneously, whereas the tenth is kept in reserve as a spare, to be turned on in case of failure of another airgun. The four airgun strings will be towed ~100 m behind the *Langseth* and will distributed across an area of ~24×16 m. The shot interval will be relatively short (22 s or 50 m) for multichannel seismic (MCS) surveying with the hydrophone streamer, and long (300 s or 650 m) when recording data on the OBSs. The firing pressure of the array is 1900 psi. During firing, a brief (~0.1 s) pulse of sound is emitted. The airguns will be silent during the intervening periods.

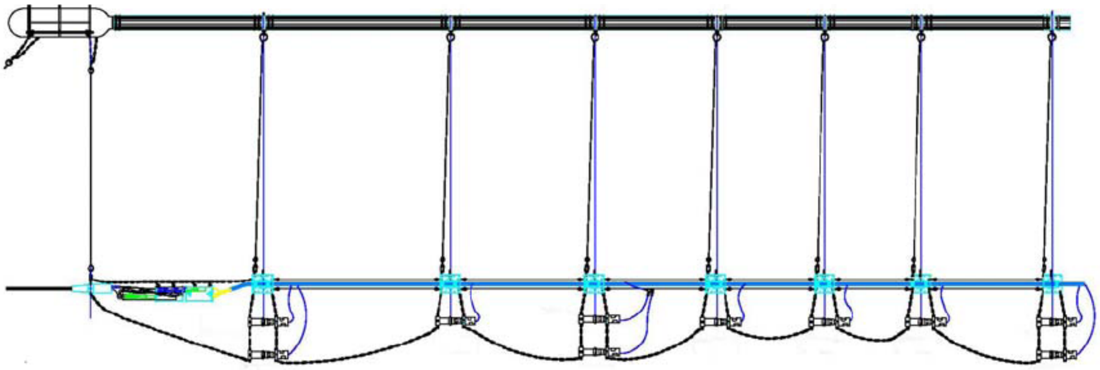

FIGURE 2. One linear airgun array or string with ten airguns, nine of which would be operating.

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

36-Airgun Array Specifications

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

Acoustic Measurements

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

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

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

Predicted Sound Levels

Results of the propagation measurements showed that radii around the airguns for various received levels varied with water depth (Tolstoy et al. 2009). In addition, propagation varies with array tow depth. The empirical values that resulted from Tolstoy et al. (2009) are used here to determine exclusion zones for the 36-airgun array. However, the depth of the array was different in the Gulf of Mexico calibration study (6 m) than in the proposed survey (9 m); thus, correction factors have been applied to the distances

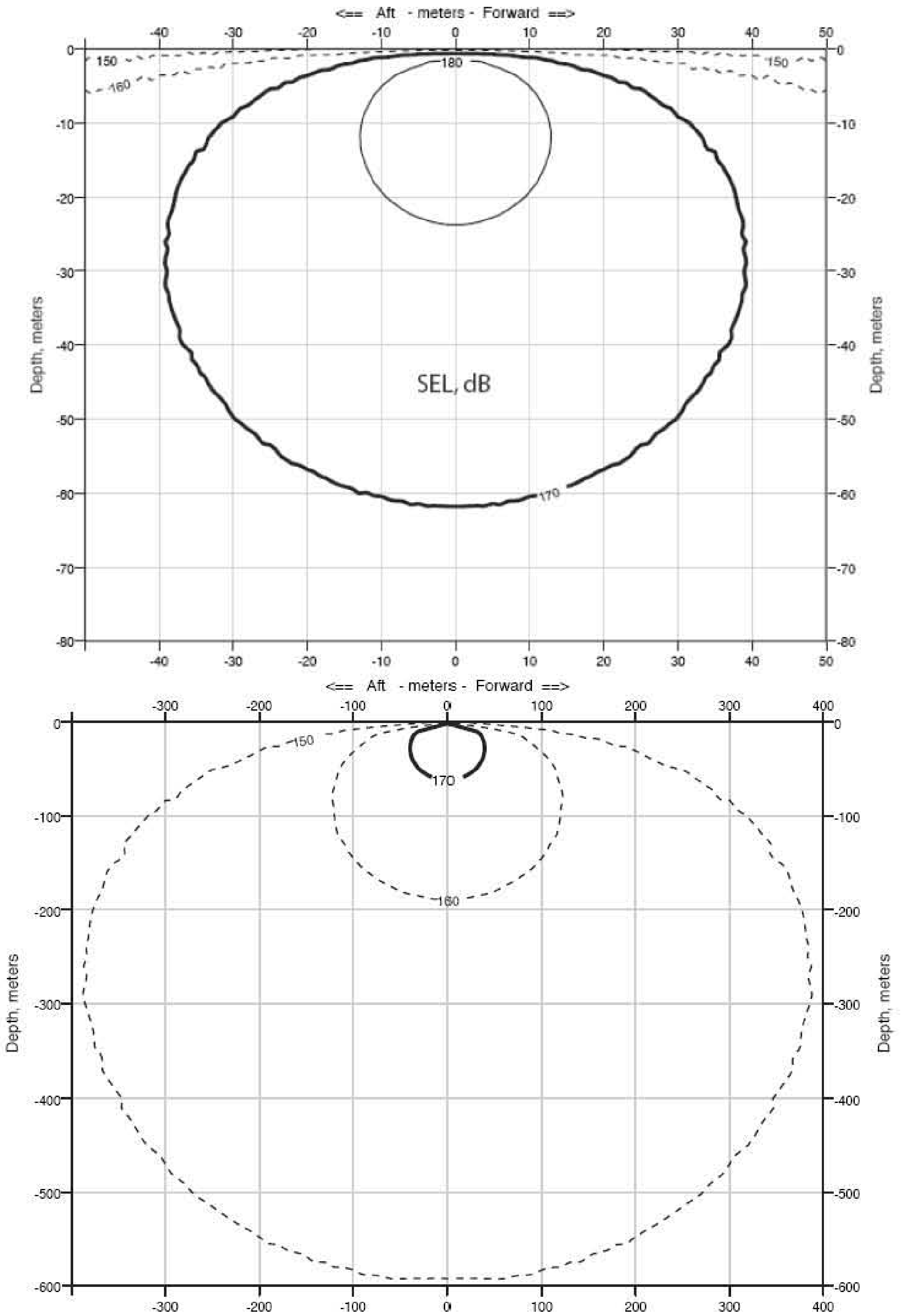

FIGURE 3. Modeled received sound levels (SELs) from a single 40-in^3 airgun operating in deep water, which is planned for use during the survey in the ETP during April–May 2011. Received rms levels (SPLs) are expected to be ~10 dB higher.

reported by Tolstoy et al. (2009). The correction factors used were the ratios of the 160-, 170-, 180-, and 190-dB distances from the modeled results for the 6600-in^3 airgun array towed at 6 m vs. 9 m, from LGL (2008): 1.285; 1.381; 1.338; and 1.364, respectively.

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

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

TABLE 1. Measured (array) or predicted (single airgun) distances to which sound levels ≥190, 180, and 160 dB re 1 μPa$_{rms}$ are expected to be received in deep water during the proposed survey in the central Pacific Ocean, 26 November–29 December 2011. Radii for the array are based on empirical data in Tolstoy at al. (2009), corrected for tow depth using model results, and predicted radii for a single airgun are based on L-DEO's model, assuming that received levels on an RMS basis are, numerically, 10 dB higher than the SEL values shown in Figure 3.

	Predicted RMS Distances (m) in deep (>1000 m) water		
Source and Volume	**190 dB**	**180 dB**	**160 dB**
Single Bolt airgun, 40 in^3	12	40	385
4 strings, 36 airguns, 6600 in^3, tow depth 9 m	400	940	3850

Description of Operations

The source vessel, the R/V *Marcus G. Langseth*, will deploy an array of 36 airguns as an energy source at a tow depth of 9 m. The receiving system will consist of one 6-km long hydrophone streamer and/or ocean bottom seismometers (OBSs). As the airgun array is towed along the survey lines, the hydrophone streamer will receive the returning acoustic signals and transfer the data to the on-board processing system. The OBSs record the returning acoustic signals internally for later analysis. Upon arrival at the survey area, ~34 short-period (SP) OBSs will be deployed. The streamer and airgun array will then be deployed, and seismic operations will commence. After completion of seismic operations, the SP OBSs will be recovered and 27 broad-band (BB) OBSs and 5 magneto-telluric (MT) instruments will be deployed. These instruments will remain in the survey area for 1 year.

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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 Chirp 3260 SBP.

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 $\mu\text{Pa}\cdot\text{m}_{\text{rms}}$. Each "ping" consists of eight (in water >1000 m deep) or four (<1000 m) successive fan-shaped transmissions, each ensonifying a sector that extends 1° fore–aft. Continuous-wave (CW) pulses increase from 2 to 15 ms long in water depths up to 2600 m, and FM chirp pulses up to 100 ms long are used in water >2600 m. The successive transmissions span an overall cross-track angular extent of about 150°, with 2-ms gaps between the pulses for successive sectors.

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

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

Maximum source output (downward)	222 dB re 1 μPa·m
Dominant frequency components	3.5 kHz; up to 210 kHz
Nominal beam width	~27 degrees
Pulse duration	up to 64 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 5–10°N and 150–156°W in International Waters in the central Pacific Ocean ~1300 km south of Hawaii (Fig. 1). Water depth in the survey area is ~5000 m. The exact dates of the activities depend on logistics and weather conditions. The R/V *Langseth* will depart from Honolulu, HI, on ~26 November 2011 and return there on 29 December 2011. Seismic operations will be carried out for an estimated 11 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-six marine mammal species could occur in the central Pacific survey area. To avoid redundancy, we have included the required information about the species and (insofar as it is known) numbers of these species in § IV, below.

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

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

Sections III and IV are integrated here to minimize repetition.

Twenty-five cetacean species could occur in the central Pacific survey area, including odontocetes (toothed cetaceans, such as dolphins) and mysticetes (baleen whales); although considered unlikely, the Hawaiian monk seal could also be encountered (Table 2). Information on the occurrence, population size, and conservation status for each of the 25 cetacean species is presented in Table 2. The status of these species is based on the ESA, the 2010 International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2010), and the Convention on International Trade in Endangered Species in Wild Fauna and Flora (CITES; UNEP-WCMC 2010). Five of these species are listed under the ESA as ***Endangered***, including the sperm, humpback, fin, sei, and blue whales.

Mysticetes

Humpback Whale (*Megaptera novaeangliae*)

The humpback whale is found throughout all of the oceans of the world (Clapham 2002). The species is listed as ***Endangered*** under the ESA and ***Least Concern*** on the IUCN Red List of Threatened Species (IUCN 2010), and it is listed in CITES Appendix I (UNEP-WCMC 2010) (Table 2). The worldwide population of humpback whales is divided into northern and southern ocean populations, but genetic analyses suggest some gene flow (either past or present) between the North and South Pacific (e.g., Baker et al. 1983; Caballero et al. 2001). Based on a collaborative study involving numerous jurisdictions, the entire North Pacific stock has been recently estimated at 18,302, excluding calves (Calambokidis et al. 2008). Barlow et al. (2009a) provided a bias-corrected abundance estimate of 20,800. Overall, the North Pacific stock is increasing (Calambokidis et al. 2008).

North Pacific humpback whales migrate between summer feeding grounds along the Pacific Rim and the Bering and Okhotsk seas, and winter calving and breeding areas in subtropical and tropical waters (Pike and MacAskie 1969; Rice 1978; Winn and Reichley 1985; Calambokidis et al. 2000, 2001, 2008). North Pacific humpback whales are known to assemble in three different winter breeding areas: (1) the eastern North Pacific along the coast of Mexico and Central America, and near the Revillagigedo Islands; (2) around the main Hawaiian Islands; and (3) in the western Pacific, particularly around the Ogasawara and Ryukyu islands in southern Japan and the northern Philippines (Perry et al. 1999a; Calambokidis et al. 2008). There is a low level of interchange of whales among the three main wintering areas and among feeding areas (e.g., Darling and Cerchio 1993; Salden et al. 1999; Calambokidis et al. 2001, 2008).

Although considered to be mainly a coastal species, humpback whales often traverse deep pelagic areas while migrating (Clapham and Mattila 1990; Norris et al. 1999; Calambokidis et al. 2001). The diving behavior of humpback whales is related to time of year and whale activity (Clapham and Mead 1999). On winter breeding grounds, humpback dives have been recorded at depths >100 m (Baird et al. 2000). In summer feeding areas, humpbacks typically forage in the upper 120 m of the water column, with a maximum recorded dive depth of 500 m (Dolphin 1987; Dietz et al. 2002). Humpback whales are often sighted singly or in groups of two or three; however, while on their breeding and feeding ranges, they can occur in groups of up to 15 (Leatherwood and Reeves 1983; Donoghue 1996). Jackson et al. (2008) reported a mean group size of 1.5 for the ETP.

TABLE 2. The habitat, abundance, and conservation status of marine mammals that could occur in or near the proposed seismic survey area in the central Pacific Ocean.

Species	Occurrence in survey area	Habitat	Abundance in Hawaii[1]	Abundance in the North Pacific or ETP	ESA[2]	IUCN[3]	CITES[4]
Mysticetes Humpback whale	Rare	Mainly nearshore waters and banks	7120–10,425[5]	20,800[6]	EN	LC	I
Minke whale	Rare	Coastal	N.A.	9000[7]	NL	LC	I
Bryde's whale	Common	Pelagic, coastal	469	13,000[8]	NL	DD	I
Sei whale	Rare	Mostly pelagic	N.A.	7260–12,620[9]	EN	EN	I
Fin whale	Rare	Slope, pelagic	N.A.	13,620–18,680[10]	EN	EN	I
Blue whale	Rare	Pelagic, coastal	N.A.	1400[11], 2842[12]	EN	EN	I
Odontocetes Sperm whale	Common	Pelagic, steep topography	6919	26,053[13] 24,000[14]	EN	VU	I
Pygmy sperm whale	Uncommon	Deep, off shelf	7138	N.A.	NL	DD	II
Dwarf sperm whale	Common	Deep, shelf, slope	17,519	11,200[15]	NL	DD	II
Cuvier's beaked whale	Common	Slope, pelagic	15,242	20,000[11]	NL	LC	II
Longman's beaked whale	Uncommon	Pelagic	1007	291[16]	NL	DD	II
Ginkgo-toothed beaked whale	Rare	Pelagic	N.A.	25,300[17]	NL	DD	II
Blainville's beaked whale	Uncommon	Pelagic	2872.	25,300[17]	NL	DD	II
Rough-toothed dolphin	Common	Mainly pelagic	8709	107,633[18]	NL	LC	II
Common bottlenose dolphin	Common	Coastal, shelf, deep	3215	335,834[18]	NL	LC	II
Pantropical spotted dolphin	Common	Coastal and pelagic	8978	1,297,092[19]	NL	LC	II
Spinner dolphin	Common	Coastal and pelagic	3351	1,797,716[19]	NL	DD	II
Striped dolphin	Common	Off continental shelf	13,143	964,362[18]	NL	LC	II
Fraser's dolphin	Common	Pelagic	10,226	289,300[11]	NL	LC	II
Risso's dolphin	Uncommon	Shelf, slope, mounts	2372	110,457[18]	NL	LC	II
Melon-headed whale	Common	Pelagic	2950	45,400[11]	NL	LC	II
Pygmy killer whale	Uncommon	Pelagic, coastal	956	38,900[11]	NL	DD	II
False killer whale	Common	Pelagic	484[20]	39,800[11]	NL	DD	II
Killer whale	Uncommon	Widely distributed	349	8500[21]	NL	DD	II
Short-finned pilot whale	Common	Pelagic, high-relief	8870	589,315[22]	NL	DD	II
Pinnipeds Hawaiian monk seal	Rare	Mainly coastal	1202[23]	N.A.	EN	CR	I

N.A. = Not available, not applicable, or not assessed; ETP = Eastern Tropical Pacific.

[1] Barlow (2006)

[2] U.S. ESA: EN = Endangered, T = Threatened, NL = Not listed

[3] Codes for IUCN (2010): EN = Endangered; VU = Vulnerable; LC = Least Concern; DD = Data Deficient

[4] CITES (UNEP-WCMC 2010): Appendix I = threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled

[5] Calambokidis et al. (2008)

[6] North Pacific (Barlow et al. 2009a)

[7] Wada (1976)

[8] Wade and Gerrodette (1993); estimate is for *Balaenoptera edeni* but may include some *B. borealis*.

[9] Tillman (1977)

[10] Ohsumi and Wada (1974)

[11] ETP (Wade and Gerrodette 1993)

[12] U.S. west coast (Carretta et al. 2010)

[13] ETP (Whitehead 2002a)

[14] Eastern Temperate North Pacific (Whitehead 2002a)

[15] Wade and Gerrodette (1993); estimate for ETP mostly for *K. sima* but may also include *K. breviceps*

[16] ETP (Ferguson and Barlow 2003)

[17] This estimate includes all species of the genus *Mesoplodon* in the ETP (Wade and Gerrodette 1993)

[18] ETP for 2006 (Gerrodette et al. 2008)

[19] ETP for 2006 for the two offshore spotted dolphin, and the eastern and whitebelly spinner dolphin, stocks (Gerrodette et al. 2008)

[20] Hawaii pelagic stock (Barlow and Rankin 2007)

[21] ETP (Ford 2002)

[22] This estimate is for *G. macrorhynchus* and *G. melas* in the ETP (Gerrodette and Forcada 2002)

[23] NMFS (2007)

Calambokidis et al. (2008) estimated that over 50% of the North Pacific population (from the central and eastern stocks) winters in Hawaiian waters. Hawaii is the primary wintering area for whales from feeding areas in the Gulf of Alaska, southeast Alaska, and northern British Columbia (B.C.), Canada; some individuals from the Bering Sea feeding area also winter in Hawaii (Calambokidis et al. 2008). Humpbacks use the area for breeding from December to April; peak abundance around the Hawaiian Islands is from late February through early April (Mobley et al. 2001). The Hawaiian population is increasing at a rate of 5.5–6% (Calambokidis et al. 2008). Although interchange among feeding and wintering areas is limited, several individuals have been seen in the wintering areas of Asia and Hawaii in separate years (Darling and Cerchio 1993; Salden et al. 1999; Calambokidis et al. 2001, 2008), and the same whales have also been seen in both Hawaii and the Mexican wintering areas (Calambokidis et al. 2008).

During the winter months, aerial surveys have been flown to determine the abundance of humpbacks in Hawaiian waters (e.g., Mobley et al. 2001). However, humpbacks are not expected to occur further than 100 km from the Hawaiian coastline (DoN 2005). It is not known how many whales occur in areas further offshore and to the south of Hawaii, but sightings during the November–December survey period are likely to be rare. No sightings were made southwest of Hawaii, during the Pacific Islands Cetacean and Ecosystem Assessment Survey (PICEAS) during July–November 2005 (Barlow et al. 2008). Because the proposed survey area is located far offshore from any areas where breeding occurs, it is unlikely that humpback whales would occur in the survey area at any time of the year and therefore no takes are anticipated or requested.

Minke Whale (*Balaenoptera acutorostrata*)

The minke whale has a cosmopolitan distribution that spans polar, temperate, and tropical regions (Jefferson et al. 2008). In the Northern Hemisphere, minke whales are usually seen in coastal areas, but can also be seen in pelagic waters during northward migrations in spring and summer, and southward migration in autumn (Stewart and Leatherwood 1985). In the North Pacific, the summer range of the minke whale extends to the Chukchi Sea; in the winter, the whales move further south to within 2º of the equator (Perrin and Brownell 2002).

The minke whale is relatively solitary, but can occur in aggregations of up to 100 when food resources are concentrated (Jefferson et al. 2008). The small size, inconspicuous blows, and brief surfacing times of minke whales mean that they are easily overlooked in heavy sea states, although they are known to approach vessels in some circumstances (Stewart and Leatherwood 1985). Little is known about the diving behavior of minke whales, but they are not known to make prolonged deep dives (Leatherwood and Reeves 1983).

The International Whaling Commission (IWC) recognizes three stocks of minke whales in the North Pacific: the Sea of Japan/East China Sea, the rest of the western Pacific west of 180ºN, and the remainder of the Pacific (Donovan 1991). However, for management purposes in Pacific U.S. waters, three stocks of minke whales are recognized: the Alaska, Hawaii, and California/Oregon/Washington stocks (Carretta et al. 2010). The minke whale is generally believed to be uncommon in Hawaiian waters, although Rankin et al. (2007) suggest that minke whales may be more common than previously thought. A lack of sightings is likely related to misidentification or low detection capability in poor sighting conditions (Rankin et al. 2007). The minke whale is thought to occur seasonally in Hawaii, from November through March (Rankin and Barlow 2005).

A minke whale sighting was made to the west of Hawaii in November during shipboard surveys in July–November 2002 (Barlow et al. 2004). Acoustic detections as well as a visual sighting of a minke were made during a survey in the Hawaiian Islands in February 2005 (Rankin et al. 2007). The sighting was the first report of a minke whale in nearshore (<50 km) Hawaiian waters (Rankin et al. 2007). Acoustic detections were also made around the Hawaiian Islands during surveys in 1997, 2002, and 2003 (Rankin and Barlow 2005), as well as in 2005 (Barlow et al. 2008; Rankin et al. 2008). No sightings were made west of the survey area during the PICEAS survey in July-November 2005 (Barlow et al. 2008). Minke whales are not expected to occur in the proposed survey area and therefore no takes are anticipated or requested.

Bryde's Whale *(Balaenoptera edeni/brydei)*

Bryde's whale is found in tropical and subtropical waters throughout the world between 40ºN and 40ºS, generally in waters warmer than 20ºC, but at minimum 15ºC (Kato 2002; Kanda et al. 2007). 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. Populations in the western North Pacific, western South Pacific, eastern South Pacific, and eastern Indian Ocean currently show low levels of genetic interchange (Kanda et al. 2007). Here, we follow Kato (2002) in recognizing the uncertainty and using *B. edeni/brydei*.

Bryde's whales are known to occur in both shallow coastal and deeper offshore waters (Jefferson et al. 2008). Some populations show a general pattern of movement toward the equator in winter and toward higher latitudes in summer, though the locations of actual winter breeding grounds are unknown (Kato 2002; Kanda et al. 2007). Bryde's whales are usually solitary or in pairs, although groups of 10–20 are known from feeding grounds (Jefferson et al. 2008). Barlow (2006) reported a mean group size of 1.5 for Hawaii, and Barlow et al. (2008) reported a mean group size of 3.8 for the PICEAS area. For the ETP, Wade and Gerrodette (1993) and Jackson et al. (2008) reported mean group sizes of 1.7 and 1.5, respectively. The duration of Bryde's whale dives range from 1 to 20 min (Cummings 1985).

In Hawaii, Bryde's whales are typically seen offshore (e.g., Barlow 2006), but Hopkins et al. (2009) reported a Bryde's whale sighting within 70 km of the main Hawaiian Islands. The population size of Bryde's whales in Hawaii was estimated at 469 (Barlow 2006), and the population in the ETP was estimated at 13,000 (Wade and Gerrodette 1993). Bryde's whales were sighted northwest of Hawaii during surveys in July–December 2002, with sightings in August, September, and October, and possible sightings in July (Barlow et al. 2004). At least eight sightings were also made west of the survey area near and at Palmyra Atoll during the PICEAS survey in July–November 2005 (Barlow et al. 2008). During surveys of the ETP in July–December 2006, three Bryde's whales sightings were made in the proposed seismic survey area (Jackson et al. 2008).

Sei Whale *(Balaenoptera borealis)*

The sei whale is listed as ***Endangered*** under the ESA and on the IUCN Red List of Threatened Species (IUCN 2010), and is listed in CITES Appendix I (UNEP-WCMC 2010) (Table 2). Sei whale populations were depleted by whaling, and the current status of this species is generally uncertain (Horwood 1987). The global population is thought to be ~80,000 (Horwood 2002), with up to ~12,620 in the North Pacific (Tillman 1977). The sei whale is poorly known because of confusion with Bryde's whale and unpredictable distribution patterns; it can be common in an area for several years and then seemingly disappears (Schilling et al. 1992; Jefferson et al. 2008).

The sei whale is pelagic and generally not found in coastal waters (Harwood and Wilson 2001). It is found in deeper waters characteristic of the continental shelf edge region (Hain et al. 1985) and in other regions of steep bathymetric relief such as seamounts and canyons (Kenney and Winn 1987; Gregr and Trites 2001). On feeding grounds, sei whales associate with oceanic frontal systems (Horwood 1987) such as the cold eastern currents in the North Pacific (Perry et al. 1999a). Sei whales are frequently seen in groups of 2–5 (Leatherwood et al. 1988; Jefferson et al. 2008), although larger groups sometimes form on feeding grounds (Gambell 1985a). Sei whales generally do not dive deeply, and dive durations are 15 min or longer (Gambell 1985a).

The distribution of the sei whale is not well known, but it is found in all oceans and appears to prefer mid-latitude temperate waters (Jefferson et al. 2008). Sei whales migrate from temperate zones occupied in winter to higher latitudes in the summer, where most feeding takes place (Gambell 1985a). During summer in the North Pacific, the sei whale can be found from the Bering Sea to the Gulf of Alaska and down to southern California, as well as in the western Pacific from Japan to Korea. Its winter distribution is concentrated at about 20°N, and sightings have been made between southern Baja California and the Islas Revillagigedo (Rice 1998).

In Hawaii, the occurrence of sei whales is considered rare (DoN 2005). However, they have been sighted near the islands and to the northwest during surveys in July–December 2002; most of those sightings were made during the month of November (Barlow et al. 2004). Sei whales, including subadults, were seen east of Oahu in November 2007 (Hopkins et al. 2009). As breeding and calving areas in the Pacific are unknown, the sightings of subadult sei whales suggest that Hawaii may be an important reproductive area for this species (Hopkins et al. 2009). Sightings of *B. edeni/borealis* were made to the west of the proposed seismic survey area during the PICEAS survey in July–November 2005 (Barlow et al. 2008) and within the proposed survey area during summer–fall 2006 (Jackson et al. 2008). Given the difficulty in distinguishing sei from Bryde's whales, those could have been sei whales, but in both cases Bryde's whales were positively identified and sei whales were not. Sei whales are not expected to occur in the proposed survey area and therefore no takes are anticipated or requested.

Fin Whale *(Balaenoptera physalus)*

The fin whale is widely distributed in all the world's oceans (Gambell 1985b), but typically occurs in temperate and polar regions from 20° to 70° north and south of the equator (Perry et al. 1999b). It is listed as ***Endangered*** under the ESA and on the IUCN Red List of Threatened Species (IUCN 2010), and it is listed in CITES Appendix I (UNEP-WCMC 2010) (Table 2). Probably at least in part because of its initially high abundance, wide distribution, and diverse feeding habits, the fin whale does not seem to have been as badly depleted as the other large whales in the North Pacific. Northern and southern fin whale populations are distinct and are sometimes recognized as different subspecies (Aguilar 2002).

Fin whales occur in coastal, shelf, and oceanic waters. Moore et al. (2002a) reported that in the eastern Bering Sea, sighting rates were more than twice as high in water >100 m deep than in water 50–100 m deep; no sightings occurred in water <50 m deep. Sergeant (1977) proposed that fin whales tend to follow steep slope contours, either because they detect them readily or because biological productivity is high along steep contours because of tidal mixing and perhaps current mixing. Stafford et al. (2009) noted that sea-surface temperature is a good predictor variable for fin whale call detections in the North Pacific.

Fin whales can be found as individuals or groups of 2–7, but can form much larger feeding aggregations, sometimes with humpback and minke whales (e.g., Waite 2003; Jefferson et al. 2008). Barlow et al. (2004) reported a mean group size of 1.2 for Hawaii, and Jackson et al. (2008) reported a group size of 1.2 for the ETP. Foraging fin whales have mean dive depths and times of 98 m and 6.3 min, and non-foraging fin whales have mean dive depths and times of 59 m and 4.2 min (Croll et al. 2001). Dive depths of >150 m coinciding with the diel migration of krill were reported by Panigada et al. (1999).

Fin whales appear to have complex seasonal movements and are likely seasonal migrants (Gambell 1985b). They mate and calve in temperate waters during the winter and migrate to feed at northern latitudes during the summer (Mackintosh 1965 *in* Gambell 1985b). The North Pacific population summers from the Chukchi Sea to California and winters from California southwards (Gambell 1985b).

Recent information about the seasonal distribution of fin whales in the North Pacific has been obtained from the reception of fin whale calls by bottom-mounted, offshore hydrophone arrays along the U.S. Pacific coast, in the central North Pacific, and in the western Aleutian Islands (Moore et al. 1998, 2006; Watkins et al. 2000a,b; Stafford et al. 2007, 2009). Fin whale calls are detected year-round in the Northern Pacific (Moore et al. 2006; Stafford et al. 2007, 2009). In the central North Pacific, the Gulf of Alaska, and the Aleutian Islands, call rates peak during fall and winter (Moore et al. 1998, 2006; Watkins et al. 2000a,b; Stafford et al. 2009).

A recent review of fin whale distribution in the North Pacific noted the lack of sightings across the pelagic waters between eastern and western winter areas (Mizroch et al. 2009). In Hawaii, fin whales are considered uncommon (DoN 2005). Thompson and Friedl (1982) suggested that fin whales migrate to Hawaiian waters during the fall and winter; but during spring–summer, their occurrence in Hawaii is considered rare (DoN 2005). Two fin whales were sighted northwest of Hawaii during shipboard surveys in July–December 2002 (Barlow et al. 2004). No sightings were made west of the proposed survey area during the PICEAS survey in July–November 2005 (Barlow et al. 2008). Fin whales are not expected to occur in the proposed survey area and therefore no takes are anticipated or requested.

Blue Whale (*Balaenoptera musculus*)

The blue whale has a cosmopolitan distribution and tends to be pelagic, only coming nearshore to feed and possibly to breed (Jefferson et al. 2008). It is listed as ***Endangered*** under the ESA and on the IUCN Red List of Threatened Species (IUCN 2010), and it is listed in CITES Appendix I (UNEP-WCMC 2010) (Table 2). All blue whale populations have been exploited commercially, and many have been severely depleted as a result. 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 in the eastern North Pacific (Carretta et al. 2010).

Blue whales are typically found singly or in groups of two or three (Yochem and Leatherwood 1985; Jefferson et al. 2008). For the ETP, Wade and Gerrodette (1993) and Jackson et al. (2008) reported mean group sizes of 1.5 and 1.9, respectively. Croll et al. (2001) reported mean dive depths and times of 140 m and 7.8 min for foraging blue whales, and 68 m and 4.9 min for non-foraging individuals. Four satellite-radio-tagged blue whales in the northeast Pacific Ocean spent 94% of their time underwater; 72% of dives were <1 min long, and “true” dives (>1 min) were 4.2–7.2 min long. Shallow (<16-m) dives were most common (75%), and the average depth of deep (>16-m) dives was 105 m (Lagerquist et al. 2000). Dives of up to 300 m were recorded for tagged blue whales (Calambokidis et al. 2003).

Generally, blue whales are seasonal migrants between high latitudes in the summer, where they feed, and low latitudes in the winter, where they mate and give birth (Lockyer and Brown 1981). However, little information is available on blue whale wintering areas (Perry et al. 1999a). Some individuals may stay in low or high latitudes throughout the year (Reilly and Thayer 1990; Watkins et al. 2000b). In the North Pacific, blue whale calls are received year-round (Moore et al. 2002b, 2006). Stafford et al. (2009) noted that sea-surface temperature is a good predictor variable for blue whale call detections in the North Pacific.

Although it has been suggested that there are at least five subpopulations of blue whales in the North Pacific (NMFS 1998), analysis of blue whale calls monitored from the U.S. Navy Sound Surveillance System (SOSUS) and other offshore hydrophones (see Stafford et al. 1999, 2001, 2007; Watkins et al. 2000a; Stafford 2003) suggest that there are two separate populations—one in the eastern and one in the western North Pacific (Sears 2002). The western North Pacific stock includes whales that are found around Hawaii during winter; the eastern North Pacific stock includes whales that feed primarily off California (Carretta et al. 2010). Broad-scale acoustic monitoring indicates that blue whales of the eastern stock range from the Gulf of Alaska to the ETP, and as far west as Wake Island (Stafford et al. 1999, 2001). Blue whales from the eastern stock feed from June to November and migrate south in winter/spring (Calambokidis et al. 1990; Mate et al. 1999). The western Pacific stock feeds off Kamchatka, south of the Aleutians, and in the Gulf of Alaska in summer (Stafford 2003; Watkins et al. 2000b); in the winter, they migrate to lower latitudes in the western Pacific and occasionally to the central Pacific, such as Hawaii (Stafford et al. 2001). Nonetheless, blue whales are considered rare in Hawaii (DoN 2005; Carretta et al. 2010); they are most likely to migrate there during the summer and winter (Thompson and Friedl 1982). No sightings were made in Hawaii during shipboard surveys in July–December 2002 (Barlow et al. 2004) or during the PICEAS survey in July–November 2005 (Barlow et al. 2008).

Odontocetes

Sperm Whale *(Physeter macrocephalus)*

Sperm whales are the largest of the toothed whales, with an extensive worldwide distribution (Rice 1989). The species is listed as ***Endangered*** under the U.S. ESA, but on a worldwide basis it is abundant and not biologically endangered. It is listed as ***Vulnerable*** on the IUCN Red List of Threatened Species (IUCN 2010), and is listed in CITES Appendix I (UNEP-WCMC 2010) (Table 2). There currently is no accurate estimate for the size of any sperm whale population (Whitehead 2002b). Best estimates probably are those of Whitehead (2002a), who provided sperm whale population sizes of 24,000 for the eastern temperate North Pacific and 26,053 for the ETP.

Sperm whale distribution is linked to social structure: mixed groups of adult females and juvenile animals of both sexes generally occur in tropical and subtropical waters, whereas adult males are commonly found alone or in same-sex aggregations, often occurring in higher latitudes outside the breeding season (Best 1979; Watkins and Moore 1982; Arnbom and Whitehead 1989; Whitehead and Waters 1990). Males can migrate north in the summer to feed in the Gulf of Alaska, Bering Sea, and waters around the Aleutian Islands (Kasuya and Miyashita 1988). Mature male sperm whales migrate to warmer waters to breed when they are in their late twenties (Best 1979). They spend periods of at least months on the breeding grounds, moving between mixed groups of ~20–30 animals (Whitehead 1993, 2003). For Hawaii, the mean group size was reported as 7.3 (Barlow 2006), and for the PICEAS area, it was estimated at 7.9 (Barlow et al. 2008). For the ETP, Wade and Gerrodette (1993) and Jackson et al. (2008) reported mean group sizes of 7.9 and 6.1, respectively.

Sperm whales generally are distributed over large areas that have high secondary productivity and steep underwater topography, in waters at least 1000 m deep (Jaquet and Whitehead 1996; Whitehead 2002b). They are often found far from shore, but can be found closer to oceanic islands that rise steeply from deep ocean waters (Whitehead 2002b). Adult males can occur in water depths <100 m and as shallow as 40 m (Whitehead et al. 1992; Scott and Sadove 1997). They can dive as deep as ~2 km and possibly deeper on rare occasions for periods of over 1 h; however, most of their foraging occurs at depths of ~300–800 m for 30–45 min (Whitehead 2003). A recent study of tagged male sperm whales off Norway found that foraging dives extended to highly variable maximum depths, ranging from 14 to 1860 m, with a median 175 m (Teloni et al. 2008). During a foraging dive, sperm whales typically travel ~3 km horizontally and 0.5 km vertically (Whitehead 2003). Whales in the Galápagos Islands typically dove for ~40 min and then spent 10 min at the surface (Papastavrou et al. 1989).

In the North Pacific Ocean, sperm whales are distributed widely, with the northernmost occurrences at Cape Navarin (62ºN) and the Pribilof Islands (Omura 1955). Sperm whale abundance in Hawaii in 2002 was estimated at 6919 (Barlow 2006). Sperm whales were sighted to the east of the proposed survey area during summer–fall surveys of the ETP during 1986–1996 (Wade and Gerrodette 1993; Ferguson and Barlow 2001). During the PICEAS survey west of the proposed survey area in July–November 2005, at least six sperm whale sightings were made near Palmyra Atoll (Barlow et al. 2008); 24 acoustic detections were also made during the survey (Barlow et al. 2008; Rankin et al. 2008).

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

Pygmy sperm whales (*Kogia breviceps*) and dwarf sperm whales (*K. sima*) are distributed widely throughout tropical and temperate seas, but their precise distributions are unknown as most information on these species comes from strandings (McAlpine 2002). They are difficult to sight at sea, perhaps because of their avoidance reactions to ships and behavior changes in relation to survey aircraft (Würsig et al. 1998). The two species are difficult to distinguish from one another when sighted (McAlpine 2002).

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

Pygmy sperm whales feed mainly on various species of squid in the deep zones of the continental shelf and slope (McAlpine et al. 1997). In the Gulf of California, median dive and surface times for dwarf 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).

Although there are few useful estimates of abundance for pygmy or dwarf sperm whales anywhere in their range, they are thought to be fairly common in some areas. For the ETP, the *Kogia* population size was estimated at 11,200 (Wade and Gerrodette 1993). For Hawaii, it was estimated that the population of pygmy sperm whales in 2002 numbered 7138 and that the population of dwarf sperm whales numbered 17,519 (Barlow 2006). Except for one sighting of *K. sima* in the ETP, no *Kogia* sp. were seen during the PICEAS survey in July–November 2005 (Barlow et al. 2008). During summer/fall surveys of the ETP during 1986–1996, *Kogia* sp. were sighted as far west as 140°W (Ferguson and Barlow 2001).

Cuvier's Beaked Whale *(Ziphius cavirostris)*

Cuvier's beaked whale is probably the most widespread of the beaked whales, although it is not found in polar waters (Heyning 1989). Cuvier's beaked whale 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 rarely observed at sea and is mostly known from strandings. It strands more commonly than any other beaked whale (Heyning 1989). Its inconspicuous blows, deep-diving behavior, and tendency to avoid vessels all help to explain the infrequent sightings (Barlow and Gisiner 2006).

Adult males of this species usually travel alone, but these whales can be seen in groups of up to 15 (Heyning 2002), with a mean group size of 2.3 (MacLeod and D'Amico 2006). Barlow (2006) reported a mean group size of 2 for Hawaii, and Barlow et al. (2008) reported a mean group size of 3.0 for the PICEAS area. For the ETP, Wade and Gerrodette (1993) and Jackson et al. (2008) reported mean group sizes of 2.2 and 1.8, respectively. Cuvier's beaked whale dives generally last 30–60 min, but dives of 85 min have been recorded (Tyack et al. 2006). The maximum dive depth recorded by Baird et al. (2006) was 1450 m.

In Hawaii, the population size in 2002 was estimated at 15,242 (Barlow 2006), and in the ETP, the estimated population size was 20,000 (Wade and Gerrodette 1993). Cuvier's beaked whales were sighted just to the east of the proposed survey area during summer–fall surveys of the ETP during 1986–1996 (Wade and Gerrodette 1993; Ferguson and Barlow 2001). In 2006, a Cuvier's beaked whale sighting was made east of the proposed survey area, and an unidentified ziphiid was seen in the proposed survey area (Jackson et al. 2008). During the PICEAS survey in July–November 2005, two sightings were made at Johnston Atoll and one was made west of Hawaii (Barlow et al. 2008). Another three sightings of unidentified ziphiids were made at Johnston Atoll and Hawaii, and in adjacent waters (Barlow et al. 2008).

Longman's Beaked Whale (*Indopacetus pacificus*)

Initially, Longman's beaked whale was thought to be extremely rare, and it was known only from two skulls (Pitman et al. 1987). Subsequent morphometric and genetic analyses of those two original specimens and an additional four specimens have allowed a more detailed characterization of the species (Dalebout et al. 2003). It seems likely that it is, in fact, the cetacean that has been seen in Indo-Pacific waters and called the "tropical bottlenose whale". Some authorities place the species in the genus *Mesoplodon*, but there now seems to be sufficient information to afford it status as a separate genus (Dalebout et al. 2003). Records of this species exist within an area from 10ºS to 40ºN.

Longman's beaked whales have been sighted in waters with temperatures 21–31ºC and have been seen in the tropics in every month of the year except June, indicating year-round residency (Pitman et al. 1999; Jefferson et al. 2008). Although widespread throughout the tropical Pacific, the species must still be considered rare because of a scarcity of sightings despite a great deal of survey effort (Pitman et al. 1999). Longman's beaked whales have been seen alone, but more commonly in groups of at least 10 and up to 100, with an average group size of 15–20 (Jefferson et al. 2008). Pitman et al. (1999) reported a mean group size of 18.5 in the tropics, whereas group sizes were smaller in the ETP, averaging 8.6. For Hawaii, Barlow (2006) reported a group size of 17.8. Dives are thought to last 18–33 min (Jefferson et al. 2008).

It was estimated that ~1007 Longman's beaked whales occur within the exclusive economic zone (EEZ) of Hawaii (Barlow 2006). In the ETP, the population size was estimated at 291 (Ferguson and Barlow 2003). During the PICEAS survey in July–November 2005, one sighting was made at Johnston Atoll (Barlow et al. 2008). There were no sightings near the proposed survey area during summer–fall surveys of the ETP during 2006 (Jackson et al. 2008).

Mesoplodont Beaked Whales

Two species of mesoplodont whales can occur in deep waters of the proposed survey area in the central Pacific Ocean: Blainville's and gingko-toothed beaked whales. Almost everything that is known regarding most mesoplodont species has come from stranded animals (Pitman 2002). Because of the scarcity of sightings, most are thought to be rare. The different mesoplodont species are difficult to distinguish in the field, and confirmed at-sea sightings are rare (Mead 1989; Carretta et al. 2010; Jefferson et al. 2008).

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 (Carretta et al. 2010). Dive depths of most of these species are undocumented.

Typical group sizes range from one to six (Pitman 2002). Mean group sizes are unknown for many of the *Mesoplodon* spp. For the ETP, Wade and Gerrodette (1993) and Jackson et al. (2008) reported mean group sizes of 3.0 and 2.4, respectively. Wade and Gerrodette (1993) estimated the abundance of all mesoplodonts in the ETP at 25,300.

Except for two sightings of *Mesoplodon* sp. in the ETP, no other sightings of *Mesoplodon* spp. were made during the PICEAS survey in July–November 2005 (Barlow et al. 2008). There were three sightings of unidentified *Mesoplodon* in offshore waters west of Hawaii during July–December 2002 (Barlow et al. 2004).

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

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

In Hawaii, the population size in 2002 was estimated at 2872 (Barlow 2006). A Blainville's beaked whale sighting was made to the east of the proposed survey area during summer–fall surveys of the ETP during 1986–1990 (Wade and Gerrodette 1993).

***Ginkgo-toothed beaked whale* (*Mesoplodon ginkgodens*)**.—This species is only known from stranding records (Mead 1989; Jefferson et al. 2008). The ginkgo-toothed whale is hypothesized to occupy warm temperate and tropical waters of the Indian and Pacific oceans (Pitman 2002). Strandings have been reported for the western and eastern North Pacific, South Pacific, and Indian oceans, and from the Galápagos Islands (Palacios 1996). The species is thought 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 1996).

Rough-toothed Dolphin *(Steno bredanensis)*

The rough-toothed dolphin is widely distributed around the world, mainly occurring in tropical and warm temperate waters (Miyazaki and Perrin 1994). In the Pacific, rough-toothed dolphins occur from central Japan and northern Australia to Baja California, Mexico, and southern Peru (Jefferson 2002). Rough-toothed dolphins generally occur in deep, oceanic waters, but can be found in shallower coastal waters in some regions (Jefferson et al. 2008). Rough-toothed dolphins are deep divers and can dive for up to 15 min (Jefferson et al. 2008). They usually form groups of 10–20, but aggregations of hundreds have been seen (Jefferson et al. 2008). Barlow (2006) reported a mean group size of 14.8 for Hawaii, and Barlow et al. (2008) reported a mean group size of 13.4 for the PICEAS area. For the ETP, mean group sizes were 9.9–15.5 (Wade and Gerrodette 1993; Ferguson et al. 2006b; Jackson et al. 2008).

In Hawaii, the population size in 2002 was estimated at 8709 (Barlow 2006), and in the ETP, the population size in 2006 was estimated at 107,633 (Gerrodette et al. 2008). Rough-toothed dolphins have been seen just to the east of the proposed survey area during summer–fall surveys of the ETP during 1986–1996 (Wade and Gerrodette 1993; Ferguson and Barlow 2001) and 2006 (Gerrodette et al. 2008; Jackson et al. 2008). During the PICEAS survey in July–November 2005, at least three sightings were made near Palmyra Atoll (Barlow et al. 2008). Acoustic detections were also made in the PICEAS area and east of the proposed survey area (Barlow et al. 2008; Rankin et al. 2008).

Common Bottlenose Dolphin (*Tursiops truncatus*)

The bottlenose dolphin is distributed worldwide. It is found mainly where surface temperatures are 10–32ºC (Reeves et al. 2002). Generally, there are two distinct bottlenose dolphin types: a shallow water type, mainly found in coastal waters, and a deep water type, mainly found in oceanic waters (Duffield et al. 1983; Hoelzel et al. 1998; Walker et al. 1999). As well as inhabiting different areas, these ecotypes differ in their diving abilities (Klatsky 2004) and prey types (Mead and Potter 1995). Bottlenose dolphins have been reported to 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). Mean group sizes have been reported as 9.0 for Hawaii (Barlow 2006) and 11.8 for the PICEAS area (Barlow et al. 2008). Mean group sizes for the ETP were 22–24 (Wade and Gerrodette 1993; Smith and Whitehead 1999; Ferguson et al. 2006b; Jackson et al. 2008).

In Hawaii, the population size in 2002 was estimated at 3215 (Barlow 2006), and in the ETP, the population size in 2006 was estimated at 335,834 (Gerrodette et al. 2008). Bottlenose dolphins were sighted to the east of the proposed survey area during summer–fall surveys of the ETP during 1986–1996 (Ferguson and Barlow 2001) and 2006 (Gerrodette et al. 2008; Jackson et al. 2008). During the PICEAS survey in July–November 2005, at least five sightings were made near Palmyra Atoll (Barlow et al. 2008); acoustic detections were also made (Barlow et al. 2008; Rankin et al. 2008).

Pantropical Spotted Dolphin (*Stenella attenuata*)

The pantropical spotted dolphin can be found throughout tropical and some subtropical oceans of the world (Perrin and Hohn 1994). The southernmost limit of its range is ~40°S (Perrin 2002). There are two forms of pantropical spotted dolphin—coastal and offshore—although the coastal form occurs mainly in the ETP from Baja California to South America (Jefferson et al. 2008). In the ETP, this dolphin is associated with warm (>25ºC) tropical surface water (Au and Perryman 1985; Reilly 1990; Reilly and Fiedler 1994). The offshore form inhabits tropical, equatorial, and southern subtropical water masses (Perrin 2002). This species is found primarily in deeper waters, and rarely over the continental shelf or continental shelf edge (Davis et al. 1998).

Pantropical spotted dolphins are extremely gregarious, forming groups of hundreds or even thousands. Barlow (2006) reported a mean group size of 60 for Hawaii, and Barlow et al. (2008) reported a mean group size of 50 for the PICEAS area. For the offshore stock in the ETP, Jackson et al. (2008) reported a mean group size of 95, Ferguson et al. (2006b) estimated a mean group size of 131, and Gerrodette and Forcada (2005) estimated a mean group size of 114. Pantropical spotted and spinner dolphins are commonly seen together in mixed-species groups, e.g., in the ETP (Au and Perryman 1985), off Hawaii (Psarakos et al. 2003), and the Marquesas Archipelago (Gannier 2002).

In Hawaii, the population size in 2002 was estimated at 8978 (Barlow 2006). For the ETP, the population size for two offshore stocks in 2006 was estimated at 1,297,092 (Gerrodette et al. 2008). The spotted dolphin is expected to be one of the most abundant cetaceans in the proposed project area; based on the Southwest Fisheries Science Center (SWFSC) surveys and model used to calculate densities in the proposed survey area (see § VII), it is the second-ranked species there. Pantropical spotted dolphins have been seen in and near the proposed survey area during summer–fall surveys of the ETP during 1982–2006 (Wade and Gerrodette 1993; Ferguson and Barlow 2001; Gerrodette and Forcada 2005; Gerrodette et al. 2008; Jackson et al. 2008). During the PICEAS survey in July–November 2005, at least 12 sightings were made near Palmyra Atoll; acoustic detections were also made (Barlow et al. 2008; Rankin et al. 2008).

Spinner Dolphin *(Stenella longirostris)*

The spinner dolphin is distributed in oceanic and coastal tropical waters, although in the ETP, its range is mostly oceanic (Jefferson et al. 2008). In the ETP, it is associated with warm, tropical surface water, similar in distribution to the pantropical spotted dolphin (Au and Perryman 1985; Reilly 1990; Reilly and Fiedler 1994). Spinner dolphins are extremely gregarious, and usually form large schools in the open sea and small ones in coastal waters (Perrin and Gilpatrick 1994). Mean group sizes have been reported as 32 for Hawaii (Barlow 2006), 42–155 for the PICEAS area (Barlow et al. 2008), and 83–148 for the ETP (Wade and Gerrodette 1993; Ferguson et al. 2006b). Spinner dolphins and pantropical spotted dolphins are commonly seen together in mixed-species groups, e.g., in the ETP (Au and Perryman 1985) and off Hawaii (Psarakos et al. 2003).

In Hawaii, there is one subspecies of spinner dolphin, Gray's spinner dolphin (*S. l. longirostris*). In the ETP, three types of spinner dolphins have been identified, two of which 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 (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. 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). In the proposed survey area, Gray's and the whitebelly spinner can occur.

In Hawaii, the population size in 2002 was estimated at 3351 (Barlow 2006). For the whitebelly and eastern stocks in the ETP, the population sizes in 2006 were estimated at 734,837 and 1,062,879 respectively (Gerrodette et al. 2008). This species is expected to be the most abundant cetacean in the proposed survey area; based on the SWFSC surveys and model used to calculate densities in the study area (see § VII), it is the first-ranked species there. Spinner dolphins have been seen in and near the proposed survey area during summer–fall surveys of the ETP during 1986–2006 (Wade and Gerrodette 1993; Ferguson and Barlow 2001; Gerrodette and Forcada 2005; Gerrodette et al. 2008; Jackson et al. 2008). During the PICEAS survey in July–November 2005, at least 21 sightings of spinner dolphins (3 Gray's, at least 8 whitebelly or southwestern, and at least 8 unidentified) were made in and adjacent to Palmyra Atoll (Barlow et al. 2008). Acoustic detections of spinner dolphins were also made in the PICEAS area as well as east of the proposed survey area (Barlow et al. 2008; Rankin et al. 2008).

Striped Dolphin *(Stenella coeruleoalba)*

The striped dolphin has a cosmopolitan distribution in tropical to warm temperate waters (Perrin et al. 1994a) and is generally seen south of 43ºN (Archer 2002). It is typically found in waters outside the continental shelf and is often associated with convergence zones and areas of upwelling (Archer 2002). The striped dolphin is fairly gregarious (groups of 20 or more are common) and active at the surface (Whitehead et al. 1998). Mean group sizes were reported as 37 for Hawaii (Barlow 2006), 46 for the PICEAS area (Barlow et al. 2008), and 50 for the Galápagos Islands (Smith and Whitehead 1999). For the ETP, reported mean group sizes were 52–61 (Wade and Gerrodette 1993; Ferguson et al. 2006b; Jackson et al. 2008).

In Hawaii, the population size in 2002 was estimated at 13,143 (Barlow 2006), and in the ETP, the population size in 2006 was estimated at 964,362 (Gerrodette et al. 2008). The striped dolphin is expected to be one of the most abundant cetaceans in the proposed survey area; based on the SWFSC surveys and model used to calculate densities in the study area (see § VII), it is the third-ranked species there. Striped dolphins have been seen just to the east of the proposed survey area during summer–fall surveys of the ETP in 1986–2006 (Wade and Gerrodette 1993; Ferguson and Barlow 2001; Gerrodette et al. 2008; Jackson et al. 2008). During the PICEAS survey in July–November 2005, at least 12 sightings were made near Palmyra Atoll (Barlow et al. 2008). Acoustic detections were also made in the PICEAS area and east of the proposed survey area (Barlow et al. 2008; Rankin et al. 2008).

Fraser's Dolphin (*Lagenodelphis hosei*)

Fraser's dolphin is a tropical species found between 30°N and 30°S (Dolar 2002). It occurs rarely in temperate regions, and then only in relation to temporary oceanographic anomalies such as El Niño events (Perrin et al. 1994b). The species typically occurs in deep, oceanic waters. In the ETP, most sightings were 45–100 km from shore in waters 1500–2500 m deep (Dolar 2002). Off Huahine and Tahiti (Society Islands), it was observed in waters 500–1500 m deep (Gannier 2000). Fraser's dolphin travels in groups ranging from just a few animals to 100 or even 1000 (Perrin et al. 1994b). Barlow (2006) reported a mean group size of 286 for Hawaii. For the ETP, Wade and Gerrodette (1993) and Ferguson et al. (2006b) reported mean group sizes of 395 and 440, respectively.

In Hawaii, the population size in 2002 was estimated at 10,226 (Barlow 2006), and in the ETP, the population size during 1986–1990 was estimated at 289,300 (Wade and Gerrodette 1993). Fraser's dolphins were seen to the east of the proposed survey area during summer–fall surveys of the ETP during 1986–1996 (Wade and Gerrodette 1993; Ferguson and Barlow 2001) and 2006 (Jackson et al. 2008). During the PICEAS survey in July–November 2005, two sightings were made near Palmyra Atoll (Barlow et al. 2008). Acoustic detections of Fraser's dolphins were also made in the PICEAS area and east of the proposed survey area (Barlow et al. 2008; Rankin et al. 2008).

Risso's Dolphin (*Grampus griseus*)

Risso's dolphin is primarily a tropical and mid-temperate species distributed worldwide. It occurs between 60ºN and 60ºS, where surface water temperatures are at least 10ºC (Kruse et al. 1999). Water temperature appears to be an important factor affecting its distribution (Kruse et al. 1999; see also Becker 2007). Off the U.S. west coast, Risso's dolphin is believed to make seasonal north-south movements related to water temperature, spending colder winter months off California and moving north to waters off Oregon–Washington during the spring and summer as northern waters begin to warm (Green et al. 1992, 1993; Buchanan et al. 2001; Barlow 2003; Becker 2007).

Risso's dolphins are pelagic, mostly occurring on the upper continental slope shelf edge in waters 350–1000 m deep (Baumgartner 1997; Davis et al. 1998). They occur individually or in small to moderate-sized groups, normally 2–250, although groups as large as 4000 have been sighted (Baird 2002a). However, the majority of groups consist of <50 individuals (Kruse et al. 1999; Miyashita 1993). Mean group sizes were reported as 15 for Hawaii (Barlow 2006), 14 for the PICEAS area (Barlow et al. 2008), and 9–19 for the ETP (Wade and Gerrodette 1993; Ferguson et al. 2006b; Jackson et al. 2008).

In Hawaii, the population size in 2002 was estimated at 2372 (Barlow 2006), and in the ETP, the population size during 1986–1990 was estimated at 110,457 (Gerrodette et al. 2008). Risso's dolphins were seen to the east of the proposed survey area during summer–fall surveys of the ETP during 1986–1996 (Wade and Gerrodette 1993; Ferguson and Barlow 2001). During the PICEAS survey in July–November 2005, one sighting was made at Johnston Atoll, and one sighting was made just southwest of

Hawaii (Barlow et al. 2008). Acoustic detections were also made in the PICEAS survey area and near the proposed survey area (Barlow et al. 2008; Rankin et al. 2008).

Melon-headed Whale *(Peponocephala electra)*

The melon-headed whale is a pantropical and pelagic species that occurs mainly between 20ºN and 20ºS (Perryman et al. 1994). Melon-headed whales tend to occur in groups of 100–500, but have also been seen in groups of up to 2000 (Jefferson et al. 2008). Barlow (2006) reported a mean group size of 89 for Hawaii, and Barlow et al. (2008) reported a mean group size of 101 for the PICEAS area. For the ETP, Wade and Gerrodette (1993) reported a mean group size of 199, and Ferguson et al. (2006b) estimated the mean group size at 258. Melon-headed whales are commonly seen in mixed groups with other cetaceans (Jefferson and Barros 1997; Huggins et al. 2009).

For Hawaii, the population size in 2002 was estimated at 2950 (Barlow 2006). Aschettino (2010) provided an abundance estimate of 5794 for the main Hawaiian Islands population and 447 for Hawaii residents. For the ETP, the population size during 1986–1990 was estimated at 45,400 (Wade and Gerrodette 1993). Melon-headed whales were seen far to the east of the proposed survey area during summer–fall surveys of the ETP during 1986–1996 (Wade and Gerrodette 1993; Ferguson and Barlow 2001) and 2006 (Jackson et al. 2008). During the PICEAS surveys west of the proposed survey area in July–November 2005, at least two sightings were made near Palmyra Atoll; two acoustic detections were also made in the PICEAS area (Barlow et al. 2008; Rankin et al. 2008).

Pygmy Killer Whale *(Feresa attenuata)*

The pygmy killer whale is distributed throughout tropical and subtropical oceans worldwide (Ross and Leatherwood 1994; Donahue and Perryman 2002). In warmer water, it is usually seen close to the coast (Wade and Gerrodette 1993), but it is also found in deep waters. In Hawaiian waters, the pygmy killer whale is found in nearshore waters, but not in offshore waters (Barlow 2006). In the Marquesas, it was sighted in water 100 m deep (Gannier 2002). Pygmy killer whales tend to travel in groups of 15–50, although groups of a few hundred have been sighted (Ross and Leatherwood 1994). Mean group sizes have been reported as 14 for Hawaii (Barlow 2006) and 25–30 for the ETP (Wade and Gerrodette 1993; Ferguson et al. 2006b; Jackson et al. 2008).

In Hawaii, the population size in 2002 was estimated at 956 (Barlow 2006), and in the ETP, the population size during 1986–1990 was estimated at 38,900 (Wade and Gerrodette 1993). Pygmy killer whales were sighted to the east of the proposed survey area during summer–fall surveys of the ETP during 1986–1990 (Wade and Gerrodette 1993). No sightings were made during the PICEAS survey west of the proposed survey area in July–November 2005 (Barlow et al. 2008).

False Killer Whale *(Pseudorca crassidens)*

The false killer whale is found in all tropical and warmer temperate oceans, especially in deep, offshore waters (Odell and McClune 1999). However, it is also known to occur in nearshore areas (e.g., Stacey and Baird 1991). False killer whales travel in pods of 20–100 (Baird 2002b), although groups of several hundred are sometimes observed. Mean group sizes have been reported as 10 for Hawaii (Barlow 2006), 9 for the PICEAS area (Barlow et al. 2008), and 11–12 for the ETP (Wade and Gerrodette 1993; Ferguson et al. 2006b; Jackson et al. 2008).

In the U.S. Pacific Islands region, there are currently three different stocks of false killer whales: the Hawaii insular, the Hawaii pelagic, and the Palmyra stocks (Chivers et al. 2007; Carretta et al. 2010). The Hawaii insular false killer whale is genetically distinct from other populations in the Indo-Pacific Ocean, including the central North Pacific, eastern North Pacific, Hawaii pelagic, Mexico, Panama, and American Samoa (Chivers et al. 2007, 2010). The population size of the Hawaii insular stock is estimated at 123 (Baird et al. 2005), and the pelagic stock is estimated at 484 (Barlow and Rankin 2007). The population of false killer whales inhabiting the main Hawaiian Islands is thought to have declined dramatically since 1989; the reasons for such a decline are still uncertain, although interactions with longline fisheries cannot be ruled out (Reeves et al. 2009). For the Palmyra EEZ, the population size of false killer whales has been estimated at 1329 individuals, with another 906 in the remainder of the PICEAS proposed survey area (Barlow and Rankin 2007). For the ETP, the population size during 1986–1990 was estimated at 39,800 (Wade and Gerrodette 1993).

False killer whales were sighted to the east of the proposed survey area during summer–fall surveys of the ETP during 1986–1996 (Wade and Gerrodette 1993; Ferguson and Barlow 2001) and 2006 (Jackson et al. 2008). During the PICEAS survey west of the proposed survey area in July–November 2005, at least eight sightings were made near Palmyra Atoll; acoustic detections were also made (Barlow et al. 2008; Rankin et al. 2008). One false killer whale was taken by the Hawaii-based longline fishery within the proposed seismic survey area (Forney and Kobayashi 2007).

Killer Whale *(Orcinus orca)*

The killer whale is cosmopolitan and globally fairly abundant; it has been observed in all oceans of the world (Ford 2002). It is very common in temperate waters and also frequents tropical waters, at least seasonally (Heyning and Dahlheim 1988). High densities of the species occur in high latitudes, especially in areas where prey is abundant. Although resident in some parts of its range, the killer whale can also be transient. Killer whale movements generally appear to follow the distribution of their prey, which includes marine mammals, fish, and squid. Killer whales are large and conspicuous, often traveling in close-knit matrilineal groups of a few to tens of individuals (Dahlheim and Heyning 1999). Mean group sizes have been reported as 6.5 for Hawaii (Barlow 2006), 5.3 for the PICEAS area (Barlow et al. 2008), and 5.4–8.1 for the ETP (Wade and Gerrodette 1993; Ferguson et al. 2006b; Jackson et al. 2008). 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 depth (Baird et al. 2003).

In Hawaii, the population size in 2002 was estimated at 349 (Barlow 2006), and in the ETP, the population size was estimated at 8500 (Ford 2002). Killer whales were sighted to the east of the proposed survey area during summer–fall surveys of the ETP during 1986–1996 (Wade and Gerrodette 1993; Ferguson and Barlow 2001) and 2006 (Jackson et al. 2008); an acoustic detection was also made just east of the proposed survey area (Rankin et al. 2008). During the PICEAS survey west of the proposed survey area in July–November 2005, one sighting was made near Johnston Atoll and another was made near Palmyra Atoll (Barlow et al. 2008).

Short-finned Pilot Whale *(Globicephala macrorhynchus)*

The short-finned pilot whale is found in tropical and warm temperate waters (Olson and Reilly 2002); it is seen as far south as ~40ºS, but is more common north of ~35ºS (Olson and Reilly 2002). It is generally nomadic, but may be resident in certain locations, including California and Hawaii (Olson and Reilly 2002). It is an occasional visitor as far north as the Alaska Peninsula. Pilot whales occur on the shelf break, over the slope, and in areas with prominent topographic features (Olson and Reilly 2002).

Pilot whales are very social and are usually seen in groups of 20–90 with matrilineal associations (Olson and Reilly 2002). Mean group sizes have been reported as 22.5 for Hawaii (Barlow 2006), 24.3 for the PICEAS area (Barlow et al. 2008), and 18.0–18.3 for the ETP (Wade and Gerrodette 1993; Ferguson et al. 2006b; Jackson et al. 2008). Both species (short-finned and long-finned) are known for single and mass strandings. Long-finned pilot whales outfitted with time-depth recorders dove to depths up to 828 m, although most of their time was spent above depths of 7 m (Heide-Jørgensen et al. 2002). The species' maximum recorded dive depth is 971 m (Baird pers. comm. *in* DoN 2005).

In Hawaii, the population size in 2002 was estimated at 8870 (Barlow 2006), and in the ETP, the population size of both *G. macrorhynchus* and *G. melas* was estimated at 589,315 (Gerrodette and Forcada 2002). Pilot whales were sighted to the east of the proposed survey area during summer–fall surveys of the ETP during 1986–1996 (Wade and Gerrodette 1993; Ferguson and Barlow 2001). At least nine sightings were made to the west of the proposed survey area near Palmyra Atoll during the PICEAS survey in July–November 2005 (Barlow et al. 2008). Acoustic detections of pilot whales were also made in the PICEAS area as well as to the east of the proposed survey area (Barlow et al. 2008; Rankin et al. 2008).

Pinniped

Only one species of pinniped has the potential to occur in the proposed survey area: the Hawaiian monk seal (*Monachus schauinslandi)*. The Hawaiian monk seal is listed as ***Endangered*** under the ESA and ***Critically Endangered*** on the 2010 IUCN Red List of Threatened Species (IUCN 2010), and is listed in CITES Appendix I (UNEP-WCMC 2010). The Hawaiian monk seal occurs throughout the Hawaiian Island chain, mostly in six main breeding locations in the northwestern Hawaiian Islands, with a small but increasing number of births documented in the main Hawaiian Islands (Lowry and Aguilar 2008). It is estimated that the population has declined by 49% in 49 years. Since 1999 the population has declined at a rate of ~4 % per year (Lowry and Aguilar 2008). The best estimate for the population is 1202 (NMFS 2007).

Monk seals are benthic foragers that feed on marine terraces of atolls and banks, generally to depths <40 m but occasionally to depths >500m (Parrish et al. 2000; Stewart et al. 2006). Stewart et al. (2006) used satellite tracking to examine the foraging behavior of monk seals at the six main breeding colonies in the northwestern Hawaiian Islands. Foraging trips varied by sex and by age and ranged from <1 km up to 217 km from haul-out sites. Satellite tracking of Hawaiian monk seals in the main Hawaiian Islands revealed home ranges of 34 to 800 km^2. The home ranges for monk seals in the northwestern Hawaiian Islands were much greater (163–7400 km^2; NMFS 2007).

Hawaiian monk seals are seen occasionally at Johnston Atoll, ~1400 km west of Hawaii, and at least one birth has occurred at the atoll (NMFS 2007). In addition, twelve males were translocated to Johnston Atoll over the past 20 years. In the late 1980s two Hawaiian monk seal sightings were reported at Palmyra Atoll near the proposed survey area, and one tagged seal was observed near Wake Island, ~3700 km west of Hawaii (Westlake and Gilmartin 1990).

Given the very low population abundance and that the proposed survey area is >1600 km from their most common coastal habitat, sightings are not expected in the proposed survey area and therefore no takes are anticipated or 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 central Pacific Ocean during November–December 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 central Pacific Ocean during November–December 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}.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Hearing Impairment and Other Physical Effects

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

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

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

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

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

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

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

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

of best hearing are believed to be higher (less sensitive) than are those of odontocetes at their best frequencies (Clark and Ellison 2004). From this, it is suspected that received levels causing TTS onset may also be higher in baleen whales (Southall et al. 2007). In any event, no cases of TTS are expected given three considerations: (1) the low abundance of baleen whales in the planned study area at the time of the survey; (2) the strong likelihood that baleen whales would avoid the approaching airguns (or vessel) before being exposed to levels high enough for TTS to occur; and (3) the mitigation measures that are planned.

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

NMFS (1995, 2000) concluded that cetaceans and pinnipeds should not be exposed to pulsed underwater noise at received levels exceeding, respectively, 180 and 190 dB re 1 μPa_{rms}. Those sound levels are ***not*** considered to be the levels above which TTS might occur. Rather, they were the received levels above 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 $\mu Pa_{rms} \cdot m$. 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 μPa·m_{rms} (see § I), the received level for an animal within the MBES beam 100 m below the ship would be ~202 dB re 1 μPa_{rms}, assuming 40 dB of spreading loss over 100 m (circular spreading). Given the narrow beam, only one pulse is likely to be received by a given animal as the ship passes overhead. The received energy level from a single pulse of duration 15 ms would be about 184 dB re 1 $\mu Pa^2 \cdot s$, i.e., 202 dB + 10 log (0.015 s). That is below the TTS threshold for a cetacean receiving a single non-impulse sound (195 dB re 1 $\mu Pa^2 \cdot s$) and even further below the anticipated PTS threshold (215 dB re 1 $\mu Pa^2 \cdot s$) (Southall et al. 2007). In contrast, an animal that was only 10 m below the MBES when a ping is emitted would be expected to receive a level ~20 dB higher, i.e., 204 dB re 1 $\mu Pa^2 \cdot s$ in the case of the EM 122. That animal might incur some TTS (which would be fully recoverable), but the exposure would still be below the anticipated PTS threshold for cetaceans. As noted by Burkhardt et al. (2007, 2008), cetaceans are very unlikely to incur PTS from operation of scientific sonars on a ship that is underway.

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

Possible Effects of the Sub-bottom Profiler Signals

An SBP will also be operated from the source vessel during the planned study. Details about this equipment were provided in § I. Sounds from the SBP are very short pulses, occurring for up to 64 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 222 dB re 1 µPa·m (see § I). Kremser et al. (2005) noted that the probability of a cetacean swimming through the area of exposure when a bottom profiler emits a pulse is small—even for an SBP more powerful than that on the *Langseth*—if the animal was in the area, it would have to pass the transducer at close range and in order to be subjected to sound levels that could cause TTS.

Masking

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

Behavioral Responses

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

Hearing Impairment and Other Physical Effects

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

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

All anticipated takes would be "takes by harassment", involving temporary changes in behavior. The mitigation measures to be applied will minimize the possibility of injurious takes. (However, as noted earlier, there is no specific information demonstrating that injurious "takes" would occur even in the absence of the planned mitigation measures.) In the sections below, we describe methods to estimate the number of potential exposures to various received sound levels and present estimates of the numbers of marine mammals that could be affected during the proposed seismic program. The estimates are based on a consideration of the number of marine mammals that could be disturbed appreciably by operations with the 36-airgun array to be used during ~2120 km of seismic surveys in the central Pacific Ocean. The sources of distributional and numerical data used in deriving the estimates are described in the next subsection.

It is assumed that, during simultaneous operations of the airgun array and the other sources, any marine mammals close enough to be affected by the MBES 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"

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. 2009b). For the ETP, the models are based on data from 12 SWFSC ship-based cetacean and ecosystem assessment surveys conducted during July–December 1986–2006, extending just into the proposed survey area. 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). For the cetacean species in the model, we used the GIS to obtain mean densities in the proposed survey area, i.e., in a rectangle bounded by 150 and 156°W and 5 and 10°N. (2) For species not included in the model, we used densities from the offshore stratum of the surveys of Hawaiian waters conducted in August–November 2002 (Barlow 2006).

Table 3 gives the estimated densities for each cetacean species that could occur in the proposed survey area. Densities have been corrected for both trackline detection probability and availability bias by the authors. Trackline detection probability bias is associated with diminishing sightability with increasing lateral distance from the trackline [$f(0)$]. Availability bias refers to the fact that there is less-than-100% probability of sighting an animal that is present along the survey trackline [$g(0)$].

Because survey effort within the proposed survey area is limited, and densities for some species are from offshore Hawaiian waters, 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.

The estimated numbers of individuals potentially exposed are based on the 160-dB re 1 μPa_{rms} criterion for all cetaceans (Table 4). It is assumed that marine mammals exposed to airgun sounds that strong might change their behavior sufficiently to be considered "taken by harassment".

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

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

TABLE 3. Densities of marine mammals near the proposed survey area. Cetacean densities are based on NMFS SWFSC ETP ship transect surveys conducted in 1986–2006 from predictive modeling (Barlow et al. 2009b; Read et al. 2009) or in 2002 from Barlow (2006). See text for details. Densities are corrected for *f*(0) and *g*(0). Species listed as "Endangered" under the ESA are in italics.

Species	Density (#/1000 km^2)	Source[1]
Mysticetes		
Humpback whale	*0*	
Minke whale	0	
Bryde's whale	0.58	Read et al. (2009)
Sei whale	*0*	
Fin whale	*0*	
Blue whale	*0.01*	*Read et al. (2009)*
Odontocetes		
Sperm whale	*2.97*	*Barlow (2006)*
Pygmy sperm whale	0.03	Read et al. (2009)
Dwarf sperm whale	7.65	Barlow (2006)
Cuvier's beaked whale	6.66	Barlow (2006)
Longman's beaked whale	0.44	Barlow (2006)
Mesoplodon spp.[2]	0.35	Read et al. (2009)
Rough-toothed dolphin	1.24	Read et al. (2009)
Bottlenose dolphin	4.94	Read et al. (2009)
Pantropical spotted dolphin	120.4	Read et al. (2009)
Spinner dolphin	183.5	Read et al. (2009)
Striped dolphin	16.45	Read et al. (2009)
Fraser's dolphin	4.47	Barlow (2006)
Risso's dolphin	0.81	Barlow (2006)
Melon-headed whale	1.29	Barlow (2006)
Pygmy killer whale	0	
False killer whale	0.10	Barlow (2006)
Killer whale	0.15	Barlow (2006)
Short-finned pilot whale	5.07	Read et al. (2009)
Pinnipeds		
Hawaiian monk seal	*0*	

[1] Where no source is given, the species was not included in Read et al. (2009) or Barlow (2006).
[2] Includes ginkgo-toothed and Blainville's beaked whales.

Potential Number of Marine Mammals Exposed to ≥160 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. During the proposed survey, one of the transect lines will be surveyed twice. Thus, the area including overlap is 1.5 x the area excluding overlap, so a marine mammal that stayed in the survey area during the entire survey could be exposed

TABLE 4. Estimates of the possible numbers of different individuals that could be exposed during L-DEO's proposed seismic survey in the central Pacific in November–December 2011. The proposed sound source consists of an 36-airgun array with a total discharge volume of 6600 in^3. Received levels of seismic sounds are expressed in dB re 1 µPa (rms, averaged over pulse duration), consistent with NMFS' practice. Not all marine mammals will change their behavior when exposed to these sound levels, but some may alter their behavior when levels are lower (see text). Species in italics are listed under the ESA as endangered or threatened. The column of numbers in boldface shows the numbers of "takes" for which authorization is requested.

Species	Number[1]	% Regional Pop'n[2]	Requested Take Authorization
Mysticetes			
Humpback whale	*0*	*0*	***0***
Minke whale	0	0	**0**
Bryde's whale	*8*	0.06	***8***
Sei whale	*0*	*0*	***0***
Fin whale	*0*	*0*	***0***
Blue whale	*0*	*<0.01*	***2***[4]
Odontocetes			
Sperm whale	*41*	*0.17*	***41***
Pygmy sperm whale	0	NA	**0**
Dwarf sperm whale	105	0.94	**105**
Cuvier's beaked whale	91	0.46	**91**
Longman's beaked whale	6	2.07	**14**[4]
Mesoplodon spp.[3]	5	0.02	**5**
Rough-toothed dolphin	17	0.02	**17**
Bottlenose dolphin	68	0.02	**68**
Pantropical spotted dolphin	1651	0.13	**1651**
Spinner dolphin	2516	0.14	**2516**
Striped dolphin	226	0.02	**226**
Fraser's dolphin	61	0.02	**182**[4]
Risso's dolphin	11	0.01	**14**[4]
Melon-headed whale	18	0.04	**101**[4]
Pygmy killer whale	0	0	**0**
False killer whale	1	<0.01	**9**[4]
Killer whale	2	0.02	**5**[4]
Short-finned pilot whale	69	0.01	**69**
Pinnipeds			
Hawaiian monk seal	*0*	*0*	***0***

NA = not available.

[1] Estimates are based on densities from Table 3 and an ensonified area (including 25% contingency) of 13,714 km^2.

[2] Regional population size estimates are from Table 2.

[3] Includes ginkgo-toothed and Blainville's beaked whales.

[4] Requested Take Authorization increased to mean group size (see text on page 59).

~2 times, on average. However, it is unlikely that a particular animal would stay in the area during the entire survey.

The numbers of different individuals potentially exposed to ≥160 dB re 1 $\mu\text{Pa}_{\text{rms}}$ were calculated by multiplying

- the expected species density, times
- the anticipated area to be ensonified to that level during airgun operations excluding overlap.

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

Applying the approach described above, ~10,971 km^2 (~13,714 km^2 including the 25% contingency) would be within the 160-dB isopleth during the survey. Because this approach does not allow for turnover in the mammal populations in the proposed survey area during the course of the survey, the actual number of individuals exposed could be underestimated. However, the approach assumes that no cetaceans will move away from or toward the trackline as the *Langseth* approaches in response to increasing sound levels prior to the time the levels reach 160 dB, which will result in overestimates for those species known to avoid seismic vessels (see § IV a).

Table 4 shows estimates of the number of different individual marine mammals that potentially could be exposed to ≥160 dB re 1 µPa$_{rms}$ during the seismic survey if no animals moved away from the survey vessel. The ***Requested Take Authorization*** is given in the far right column of Table 4. For ***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 the blue whale). For non-listed species, the ***Requested Take Authorization*** has been increased to the mean group size in the PICEAS survey area (Barlow et al. 2008) for the particular species in cases where the calculated number of individuals exposed was between 1 and the mean group size.

The estimate of the number of individual cetaceans that could be exposed to seismic sounds with received levels ≥160 dB re 1 µPa$_{rms}$ during the proposed survey is 4896 (Table 4). That total includes 41 sperm whales (listed as ***Endangered*** under the ESA) or 0.17% of the regional population.

In addition, 102 beaked whales (91 Cuvier's, 6 Longman's, and 5 *Mesoplodon* spp.) could be exposed during the survey (Table 4). Most (94.8%) of the cetaceans potentially exposed are delphinids; spinner, pantropical spotted, and striped dolphins are estimated to be the most common species in the area, with estimates of 2516 (0.14% of the regional population), 1651 (0.13%), and 226 (0.02%) exposed to ≥160 dB re 1 µPa$_{rms}$, respectively. As noted above, a more meaningful estimate for delphinids would be for sound levels ≥170 dB.

Number of Pinnipeds that could be Exposed to ≥160 dB.—The Hawaiian monk seal was sighted in the 1980s at Palmyra Atoll near the proposed survey area, but given its very low population abundance and the fact that the proposed survey area is >1600 km from its most common coastal habitat, sightings are not expected in the proposed survey area and therefore no takes are anticipated or 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 36-airgun array similar to the airgun arrays used for typical high-energy seismic surveys. The total airgun discharge volume is ~6600 in^3. Routine vessel operations, other than the proposed airgun operations, are conventionally assumed not to affect marine mammals sufficiently to constitute "taking". No "taking" of marine mammals is expected in association with echosounder operations given the considerations discussed in § I, i.e., sounds are beamed downward, the beam is narrow, and the pulses are extremely short.

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

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

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

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

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

Pinnipeds.—Only one species of pinniped has the potential to occur in the proposed survey area: the Hawaiian monk seal. However, given the very low population size and the offshore location of the proposed survey area, monk seals are unlikely to be encountered during the proposed survey.

VIII. ANTICIPATED IMPACT ON SUBSISTENCE

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

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

IX. ANTICIPATED IMPACT ON HABITAT

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

The proposed seismic survey will not result in any permanent impact on habitats used by marine mammals, or to the food sources they use. The main impact issue associated with the proposed activity will be temporarily elevated noise levels and the associated direct effects on marine mammals, as discussed in § VII, above. The following sections briefly review effects of airguns on fish and invertebrates, and more details are included in Appendices 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 µPa^2·s showed no hearing loss. During both studies, the repetitive exposure to sound was greater than would have occurred during a typical seismic survey. However, the substantial low-frequency energy produced by the airguns [less than ~400 Hz in the study by McCauley et al. (2003) and less than ~200 Hz in Popper et al. (2005)] likely did not propagate to the fish because the water in the study areas was very shallow (~9 m in the former case and <2 m in the latter). Water depth sets a lower limit on the lowest sound frequency that will propagate (the "cutoff frequency") at about one-quarter wavelength (Urick 1983; Rogers and Cox 1988).

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

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

Physiological Effects

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

Behavioral Effects

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

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

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

Effects on Invertebrates

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

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

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

Pathological Effects

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

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

Physiological Effects

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

Behavioral Effects

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

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

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

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

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

XI. MITIGATION MEASURES

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

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

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

Planning Phase

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

Proposed Exclusion Zones

Received sound levels have been predicted by L-DEO's model, in relation to distance and direction from the airguns, for the 36-airgun array and for a single 1900LL 40-in^3 airgun, which will be used during power downs. Results have been reported for propagation measurements of pulses from the 36-airgun array in two water depths (~1600 m and 50 m) in the Gulf of Mexico in 2007–2008 (Tolstoy et al. 2009). Results of the propagation measurements showed that radii around the airguns for various received levels varied with water depth (Tolstoy et al. 2009). In addition, propagation varies with array tow depth. The empirical values that resulted from Tolstoy et al. (2009) are used here to determine exclusion zones for the 36-airgun array. However, the depth of the array was different in the Gulf of Mexico calibration study (6 m) than in the proposed survey (9 m); thus, correction factors have been applied to the distances reported by Tolstoy et al. (2009). The correction factors used were the ratios of the 160-, 170-, 180-, and 190-dB distances from the modeled results for the 6600-in^3 airgun array towed at 6 m vs. 9 m, from LGL (2008): 1.285; 1.381; 1.338; and 1.364, respectively.

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

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

Mitigation During Operations

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

Power-down Procedures

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

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

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

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

The airgun array will be ramped up gradually after the marine mammal has cleared the safety zone. 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 survey, this period would be ~8 min. This period is based on the 180-dB radius for the 36-airgun array (940 m) in relation to the average planned speed of the *Langseth* while shooting (7.4 km/h). Similar periods (~8–10 min) were used during previous L-DEO surveys. Ramp up will not occur if a marine mammal or sea turtle has not cleared the safety zone as described earlier.

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

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

XII. PLAN OF COOPERATION

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

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

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

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

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

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

XIII. MONITORING AND REPORTING PLAN

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

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

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

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

Vessel-based Visual Monitoring

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

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

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

Passive Acoustic Monitoring

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

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

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

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

PSO Data and Documentation

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

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

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

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

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

Results from the vessel-based observations will provide

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

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

XIV. COORDINATING RESEARCH TO REDUCE AND EVALUATE INCIDENTAL TAKE

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

L-DEO and NSF will coordinate the planned marine mammal monitoring program associated with the seismic survey with other parties that may have interest in this area. L-DEO and NSF will coordinate with applicable U.S. agencies (e.g., NMFS), and will comply with their requirements. During the preparation of this EA, Jay Barlow, SWFSC, was contacted for permission to use densities from the SERDP GIS.

XV. LITERATURE CITED

Marine Mammals and Acoustics

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