Request by Scripps Institution of Oceanography for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during a Low-Energy Marine Seismic Survey in the Pacific Ocean off Central and South America, October–November 2010

submitted by

Scripps Institution of Oceanography
8602 La Jolla Shores Drive
La Jolla, CA. 92037

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

27 May 2010
Revised 13 July and 20 September 2010

LGL Report TA4902-2

TABLE OF CONTENTS

Page

Request by Scripps Institution of Oceanography for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during a Low-Energy Marine Seismic Survey in the Pacific Ocean off Central and South America, October–November 2010

SUMMARY

Scripps Institution of Oceanography (SIO), a part of the University of California, operates the oceanographic research vessel (R/V) *Melville* under a charter agreement with the U.S. Office of Naval Research (ONR). The title of the vessel is held by the U.S. Navy. SIO, in collaboration with Texas A&M University (TAMU), plans to conduct a seismic survey, coring, and water sampling program with the R/V *Melville* in the Pacific Ocean off Costa Rica, Panama, Colombia, Ecuador, and Peru for ~25 days in October–November 2010. The survey will use a pair of GI airguns, each with a discharge volume of 45 in^3. SIO 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). The seismic survey will be conducted in International Waters and in the EEZs of Costa Rica, Panama, Colombia, and Ecuador.

Numerous species of cetaceans and pinnipeds occur in the eastern tropical Pacific Ocean (ETP). Several of these species are listed as ***endangered*** under the U.S. Endangered Species Act (ESA), including the humpback, fin, blue, and sperm whales. SIO is proposing a marine mammal monitoring and mitigation program to minimize the impacts of the proposed activity on marine mammals present during conduct of the proposed research, and to document the nature and extent of any effects.

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

I. OPERATIONS TO BE CONDUCTED

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

Overview of the Activity

SIO plans to conduct a seismic survey in the ETP as part of an integrated geophysical and geochemical study (Fig. 1). The cruise is scheduled to take place for ~25 days in October–November 2010.

The purpose of the proposed study is to study the deposition of sediments in the upper 500 m of the sediment column using known seismic horizons in the sediment column to estimate rates of deposition downstream from potential sediment sources on the topographic highs, and to estimate loss from the

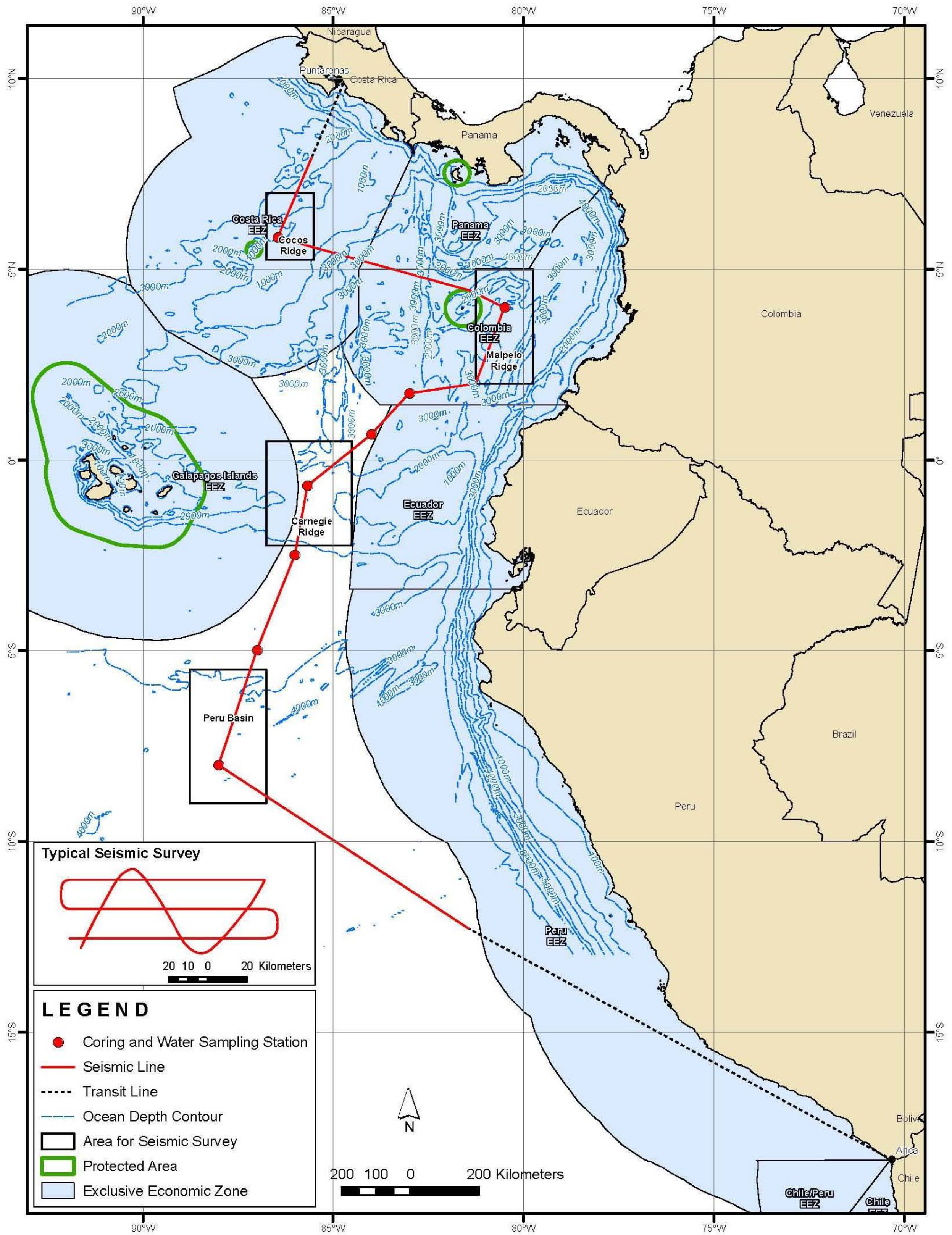

FIGURE 1. Proposed study areas for the survey in the ETP, October–November 2010.

ridges. The seismic survey and associated coring and water sampling will allow comparisons of geophysical estimates of the level of erosion from marine ridges and highs with geochemical estimates of sediment focusing based upon the distribution of Th-230, a particle-reactive isotope produced by the decay of dissolved uranium in the water column. In addition, the study will examine whether there are sediment sources for Th-230 in slowly-accumulating sediments. Also included in the research is the use of a multibeam echosounder (MBES) and a sub-bottom profiler (SBP).

The planned seismic survey (including turns) will consist of ~5475 km of survey lines. The GI airguns will be operated on a small grid (see inset in Fig. 1) for ~45 h at each of four sites (depicted with black boxes in Fig. 1), where the 40-channel streamer will be used, and for most of the time during transits between the sites, to the first site, and after the last site (see red seismic line depicted in Fig. 1), where the 16-channel streamer will be used. Water depths within the seismic survey areas are ~1000–4800 m.

In addition to the GI airguns, a multibeam echosounder (MBES) and a sub-bottom profiler (SBP) will be used throughout the cruise except while at water/core stations, to help verify seafloor conditions at possible coring sites and to collect additional seafloor bathymetric data. Passive geophysical sensors (a gravimeter and a magnetometer) will also be operated continuously throughout the entire cruise.

All planned geophysical and geochemical data acquisition activities will be conducted by SIO with on-board assistance by the scientists who have proposed the study. The Principal Investigator is Dr. Franco Marcantonio and the Co-principal Investigator is Dr. Mitchell Lyle, both of Texas A&M University. The vessel will be self-contained, and the crew will live aboard the vessel for the entire cruise.

Vessel Specifications

The R/V *Melville* has a length of 85 m, a beam of 14.0 m, and a maximum draft of 5.0 m. The ship is powered by two 1385-hp Propulsion General Electric motors and a 900-hp retracting Azimuthing bow thruster. Operation speeds of ~11 km/h (6 knots) and 15–18.5 km/h (8–10 knots) will be used during seismic acquisition within the survey areas and between the areas and stations, respectively. When not towing seismic survey gear, the R/V *Melville* cruises at 21.7 km/h (11.7 knots) and has a maximum speed of 25.9 km/h (14 knots). It has a normal operating range of ~18,630 km.

The R/V *Melville* will also serve as the platform from which vessel-based marine mammal observers will watch for marine mammals and sea turtles before and during airgun operations, as described in § XI and XIII, below.

Other details of the R/V *Melville* include the following:

Owner:	U.S. Navy
Operator:	Scripps Institution of Oceanography of the University of California
Flag:	United States of America
Date Built:	1969
Gross Tonnage:	2516
Compressors for Air Guns:	1850 psi
Accommodation Capacity:	23 crew plus 38 scientists

Airgun Description

The R/V *Melville* will tow a pair of 45-in^3 Sercel GI airguns and a streamer containing hydrophones along predetermined lines. Seismic pulses will be emitted at intervals of 8–10 seconds. At speeds of ~11–18.5 km/h, the 8–10 s spacing corresponds to shot intervals of ~25–50 m.

The generator chamber of each GI airgun, the one responsible for introducing the sound pulse into the ocean, is 45 in^3. The larger (105-in^3) injector chamber injects air into the previously-generated bubble to maintain its shape, and does not introduce more sound into the water. The two 45-in^3 GI airguns will be towed 8 m apart side by side, 21 m behind the *Melville*, at a depth of 2 m. The sound pressure field of that GI airgun variation has not been modeled, but that for two 45-in^3 Nucleus G airguns has been modeled by Lamont-Doherty Earth Observatory (L-DEO) in relation to distance and direction from the airguns (see "Mitigation Measures" below).

As the GI airgun is towed along the survey line, the towed hydrophone array in the streamer receives the reflected signals and transfers the data to the on-board processing system. Given the relatively short streamer length behind the vessel, the turning rate of the vessel while the gear is deployed is much higher than the limit of five degrees per minute for a seismic vessel towing a streamer of more typical length (>>l km). Thus, the maneuverability of the vessel is not limited much during operations.

GI Airgun Specifications

Energy Source	Two GI airguns of 45 in^3
Source output (downward)	0-pk is 3.4 bar-m (230.6 dB re 1 μPa·m); pk-pk is 6.2 bar-m (235.8 dB re 1 μPa·m)
Towing depth of energy source	2 m
Air discharge volume	~90 in^3
Dominant frequency components	0–188 Hz
Gun positions used	Two side by side airguns 8 m apart
Gun volumes at each position (in^3)	45, 45

The nominal downward-directed source levels indicated above do not represent actual sound levels that can be measured at any location in the water. Rather, they represent the level that would be found 1 m from a hypothetical point source emitting the same total amount of sound as is emitted by the combined GI airguns. The actual received level at any location in the water near the GI airguns will not exceed the source level of the strongest individual source. In this case, that will be about 224.6 dB re 1μPa-m peak, or 229.8 dB re 1μPa-m peak-to-peak. Actual levels experienced by any organism more than 1 m from either GI airgun will be significantly lower.

A further consideration is that the rms[1] (root mean square) received levels that are used as impact criteria for marine mammals are not directly comparable to the peak (p or 0–p) or peak to peak (p–p) values normally used to characterize source levels of airgun arrays. The measurement units used to describe airgun sources, peak or peak-to-peak decibels, are always higher than the rms decibels referred to in biological literature. A measured received level of 160 dB re 1 μPa_{rms} in the far field would typically correspond to ~170 dB re 1 μPa_p, and to ~176–178 dB re 1 $\mu Pa_{p\text{-}p}$, as measured for the same pulse received at the same location (Greene 1997; McCauley et al. 1998, 2000). The precise difference between rms and peak or peak-to-peak values depends on the frequency content and duration of the pulse, among other factors. However, the rms level is always lower than the peak or peak-to-peak level for an airgun-type source.

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

Received sound levels have been modeled by Lamont-Doherty Earth Observatory of Columbia University (L-DEO) for a number of airgun configurations, including two 45-in^3 Nucleus G. Guns, in relation to distance and direction from the airguns (Fig. 2). The model does not allow for bottom interactions, and is most directly applicable to deep water. Based on the modeling, estimates of the maximum distances from the GI airguns where sound levels of 190, 180, 170, and 160 dB re 1 μPa (rms) are predicted to be received in deep (>1000-m) water are shown in Table 1. Because the model results are for G. Guns, which have more energy than GI airguns of the same size, those distances overestimate the distances for the 45-in^3 GI airguns.

Empirical data concerning the 180-, 170-, and 160-dB distances have been acquired based on measurements during the acoustic verification study conducted by L-DEO in the northern Gulf of Mexico from 27 May to 3 June 2003 (Tolstoy et al. 2004). Although the results are limited, the data showed that radii around the airguns where the received level would be 180 dB re 1 μPa (rms), the safety criterion applicable to cetaceans (NMFS 2000), vary with water depth. Similar depth-related variation is likely in the 190-dB distances applicable to pinnipeds. Correction factors were developed for water depths 100–1000 m and <100 m. The proposed survey will occur in depths ~1000–4800 m, so the correction factors for shallow water are not relevant here. All of seismic operations will be in depths >1000 m.

The empirical data indicate that, for ***deep water*** (>1000 m), the L-DEO model tends to overestimate the received sound levels at a given distance (Tolstoy et al. 2004). However, to be precautionary pending acquisition of additional empirical data, it is proposed that safety radii during airgun operations in deep water will be the values predicted by L-DEO's model (Table 1). Therefore, the assumed 180- and 190-dB radii are 40 m and 10 m, respectively.

Table 1 shows the distances at which four rms sound levels are expected to be received from the GI airguns. 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; Holst and Beland 2008; Holst and Smultea 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. SIO will be prepared to revise its procedures for estimating numbers of mammals "taken", exclusion zones, etc., as may be required by any new guidelines that result. However, currently the procedures are based on best practices noted by Pierson et al. (1998) and Weir and Dolman (2007). As yet, NMFS has not specified a new procedure for determining exclusion zones.

Echosounder Descriptions

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

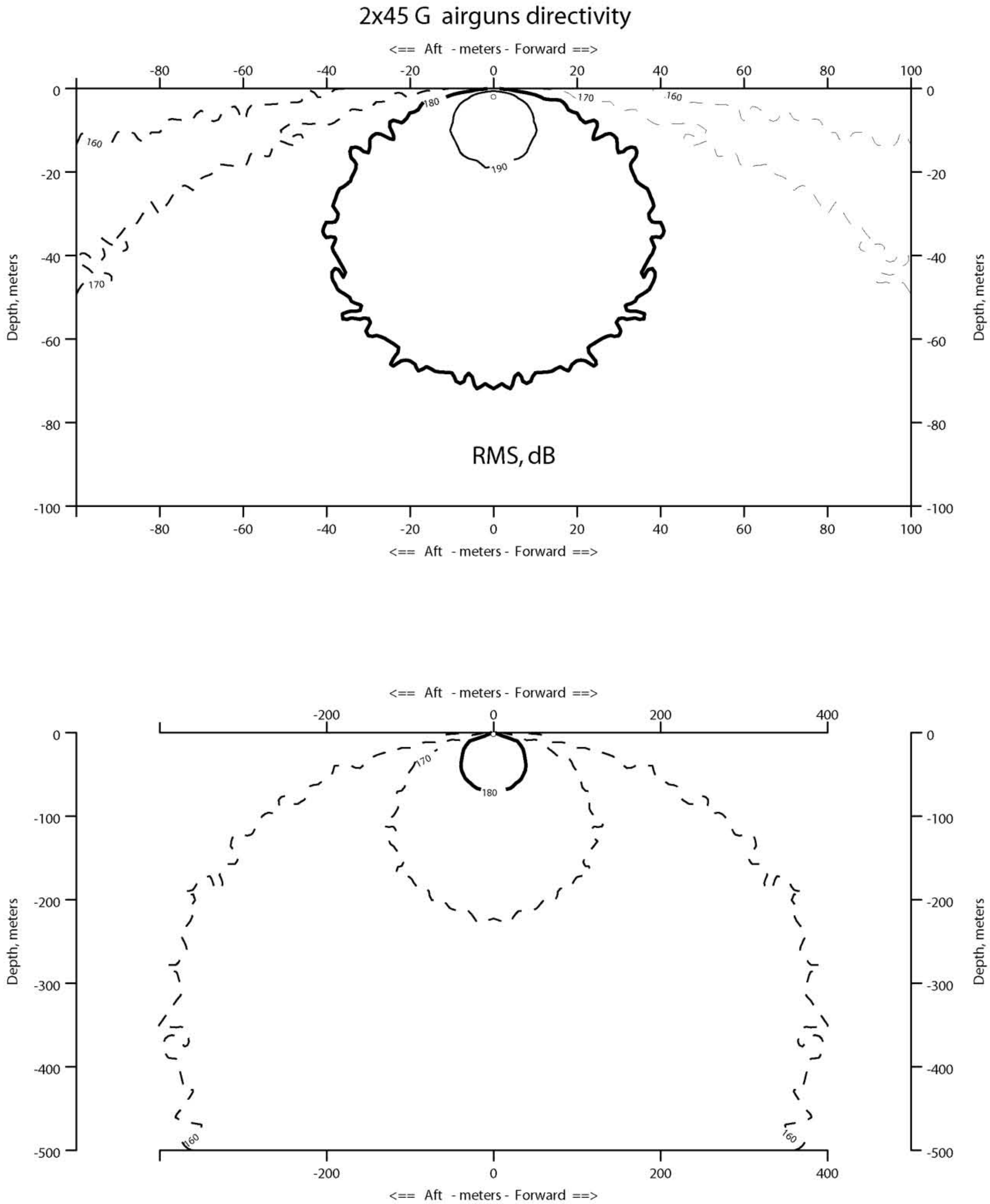

FIGURE 2. Modeled received sound levels from two 45-in3 G. Guns, similar to the two 45-in3 GI airguns that will be used during the SIO survey in the ETP during October–November 2010. Model results provided by the Lamont-Doherty Earth Observatory of Columbia University.

TABLE 1. Distances to which sound levels ≥190, 180, 170, and 160 dB re 1 μPa (rms) might be received from two 45-in^3 G. Guns, similar to the two 45-in^3 GI airguns that will be used during the seismic surveys in the ETP during October–November 2010. Distances are based on model results provided by L-DEO.

Water depth	Estimated Distances at Received Levels (m)			
	190 dB	180 dB	170 dB	160 dB
>1000 m	10	40	125	400

Knudsen 320B/R Sub-bottom Profiler.—The Knudsen Engineering Model 320B/R sub-bottom profiler is a dual-frequency transceiver designed to operate at 3.5 and/or 12 kHz. It is used in conjunction with the MBES to provide data about the sedimentary features that occur below the sea floor. The energy from the sub-bottom profiler is directed downward via a 3.5-kHz transducer array mounted in the hull of the R/V *Melville*. The maximum power output of the 320B/R is 10 kilowatts for the 3.5-kHz section and 2 kilowatts for the 12-kHz section. (The 12-kHz section is seldom used in survey mode on *R/V Melville* because of overlap with the operating frequency of the Kongsberg EM 122 MBES.)

The pulse length for the 3.5-kHz section of the 320B/R is 0.8–24 ms, controlled by the system operator in regards to water depth and reflectivity of the bottom sediments, and will usually be 6, 12, or 24 ms at the water depths at the study sites and in transit from Puntarenas and to Arica. The system produces one sound pulse and then waits for its return before transmitting again. Thus, the pulse interval is directly dependent upon water depth, and in this survey is 0.8–1.5 sec. Using the Sonar Equations and assuming 100% efficiency in the system (impractical in real world applications), the source level for the 320BR is calculated to be 211 dB re 1μPa-m. In practice, the system is rarely operated above 80% power level.

Sub-bottom Profiler Specifications (this survey)

Maximum source output (downward)	211 dB re 1 μPa-m; 10 kilowatts
Dominant frequency components	3.5 kHz
Nominal beamwidth	80 degrees
Pulse interval	0.8–1.5 sec
Pulse duration	0.8–24 ms

Description of Operations

The survey will involve one source vessel, the R/V *Melville*. For the seismic component of the research program, the source vessel will deploy a pair of low-energy Sercel Generator-Injector (GI) airguns as an energy source (each with a discharge volume of 45 in^3), plus either of two towed hydrophone streamers, one 725 m long with 40 channels, and the other 350 m long with 16 channels. The energy to the airguns is compressed air supplied by compressors on board the source vessel. As the airguns are 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 program will consist of ~5475 km of surveys, including turns (Fig. 1). Water depths within the seismic survey areas are ~1000–4800 m. The GI airguns will be operated on a small grid (see inset in Fig. 1) for ~45 h at each of four sites (depicted with black boxes in Fig. 1), where the 40-channel streamer will be used, and for most of the time during transits between the sites, to the first site, and after the last site (see red seismic line depicted in Fig. 1), where the 16-channel streamer will be used. There will be additional seismic operations associated with equipment testing, startup, and possible line changes or repeat coverage of any areas where initial data quality is sub-standard. Those additional operations are allowed for in the estimated total line km used for calculations in § VII(c). The R/V *Melville* is expected to depart Puntarenas, Costa Rica, on 19 October 2010 and spend ~15 days conducting seismic surveys, 10 days collecting water and core samples, and ~2 days in transit, arriving at Arica, Chile, on 14 November 2010.

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 R/V *Melville* is expected to depart Puntarenas, Costa Rica, on 19 October 2010 and spend ~15 days conducting seismic surveys, 10 days collecting water and core samples, and ~2 days in transit, arriving at Arica, Chile, on 14 November 2010. At each of the four sites, seismic operations will be conducted for ~2 days, and each water sampling and coring station will be occupied for 1–2 days. Some minor deviation from these dates is possible, depending on logistics and weather. The survey will encompass the area ~8ºN–12°S, ~80–91°W, off the coasts of Costa Rica, Panama, Colombia, Ecuador, and Peru (Fig. 1). Water depths in the survey area range from ~1000 m to ~4800 m. The seismic survey will be conducted in International Waters and in the EEZs of Costa Rica, Panama, Colombia, and Ecuador.

III. Species and Numbers of Marine Mammals in Area

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

Forty-three species of marine mammals, including 29 odontocetes, 7 mysticetes, 6 pinnipeds, and the marine sea otter are known to occur in the ETP. Of those, 27 cetacean species may occur in the proposed survey areas in the ETP, based on multi-year vessel surveys conducted in the wider ETP by the NMFS Southwest Fisheries Science Center (SWFSC), e.g., Polacheck 1987; Wade and Gerrodette 1993; Ferguson and Barlow 2001; Gerrodette et al. 2008; Barlow et al. 2009).

To avoid redundancy, we have included the required information about the species and (insofar as it is known) numbers of these species in Section 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.

Forty-three species of marine mammals, including 29 odontocetes, 7 mysticetes, 6 pinnipeds, and the marine sea otter are known to occur in the ETP. Of those, 27 cetacean species may occur in the proposed survey areas in the ETP (Table 2). Five of the 27 cetacean species are listed under the Endangered Species Act (ESA) as ***Endangered***: the sperm, humpback, blue, fin, and sei whales. Nine cetacean species, although present in the wider ETP, likely would not be found in the proposed seismic survey areas because their ranges do not extend that far south or north. Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) and Baird's beaked whales (*Berardius bairdii*) are seen very occasionally in the northernmost portions of the ETP (Ferguson and Barlow 2001). Southern right whales are seen on rare occasions off the coasts of Peru and Chile (Aguayo et al. 1992, Santillan et al. 2004). Gray's beaked whales (*Mesoplodon grayi*) are distributed in the southernmost portions of the ETP and off the coast of southern Peru (Culik 2010). Long-beaked common dolphins (*Delphinus capensis*) are known to occur in the northernmost areas of the ETP off Baja California, Mexico, and off the coast of Peru (Heyning and Perrin 1994). Dusky dolphins (*Lagenorhynchus obscurus*) southern right whale dolphins (*Lissodelphis peronii*), Burmeister's porpoises (*Phocoena spinipinnis*), and long-finned pilot whales (*Globicephala melas*) also occur near the Peruvian coast (Leatherwood et al. 1991; Van Waerebeek et al. 1991; Brownell and Clapham 1999; Olson and Reilly 2002).

Six species of pinnipeds are known to occur in the ETP: the Guadalupe fur seal (*Arctocephalus townsendi*), California sea lion (*Zalophus californianus*), Galápagos sea lion (*Z. wollebaeki*), Galápagos fur seal (*A. galapagoensis*), southern sea lion (*Otaria flavescens*), and the South American fur seal (*A. australis*). Ranges of the first two are substantially north of the proposed seismic survey areas, and the last four species are not expected to occur in the offshore waters of the study areas. The marine sea otter (*Enhydra lutris*) is a costal species and does not occur in offshore waters.

The ETP is a biologically productive area that supports a variety of cetacean species (Au and Perryman 1985). Several studies of marine mammal distribution and abundance have been conducted in the wider ETP. The most extensive regional distribution and abundance data that encompass the study area come primarily from multi-year vessel surveys conducted in the wider ETP by the NMFS Southwest Fisheries Science Center (SWFSC). Information on the distribution of cetaceans inhabiting the ETP has been summarized in several studies (e.g., Polacheck 1987; Wade and Gerrodette 1993; Ferguson and Barlow 2001; Gerrodette et al. 2008). However, for some species, abundance in the proposed seismic survey area could be quite different from that of the wider ETP, depending on local oceanographic variabilities. In addition, procedures used during the various surveys that are cited have differed somewhat, and those differences could affect the results. For example, Ferguson and Barlow (2001) calculated cetacean densities in the ETP based on summer/fall research surveys in 1986–1996. Their densities are corrected for both changes in detectability of species with distance from the survey track line [$f(0)$], and for perception and availability bias [$g(0)$]. Gerrodette et al. (2008) calculated dolphin abundance in the ETP based on summer/fall research surveys in 1986–1990, 1998-2000, 2003, and 2006. Their estimates are corrected for $f(0)$ but not $g(0)$.

Additional sighting records are available from recent surveys in the ETP. Jackson et al. (2008) described cetacean sightings data collected during a survey from 28 July to 7 December 2006. The survey area extended from 30ºN to 18ºS from the coastline to 153ºW, overlapping with the proposed seismic survey area. Rasmussen et al. (2004) and Calambokidis et al. (2010) described cetacean sightings resulting from humpback whale surveys off Costa Rica and surrounding waters from January to March in 1996–2003 and 2010. Recent at-sea monitoring for Lamont-Doherty Earth Observatory in the ETP also provided sighting records for cetaceans during seismic programs. Seismic monitoring programs took place at the Hess Deep in July 2003, ~1100 km west of the Galapagos Islands (Smultea and Holst 2003); from Costa Rica to El Salvador in November–December 2004, mainly within ~100 km of the coast in water depths extending to 5000 m (Holst et al. 2005b); from Costa Rica to Nicaragua in March–April 2008, up to ~200 km from the coast in water depths extending to 5000 m (Holst and Smultea 2008); and ~1600–1900 km west of the study area in April–August 2008 (Hauser et al. 2008).

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

Species	Occurrence in survey area during Oct–Nov	Habitat	Abundance in the ETP[1]	ESA[2]	IUCN[3]	CITES[4]	Nature Serve[5]
Mysticetes							
Humpback whale	Very rare	Mainly nearshore waters and banks	NE Pacific 1392[6]; SE Pacific 2900[7]	EN	LC	I	G4
Common minke whale	Rare	Coastal	N.A.	NL	LC	I	G5
Bryde's whale	Uncommon	Pelagic and coastal	13,000[8]	NL	DD	I	G4
Sei whale	Very rare	Mostly pelagic	N.A.	EN	EN	I	G3
Fin whale	Very rare	Slope, mostly pelagic	2636[6]	EN	EN	I	G3G4
Blue whale	Uncommon	Pelagic and coastal	1415[9]	EN	EN	I	G3G4
Odontocetes							
Sperm whale	Common	Usually deep pelagic, steep topography	26,053[10]	EN	VU	I	G3G4
Pygmy sperm whale	Rare	Deep waters off shelf	N.A.[11]	NL	DD	II	G4
Dwarf sperm whale	Very rare	Deep waters off shelf	11,200[12]	NL	DD	II	G4
Cuvier's beaked whale	Common	Slope and pelagic	20,000[9]	NL	LC	II	G4
Longman's beaked whale	Very rare	Pelagic	291[13]	NL	DD	II	N.A.
Pygmy beaked whale	Uncommon	Pelagic	25,300[14]	NL	DD	II	GNR
Ginkgo-toothed beaked whale	Very rare	Pelagic	25,300[14]	NL	DD	II	G3
Blainville's beaked whale	Uncommon	Pelagic	25,300[14]	NL	DD	II	G4
Rough-toothed dolphin	Common	Mainly pelagic	107,633	NL	LC	II	G4
Bottlenose dolphin	Very common	Coastal, shelf, pelagic	335,834	NL	LC	II	G5
Pantropical spotted dolphin	Very common	Coastal and pelagic	857,884	NL	LC	II	G5
Spinner dolphin	Very common	Coastal and pelagic	1,797,716	NL	DD	II	G5
Striped dolphin	Very common	Off continental shelf	964,362	NL	LC	II	G5
Fraser's dolphin	Common	Pelagic	289,300[9]	NL	LC	II	G4
Short-beaked common dolphin	Very common	Shelf, pelagic, high relief	3,127,203	NL	LC	II	G5
Risso's dolphin	Very common	Shelf, slope, seamounts	110,457	NL	LC	II	G5
Melon-headed whale	Common	Pelagic	45,400[9]	NL	LC	II	G4
Pygmy killer whale	Uncommon	Pelagic	38,900[9]	NL	DD	II	G4
False killer whale	Uncommon	Pelagic	39,800[9]	NL	DD	II	G4
Killer whale	Uncommon	Widely distributed	8500[15]	NL	DD	II	G4G5
Short-finned pilot whale	Common	Mostly pelagic, high-relief	589,315[16]	NL	DD	II	G5
Pinnipeds							
California sea lion	Very rare	Coastal, shelf	238,000[17]	NL	LC	NL	G5
Galápagos sea lion	Very rare	Coastal	14,000-16,000[18]	NL	EN	NL	GNR
South American sea lion	Very rare	Coastal, shelf	150,000[19]	NL	LC	NL	NL
Galápagos fur seal	Very rare	Coastal	6000-8000[18]	NL	EN	II	NL
South American fur seal	Very rare	Coastal, shelf	41,400[20]	NL	LC	II	NL
Guadalupe fur seal	Very rare	Coastal, shelf	7,408[21]	T	NT	I	G1

N.A. Not available or not assessed.
[1] Abundance from Gerrodette et al. (2008) unless otherwise stated.
[2] U.S. Endangered Species Act: EN = Endangered, T = Threatened, NL = Not listed
[3] Codes for IUCN classifications: EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient. Classifications are from the 2010 IUCN *Red List of Threatened Species* (IUCN 2010).
[4] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2010); NL = Not listed.
[5] NatureServe Status (NatureServe 2009); GNR = unranked, G2 = Imperiled, G3 = Vulnerable, G4 = Apparently secure; G5 = Secure.
[6] U.S. west coast (Carretta et al. 2010)
[7] Southeast Pacific; Félix et al. (2005)
[8] This estimate is mainly for *Balaenoptera edeni* but may include some *B. borealis*.
[9] ETP (Wade and Gerrodette 1993)
[10] Eastern temperate North Pacific (Whitehead 2002)
[11] California/Oregon/Washington (Carretta et al. 2010).
[12] This abundance estimate is mostly for *K. sima* but may also include some *K. breviceps*.
[13] ETP (Ferguson and Barlow 2001).
[14] This estimate includes all species of the genus *Mesoplodon* in the ETP (Ferguson and Barlow 2001).
[15] ETP (Ford 2002).
[16] This estimate is for *G. macrorhynchus* and *G. melas* in the ETP (Gerrodette and Forcada 2002)
[17] U.S. stock (Carretta et al. 2010)

[18] Galapagos Islands (Alava and Salazar 2006).
[19] Peru and Chile (Campagna 2008a).
[20] Peru and Chile (Campagna 2008b).
[21] Mexico (Gallo 1994 *in* Carretta et al. 2010).

Information on the occurrence, distribution, population size, and conservation status for each of the 27 cetacean species and 6 pinniped species that may occur in the proposed project area is presented in Table 2. The status of these species is based on the U.S. ESA, the IUCN Red List, the Convention on International Trade in Endangered Species (CITES), and NatureServe (an international network of biological inventories that provides conservation status ranks for Latin America).

Mysticetes

Humpback Whale (*Megaptera novaeangliae*)

The humpback whale is listed as ***Endangered*** under the U.S. ESA and ***Least concern*** on the 2010 IUCN Red List of Threatened Species (IUCN 2010), and is listed in CITES Appendix I (UNEP-WCMC 2009). The worldwide population of humpback whales is divided into various northern and southern ocean populations (Mackintosh 1965). Geographical overlap of these populations has been documented only off Central America (Acevedo and Smultea 1995; Rasmussen et al. 2004, 2007). The humpback whale is one of the most abundant cetaceans off the Pacific coast of Costa Rica during the winter breeding season of northern hemisphere humpbacks, and off the coasts of Ecuador, Columbia, and Panama during the winter breeding period for southern hemisphere humpbacks (e.g., Rasmussen et al. 2004; May-Collado et al. 2005, Félix and Haase 2005). The estimate of abundance for the California/Oregon/Washington humpback whale stock is 1392 (Carretta et al. 2010) and the estimated abundance for the southeast Pacific stock is ~2900 (Félix et al. 2005)

Humpback whales occur worldwide, migrating from tropical breeding areas to polar or sub-polar feeding areas (Jefferson et al. 2008). Although the humpback whale is considered mainly a coastal species, it often traverses deep pelagic areas while migrating (Clapham and Mattila 1990; Norris et al. 1999; Calambokidis et al. 2001). Some males occur in waters >3000 m deep and up to 57 km from the coast in the Caribbean (Swartz et al. 2003).

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

Rasmussen et al. (2007) reported 207 humpback whale sightings off Central America during surveys in the austral winters of 2001–2004. Based on eight years (1996–2003) of survey effort off Costa Rica from January to March and three years (2001–2003) off Panama, Rasmussen et al. (2004) reported 177 sightings. Calambokidis et al. (2010) recorded 56 sightings during a two-week survey along the Osa Peninsula, Costa Rica in January–February 2010. May-Collado et al. (2005) reported 186 sightings of 246 humpbacks in 1979–2001 off Costa Rica during January–March, all close to shore and concentrated around Osa Peninsula. Acevedo-Gutiérrez and Smultea (2005) reported sightings off Isla del Cocos in August 1992 and January 1993. Humpback whales were also observed off the coasts of Columbia, Ecuador and Peru, and occasionally in offshore waters >200 km from the coast (Félix and Haase 2005).

Eleven groups of 16 humpbacks were seen during an L-DEO seismic survey off Costa Rica and Nicaragua in November–December 2004 (Holst et al. 2005b). Two of these individuals were also recorded singing, a behavior associated predominantly with the winter breeding season. Small concentrations of humpbacks were seen in the same region later that winter in 2005 (J. Calambokidis, pers. comm. to LGL, Dec. 2005). Three sightings of individual humpback whales were observed during an L-DEO seismic program off Costa Rica and Nicaragua in February–March 2008 (Holst and Smultea 2008). No humpback whales were seen during L-DEO seismic programs in the Hess Deep ~1100 km west of the Galapagos Islands in July 2003 (Smultea and Holst 2003) or 1600–1950 km west of the proposed survey area in April–August 2008 (Hauser et al. 2008).

Systematic vessel-based surveys of the ETP have been conducted during July–December. No humpback whales were found in the proposed project region over a 10-year period by Ferguson and Barlow (2001) or by Jackson et al. (2008) in 2006. Humpback whales were reported in more coastal waters off the coast of Ecuador (Ferguson and Barlow 2001) and sightings were observed by Jackson et al. (2008) in the coastal waters of Costa Rica and Panama. One sighting was recorded near the study area in offshore waters north of the Galápagos Islands. Humpback whales are unlikely to occur in the planned offshore seismic survey areas between mid-October and mid-November.

Minke Whale (*Balaenoptera acutorostrata*)

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

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

The general distribution of minke whales includes the offshore waters of the study area (e.g., Reeves et al. 2002). However, minke whales are likely to be rare in the survey area. This species has been found off the coast of Costa Rica on occasion (Rodríguez-Herrera et al. 2002). No minke whales were found in the proposed project region during July–December surveys during 1986–1996 by Ferguson and Barlow (2001) or in 2006 by Jackson et al. (2008). Rasmussen et al. (2004) did not report seeing any minke whales in eight years of surveys (1996–2003) off Costa Rica or in 2001–2003 off Panama. May-Collado et al. (2005) also did not report any minkes based on compiled sightings off Costa Rica during 1979–2001, nor have minkes been reported among compiled strandings off Costa Rica (Rodríguez-Fonseca and Cubero-Pardo 2001).

One probable minke was observed off west-central Panama in waters <2000 m deep during an L-DEO seismic survey in November–December 2004 (Holst et al. 2005b). No minke whales were observed during L-DEO seismic surveys in the Hess Deep ~1100 km west of the Galapagos Islands in July 2003, off Costa Rica and Nicaragua in February–March 2008, or 1600–1950 km west of the proposed survey area in April–August 2008 (Smultea and Holst 2003; Holst and Smultea 2008; Hauser et al. 2008). Minke whales are unlikely to occur in the planned survey areas.

Bryde's Whale (*Balaenoptera edeni*)

Bryde's whale occurs in tropical and subtropical waters, generally between 40°N and 40°S (Jefferson et al. 2008). It is common throughout the ETP, with a concentration near the equator east of 110ºW, decreasing west of 140ºW (Lee 1993; Wade and Gerrodette 1993). Wade and Gerrodette (1993) estimated Bryde's whale population size in the ETP at 13,000, based on data collected during 1986–1990. This species has also been sighted off Columbia and Ecuador (Gallardo et al. 1983), and may occur around the Galápagos Islands (Clarke and Aguayo 1965 *in* Gallardo et al. 1983). The International Whaling Commission (IWC) recognizes a cross-equatorial or Peruvian stock of Bryde's whale (Donovan 1991).

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

Based on the SWFSC surveys and model used to calculate densities in the study area in § IV(3), Bryde's whale is the most common mysticete in the survey area. Off Costa Rica, May-Collado et al. (2005) reported at least 16 and possibly up to 24 sightings of at least 32 (possibly up to 43) Bryde's whales in 1979–2001; these numbers are uncertain because it is now surmised that early reports of Bryde's/sei whales in this region were most likely Bryde's whales. Both categories of sightings occurred from coastal to oceanic waters off Costa Rica. Rasmussen et al. (2004) reported one sighting of a Bryde's whale in January–March in eight years of surveys (1996–2003) off Costa Rica and from 2001 to 2003 off Panama. Jackson et al. (2008) also encountered two Bryde's whales near the study area during July–December 2006 surveys; one in the offshore waters of Ecuador and one in the offshore waters of northern Peru. One Bryde's whale stranding on the central Pacific coast at Playa Bandera was reported during 1966–1999 (Rodríguez-Fonseca and Cubero-Pardo 2001).

One Bryde's whale was sighted in transit to the L-DEO seismic survey area 1600–1950 km west of the proposed survey area in April–August 2008 (Hauser et al. 2008). No Bryde's whales were sighted during L-DEO seismic surveys off Costa Rica or Nicaragua in November–December 2004 or February–March 2008 (Holst et al. 2005b; Holst and Smultea 2008), or in the Hess Deep ~1100 km west of the Galápagos Islands in July 2003 (Smultea and Holst 2003).

Sei Whale (*Balaenoptera borealis*)

The sei whale is listed as ***Endangered*** under the U.S. ESA and on the 2010 IUCN Red List of Threatened Species (IUCN 2010), and is listed in CITES Appendix I (UNEP-WCMC 2009). Sei whale current status is generally uncertain (Horwood 1987) and the global population size is unknown but thought to be small.

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

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

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

Sei whales are likely to be very rare in the survey area. Neither Ferguson and Barlow (2001) or Jackson et al. (2008) positively identified sei whales in or near the proposed project area during surveys conducted during July–December. Similarly, Rasmussen et al. (2004) did not report sei whales in eight years of surveys off Costa Rica or Panama. No sei whales were detected during L-DEO seismic surveys off Costa Rica or Nicaragua in November–December 2004 or February–March 2008 (Holst et al. 2005b; Holst and Smultea 2008), in the Hess Deep ~1100 km west of the Galapagos Islands in July 2003 (Smultea and Holst 2003), or 1600–1950 km west of the proposed survey area in April–August 2008 (Hauser et al. 2008).

Fin Whale (*Balaenoptera physalus*)

The fin whale is listed as ***Endangered*** under the U.S. ESA and on the 2010 IUCN Red List of Threatened Species (IUCN 2010), and is listed in CITES Appendix I (UNEP-WCMC 2009). Based on 2001 and 2005 surveys, the California/Oregon/Washington Stock of fin whales was estimated at 2636 (Caretta et al. 2010).

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

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

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

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

No fin whales were detected during L-DEO seismic surveys off Costa Rica or Nicaragua in November–December 2004 or February–March 2008 (Holst et al. 2005b; Holst and Smultea 2008), in the Hess Deep ~1100 km west of the Galapagos Islands in July 2003 (Smultea and Holst 2003), or 1600–1950 km west of the proposed survey area in April–August 2008 (Hauser et al. 2008).

Blue Whale (*Balaenoptera musculus*)

The blue whale is listed as ***Endangered*** under the U.S. ESA and on the 2010 IUCN Red List of Threatened Species (IUCN 2010), and is listed in CITES Appendix I (UNEP-WCMC 2009). The world-wide population has been estimated at 15,000, with 10,000 in the Southern Hemisphere (Gambell 1976), and 3500 in the North Pacific Ocean (NMFS 1998). Blue whale calls monitored from the U.S. Navy Sound Surveillance System (SOSUS) and other offshore hydrophones suggest that separate populations occur in the eastern and western North Pacific (Stafford et al. 1999a, 1999b, 2001, 2007; Watkins et al. 2000; Stafford 2003). The blue whale population in the ETP in the summer/fall was estimated at 1415 (Wade and Gerrodette 1993).

The blue whale is widely distributed throughout most of the world's oceans, occurring in coastal, shelf, and pelagic waters (Jefferson et al. 2008), and are most often found in cool, productive waters where upwelling occurs (Reilly and Thayer 1990). Generally, blue whales are seasonal migrants between high latitudes in the summer, where they feed, and low latitudes in winter, where they mate and give birth (Lockyer and Brown 1981). Little is known about the movements and wintering grounds of the stocks (Miz-roch et al. 1984). Some individuals may stay in low or high latitudes throughout the year (Reilly and Thayer 1990; Watkins et al. 2000). Broad-scale acoustic monitoring indicates that blue whales of the Eastern North Pacific Stock may range from the eastern tropical Pacific Ocean along the coast of North America to Canada, and offshore at least 500 km (Stafford et al. 2001).

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

140 m and 7.8 min for foraging blue whales, and 68 m and 4.9 min for non-foraging individuals. Dives of up to 300 m were recorded for tagged blue whales (Calambokidis et al. 2003).

In the ETP, blue whales have been sighted near Costa Rica, particularly the Costa Rica Dome (CRD), at and near the Galápagos Islands, and along the coasts of Ecuador and northern Peru throughout the year (Aguayo 1974; Wade and Friedrichsen 1979; Donovan 1984; Reilly and Thayer 1990; Mate et al. 1999; Palacios 1999; Chandler and Calambokidis 2004; Palacios et al. 2005; Branch et al. 2006). Palacios (1999) reported that blue whales were distributed to the west and southwest of the Galápagos Islands where the water is enriched.

Reilly and Thayer (1990) suggested that blue whales that occur in the CRD may be migrant animals from the northern or southern hemispheres or they may be a resident population. Reilly and Thayer (1990) also suggested that the whales seen along the equator are likely part of the southeast Pacific population, which occupies the coastal shelf of South America and the Antarctic (Mackintosh 1966). However, the whales could also be resident in the area, exploiting food resources in the CRD and near the South American coastline (Mate et al. 1999; Palacios 1999). Based on call similarities, Stafford et al. (1999b) linked the whales near the CRD to the population that feeds off California at the same time of year. A recent satellite-tag study confirmed that some blue whales off California migrate south in the fall to an area west of the CRD at 9ºN; the area is considered an important winter feeding area for blue whales (Bailey et al. 2009).

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

The number of sightings of blue whales in the proposed project area is low, with sightings having only been reported off the coast of Costa Rica and near the coast of Ecuador as observed during surveys in July–December (Ferguson and Barlow 2001). May-Collado et al. (2005) reported three groups of four blue whales off Costa Rica based on compiled sightings from 1979–2001. Both sightings were in deep oceanic waters. Jackson et al. (2008) also sighted two blue whales near the study area during surveys in July–December 2006: one to the southeast of the Galápagos Islands and one ~400 km off the coast of central Peru.

No blue whales were detected during L-DEO seismic surveys off Costa Rica or Nicaragua in November–December 2004 or February–March 2008 (Holst et al. 2005b; Holst and Smultea 2008), in the Hess Deep ~1100 km west of the Galapagos Islands in July 2003 (Smultea and Holst 2003), or 1600–1950 km west of the proposed survey area in April–August 2008 (Hauser et al. 2008).

Odontocetes

Sperm Whale (*Physeter macrocephalus*)

The sperm whale is listed as ***Endangered*** under the U.S. ESA and as ***Vulnerable*** on the 2010 IUCN Red List of Threatened Species (IUCN 2010), and is listed in CITES Appendix I (UNEP-WCMC 2009). Wade and Gerrodette (1993) estimated sperm whale abundance in the ETP at 22,666. Whitehead (2002) updated that estimate to 26,053.

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

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

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

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

Sperm whales commonly occur in the proposed study area according to surveys conducted in July–December (Ferguson and Barlow 2001). Jackson et al. (2008) also recorded two sperm whale sightings in or near the study area during surveys in July–December 2006: one ~100 km off the coast of Ecuador and one in deep, offshore waters of the coast of central Peru.

Polacheck (1987) and Wade and Gerrodette (1993) reported that during surveys in the summer and fall, sperm whales were widely distributed in the ETP, although they were generally more abundant in deep "nearshore" waters than far offshore. May-Collado et al. (2005) reported sperm whale sightings primarily in deep offshore waters; sightings were concentrated off southeast Costa Rica, including waters near Isla del Cocos (May-Collado et al. 2005). Rasmussen et al. (2004) reported one sperm whale sighting in eight years of surveys (1996–2003) off Costa Rica and Panama.

Rodríguez-Fonseca and Cubero-Pardo (2001) reported that the sperm whale is the cetacean species with the highest frequency of strandings in Costa Rica, with a reported seven strandings on the Pacific coast during a 33-year period. Twenty sperm whale strandings were also reported off the coast of Ecuador between 1987 and 1994 (Haase and Félix 1994).

No sperm whales were detected between Puntarenas, Costa Rica, and southern El Salvador during an L-DEO seismic survey in November–December 2004, during which >3500 km of daytime visual effort and 5200 km of 24-h PAM (Passive Acoustic Monitoring) effort took place (Holst et al. 2005b). Similarly, no sperm whales were detected during L-DEO seismic surveys off Costa Rica or Nicaragua in February–March 2008 (Holst and Smultea 2008) or in the Hess Deep ~1100 km west of the Galapagos Islands in July 2003 (Smultea and Holst 2003). However, 5 sightings of 12 sperm whales, including 1 sighting of 7, were made during L-DEO seismic surveys 1600–1950 km west of the proposed survey area in April–August 2008 (Hauser et al. 2008).

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

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

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

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

Both *Kogia* species occur in the proposed survey area, although dwarf sperm whales are likely to be very rare and pygmy sperm whales are likely to be rare. Rodríguez-Fonseca (2001) reported the presence of *Kogia* sp. off Costa Rica, but only the dwarf sperm whale has been positively identified as occurring in that area (Ferguson and Barlow 2001; Jackson et al. 2008; May-Collado et al. 2005). Similarly, the dwarf sperm whale was the only confirmed *Kogia* species off Costa Rica based on sightings compiled from 1979 to 2001 by May-Collado et al. (2005). Most of the 34 groups of *Kogia* sp. occurred in offshore waters, with frequent sightings ~90–100 km southwest of the Osa Peninsula. Rodríguez-Fonseca and Cubero-Pardo (2001) reported a stranding of six *K. simus* in 1993 on the Pacific coast. Neither species of *Kogia* was reported in the survey area during July–December 2006 surveys (Jackson et al. 2008). However, Gerrodette reported at least three dwarf sperm whale sightings in or near the proposed survey area (Gerrodette et al. 1993).

No *Kogia* sp. were detected during L-DEO seismic surveys off Costa Rica and Nicaragua in November–December 2004 (Holst et al. 2005b) or in the Hess Deep ~1100 km west of the Galapagos Islands in July 2003 (Smultea and Holst 2003). One sighting of a dwarf sperm whale and one sighting of two pygmy sperm whales were observed off the coast of Costa Rica in waters ~2000 and 3500 m deep, respectively, during an L-DEO seismic survey off Costa Rica and Nicaragua in February–March 2008 (Holst and Smultea 2008), and one unidentified *Kogia* sp. was sighted during L-DEO seismic surveys 1600–1950 km west of the proposed survey area in April–August 2008 (Hauser et al. 2008).

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 high-latitude polar waters (Heyning 1989). There are an estimated 20,000 Cuvier's beaked whales in the ETP (Wade and Gerrodette 1993).

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

Cuvier's beaked whales are likely to be common in the survey area. During surveys conducted during July–December, Cuvier's beaked whales were only observed in the northern portion of the proposed study area (Ferguson and Barlow 2001). Jackson et al. (2008) encountered ziphiids near the study area, in waters near the coast of Costa Rica and ~100 km off the coast of Ecuador, during July–December 2006 surveys. Cuvier's beaked whale was the most frequent beaked whale identified to species off Costa Rica as reported by May-Collado et al. (2005) for 1979–2001. They reported that 14 of 47 groups of beaked whale sightings were Cuvier's beaked whales; an additional 15 groups were recorded as unidentified beaked whales. Beaked whales occurred primarily in offshore deep waters (May-Collado et al. 2005). Rodríguez-Fonseca (2001) identified the waters by Isla del Cocos, and Isla del Caño and the outer part of the Osa Peninsula, as two important areas off W Costa Rica for the species, although the study of May-Collado et al. (2005) "did not show patterns to support" the importance of Isla del Cocos for Cuvier's beaked whale.

No Cuvier's beaked whales or other beaked whales were detected during L-DEO seismic surveys off Costa Rica or Nicaragua in November–December 2004 or February–March 2008 (Holst et al. 2005b; Holst and Smultea 2008), in the Hess Deep ~1100 km west of the Galapagos Islands in July 2003 (Smultea and Holst 2003), or 1600–1950 km west of the proposed survey area in April–August 2008 (Hauser et al. 2008).

Longman's Beaked Whale / Tropical Bottlenose Whale (*Indopacetus pacificus*)

Longman's beaked whale, also known as the tropical bottlenose whale, is considered rare in the ETP. Although widespread throughout the tropical Pacific, the species is considered rare because of a scarcity of sightings despite a great deal of survey effort (Pitman et al. 1999). Until very recently, Longman's beaked whale was known only from two skulls (Pitman et al. 1987). Recent 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). 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). The estimate of abundance for Longman's beaked whale in the ETP is 291 (Ferguson and Barlow 2001).

These whales are thought to prefer warmer waters with temperatures >26ºC, and have been seen in the tropics every month of the year except June, indicating year-round residency (Pitman et al. 1999). Tropical bottlenose whales have been seen in groups of up to 100, with an average group size of 19.4 (MacLeod and D'Amico 2006). Pitman et al. (1999) reported a mean group size of 18.5 in the tropics; however, they also reported that group sizes were significantly smaller in the ETP, with an average of only 8.6. Dives last 18–25 min (Reeves et al. 2002).

Pitman et al. (1999) suggested that several sightings of *Hyperoodon* spp. in the ETP were actually misidentifications (e.g., Wade and Gerrodette 1993) and were, in fact, sightings of tropical bottlenose whales. In the ETP, most tropical bottlenose whale sightings have been made between 3ºN and 10ºN (Pitman et al. 1999). Kinzey et al. (2001) reported one sighting of *I. pacificus* in the ETP at about 135ºW. Jackson et al. (2008) also reported *I. pacificus* in the ETP well to the west of the proposed study area. No Longman's (or tropical bottlenose) beaked whales were reported by May-Collado et al. (2005) based on compiled sightings off Costa Rica from 1979–2001.

The species is very rare in the study area.

Mesoplodont Beaked Whales (*Mesoplodon* spp.)

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

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

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

Jackson et al. (2008) reported four sightings of *Mesoplodon* spp. near the northern portion of the study area during July–December surveys in 2006; two near the coast of Costa Rica and two in offshore waters north of the Galápagos Islands.

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

Pygmy Beaked Whale (M. peruvianus).— Information on the pygmy beaked whale is based on scattered sightings in the ETP and a small number of strandings (Jefferson et al. 2008). The pygmy beaked whale is thought to occur between latitudes of ~28°N and 30°S, from Baja California to Peru and Chile

(Urbán-Ramírez and Aurioles-Gamboa 1992; Pitman and Lynn 2001; Jefferson et al. 2008). Reyes et al. (1991) reported 10 records of this species in south-central Peru. Pitman and Lynn (2001) reported that the species may have been known previously as *Mesoplodon* sp. "A". The pygmy beaked whale is now believed to be widespread in the ETP, but concentrated off central Mexico (Pitman and Lynn 2001). Wade and Gerrodette (1993) reported several sightings for *M. peruvianus* as well as *Mesoplodon* sp. "A" in the ETP.

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

Ferguson and Barlow (2001) did not report any pygmy beaked whale sightings in the study area during 10 years of surveys conducted in July–December, but their "small beaked whale" category included pygmy and Blainville's beaked whales and *Mesoplodon* sp. "A"; the category was relatively common (1.0–9.9/1000 m^2) in the proposed study area. No pygmy (or *M.* sp "A") beaked whales were reported off Costa Rica by May-Collado et al. (2005) or Rodríguez-Fonseca and Cubero-Pardo (2001) based on compiled sightings from 1979–2001 and strandings from 1966–1999, respectively. Jackson et al. (2008) reported two sightings of *M. peruvianus* within the ETP, both to the northwest of the study area, during July–December surveys in 2006.

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

Jackson et al. (2008) reported four sightings of *Mesoplodon* spp. near the northern portion of the study area during July–December surveys in 2006; two near the coast of Costa Rica and two in offshore waters north of the Galápagos Islands. No ginkgo-toothed beaked whales were reported off Costa Rica by May-Collado et al. (2005) based on compiled sightings from 1979–2001, or by Rodríguez-Fonseca and Cubero-Pardo (2001) using stranding records from 1966–1999. However, May-Collado et al. (2005) documented 17 sightings of *Mesoplodon* spp. during that period.

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

The most commonly observed group size for this species is 1–2 individuals, with a maximum of 9 off Hawaii (Baird et al. 2004; Jefferson et al. 2008). MacLeod and D'Amico (2006) reported a mean group size of 3.5 (n = 31), and Ritter and Brederlau (1999) reported a mean group size of 3.4. The maximum known dive depth of tagged Blainville's beaked whales is 1408 m off Hawaii (Baird et al. 2006).

In the ETP, Blainville's beaked whales have been sighted in offshore as well as nearshore areas of Central and South America (Pitman et al. 1987; Pitman and Lynn 2001). As noted above, the species was included in the "small beaked whale" category of Ferguson and Barlow (2001), which was relatively common in the proposed study area. Off Costa Rica, May-Collado et al. (2005) reported one sighting of three Blainville's beaked whales in deep offshore waters based on compiled sightings from 1979 to 2001.

Rough-toothed Dolphin *(Steno bredanensis)*

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

Rough-toothed dolphins are generally seen in deep water and in shallower waters around islands. They are typically found in groups of 10–20 animals, but groups of up to 300 have been seen (Jefferson 2002). They are deep divers and can dive for up to 15 min (Reeves et al. 2002).

In the ETP, sightings of rough-toothed dolphins have been reported by Perrin and Walker (1975), Pitman and Ballance (1992), Wade and Gerrodette (1993), Kinzey et al. (1999, 2000, 2001), Ferguson and Barlow (2001), Jackson et al. (2008), and May-Collado et al. (2005). The mean group size is 15.46 (Ferguson et al. 2006b).

Rough-toothed dolphins are common in the proposed survey area. May-Collado et al. (2005) documented 28 sightings of 513 individuals based on sightings compiled off Costa Rica from 1979–2001. These sightings were distributed from nearshore to far offshore. Rasmussen et al. (2004) reported three sightings of rough-toothed dolphins in eight years of surveys (1996–2003) off Costa Rica and from 2001 to 2003 off Panama: one in each of 1998, 2000, and 2002. Jackson et al. (2008) also reported multiple sightings of rough-toothed dolphins off the coasts of Costa Rica and Panama, in both shallow and deep waters, during July–December surveys in 2006. Several sightings were within the northern portion of the proposed survey area.

No rough-toothed dolphins were detected during L-DEO seismic surveys off Costa Rica or Nicaragua in November–December 2004 or February–March 2008 (Holst et al. 2005b; Holst and Smultea 2008), in the Hess Deep ~1100 km west of the Galapagos Islands in July 2003 (Smultea and Holst 2003), or 1600–1950 km west of the proposed survey area in April–August 2008 (Hauser et al. 2008).

Bottlenose Dolphin (*Tursiops truncatus*)

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

There are two distinct bottlenose dolphin types: a shallow water type mainly found in coastal waters and a deepwater type mainly found in oceanic waters (Duffield et al. 1983; Hoelzel et al. 1998; Walker et al. 1999). The nearshore dolphins usually inhabit shallow waters along the continental shelf and upper slope, at depths <200 m (Davis et al. 1998). Klatsky et al. (2007) reported that offshore dolphins show a preference for water <2186 m deep. Bottlenose dolphins are reported to regularly dive to depths >450 m for periods of >5 min, and even down to depths of 600–700 m for up to 12 min (Klatsky et al. 2007). Bottlenose dolphins usually occur in groups of 2–20, although groups of >100 are occasionally seen in offshore areas (Shane et al. 1986; Jefferson et al. 2008). Off Costa Rica, May-Collado et al. (2005) reported a mean group size of 21.5 individuals based on sightings from 1979–2001. For the ETP, Ferguson et al. (2006b) reported a mean group size of 24.1 and Jackson et al. (2008) reported a mean group size of 24.2 (n = 149).

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

Bottlenose dolphins are very common in the proposed survey area; based on the SWFSC surveys and model used to calculate densities in the study area in § IV(3), they are the third-ranked species there. Jackson et al. (2008) reported sightings of bottlenose dolphins in all regions of the survey area, with the highest concentrations of sightings occurring off the coasts of Costa Rica and Panama. May-Collado et al. (2005) found this species concentrated primarily in coastal waters but also in offshore oceanic waters. Rasmussen et al. (2004) reported 49 sightings of bottlenose dolphins in eight years of surveys (1996–2003) off Costa Rica and from 2001 to 2003 off Panama. Three sightings of bottlenose whales were reported during a two-week survey off Costa Rica in January–February 2010 (Calambokidis et al. 2010). Smith and Whitehead (1999) reported that bottlenose dolphins were frequently seen near the Galápagos Islands. Rodríguez-Fonseca (2001) identified Isla del Cocos as one of four important areas in Pacific Costa Rican waters for the species.

Eight groups of 69 bottlenose dolphins and five groups of 19 bottlenose dolphins were identified off Costa Rica and Nicaragua during L-DEO seismic surveys in November–December 2004 and February–March 2008, respectively (Holst et al. 2005b; Holst and Smultea 2008). The majority of these bottlenose dolphin sightings occurred in relatively shallow waters <1000 m deep. None were observed during L-DEO seismic surveys in the Hess Deep ~1100 km west of the Galapagos Islands in July 2003 (Smultea and Holst 2003) or 1600–1950 km west of the proposed survey area in April–August 2008 (Hauser et al. 2008).

Pantropical Spotted Dolphin (*Stenella attenuata*)

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

There was an overall stock decline of spotted dolphins during 1960–1980 because of the purse-seine tuna fishery (Allen 1985). Gerrodette and Forcada (2005) reported that the population of offshore northeastern spotted dolphins has not yet recovered from the earlier population declines. For 1986–1990, Wade and Gerrodette (1993) reported a population estimate of 2.1 million based on data collected during 1986–1990. The abundance estimate of spotted dolphins in the ETP for 2006 was 857,884 (Gerrodette et al. 2008).

Wade and Gerrodette (1993) identified three stocks of spotted dolphins in the ETP: the coastal stock (*S. a. grafmani*) and two offshore (*S. a. attenuata*) stocks (the northeast and the west/south stock) However, recent genetic evidence suggests that there may be nine genetically distinct stocks of this species in coastal areas from Baja California south to Ecuador (Rosales and Escorza-Trefiño 2005). Spotted dolphins from the northeast offshore stock are most likely to occur in the proposed study area.

For the ETP, Ferguson et al. (2006b) reported mean group sizes of 131 and 186 for offshore and unidentified subspecies of pantropical spotted dolphins, respectively, and Gerrodette and Forcada (2005) estimated a mean group size of 114 for the offshore stock. Off Costa Rica, May-Collado et al. (2005) reported a mean group size of 29.4 based on sightings during 1979–2001.

Pantropical spotted dolphins are very common in the proposed survey area; based on the SWFSC surveys and model used to calculate densities in the study area (see § IV[3]), they are the fourth-ranked species there. Jackson et al. (2008) reported three sightings of pantropical spotted dolphins near the study area during July–December surveys in 2006. These sightings were in deep waters offshore from Columbia and Ecuador. The majority of pantropical spotted dolphin sightings during the 2006 survey were to the northwest of the proposed study area (Jackson et al. 2008). Rodríguez-Fonseca (2001) reported that the oceanic spotted dolphin was less common than the coastal spotted dolphin in Costa Rican waters. May-Collado et al. (2005) found this species concentrated primarily in coastal waters but also in offshore oceanic waters. Rasmussen et al. (2004) reported 381 sightings of spotted dolphins in eight years of surveys during 1996–2003 off Costa Rica and during 2001–2003 off Panama. Thirty-one sightings of spotted dolphins were also recorded by Calambokidis et al. (2010) during a two-week survey off Costa Rica in January–February 2010. Two spotted dolphin strandings on the Pacific coast were included in a list of strandings for Costa Rica during 1966–1999 (Rodríguez-Fonseca and Cubero-Pardo 2001).

Eight groups of >200 pantropical spotted dolphins and two groups of 290 pantropical spotted dolphins were identified off Costa Rica and Nicaragua during L-DEO seismic surveys in November–December 2004 and February–March 2008, respectively (Holst et al. 2005b; Holst and Smultea 2008). All of the sightings occurred in relatively shallow waters of <1000 m, with the majority occurring in waters <500 m deep. None were observed during an L-DEO seismic survey in the Hess Deep ~1100 km west of the Galapagos Islands in July 2003 (Smultea and Holst 2003), and 4 single spotted dolphins were sighted in transit to and from the L-DEO seismic survey areas 1600–1950 km west of the proposed survey area in April–August 2008 (Hauser et al. 2008).

Spinner Dolphin (*Stenella longirostris*)

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

In the ETP, three types of spinner dolphins have been identified and two of those are recognized as subspecies: the eastern spinner dolphin, *S. l. orientalis*, considered an offshore species, the Central American spinner, *S. l. centroamericana* (also known as the Costa Rican spinner), considered a coastal species in Costa Rica (Perrin 1990; Dizon et al. 1991), and the 'whitebelly' spinner, which is thought to be a hybrid of the eastern spinner and Gray's spinner (*S. l. longirostris*). Although there is a great deal of overlap between the ranges of eastern and whitebelly spinner dolphins, the eastern form generally occurs in the northeastern portion of the ETP, whereas the whitebelly spinner occurs in the southern portion of the ETP, ranging farther offshore (Wade and Gerrodette 1993; Reilly and Fiedler 1994). The Costa Rican spinner dolphin is typically seen within 150 km from shore (ACS 2007).

Spinner dolphins in the ETP tend to occur in large groups compared to most other cetaceans. Ferguson et al. (2006b) reported mean group sizes of 108.8, 82.5, and 147.7 for eastern, whitebelly, and unidentified spinner dolphins, respectively, and Gerrodette and Forcada (2005) reported a mean group size of 112 for the eastern stock. Off Costa Rica, May-Collado et al. (2005) reported a mean group size of 97 based on sightings compiled from 1979–2001. Spinner dolphins usually dive to 600 m or deeper to feed (Perrin and Gilpatrick 1994).

Both whitebelly and eastern spinner dolphins commonly occur in the proposed survey area. Polacheck (1987) reported that the highest encounter rates in the ETP occurred southwest of the Galápagos Islands, but spinner dolphins are thought to be rare visitors to the Galápagos Islands (Smith and Whitehead 1999). Rasmussen et al. (2004) reported only one sighting of spinner dolphins in eight years of surveys from 1996 to 2003 off Costa Rica and from 2001 to 2003 off Panama. May-Collado et al. (2005) reported spinner dolphins primarily in oceanic waters off Costa Rica during 1979–2001, with small numbers in coastal waters. Jackson et al. (2008) reported only one sighting of eastern spinner dolphins near the study area during July–December surveys in 2006. This sighting was in offshore waters almost halfway between Costa Rica and the Galápagos Islands.

During L-DEO seismic surveys off Costa Rica and Nicaragua, three groups of ~1350 spinner dolphins (two groups off NW Costa Rica and one off Nicaragua, all in waters <1000 m deep) and two groups of 90 spinner dolphins (one off Costa Rica in waters ~3500 m deep and one off Nicaragua in waters ~200 m deep) were identified in November–December 2004 and February–March 2008, respectively (Holst et al. 2005b; Holst and Smultea 2008). None were observed during an L-DEO seismic survey in the Hess Deep ~1100 km west of the Galapagos Islands in July 2003 (Smultea and Holst 2003), and a single spinner dolphin was sighted during L-DEO seismic surveys 1600–1950 km west of the proposed survey area in April–August 2008 (Hauser et al. 2008).

Striped Dolphin (*Stenella coeruleoalba*)

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

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

The striped dolphin is expected to be one of the most abundant cetaceans in the proposed project area; based on the SWFSC surveys and model used to calculate densities in the study area (see § IV[3]), they are the second-ranked species there. Jackson et al. (2008) reported sightings of striped dolphins in all regions of the study area during July–December surveys in 2006, with the highest concentrations of sightings occurring off the coasts of Costa Rica and Panama. Multiple sightings were also recorded in offshore waters off Ecuador and northern Peru, and to the southwest of the Galápagos Islands (Jackson et al. 2008). Mayo-Collado et al. (2005) reported this species nearly exclusively from oceanic waters.

During L-DEO seismic surveys off Costa Rica and Nicaragua, one sighting of 40 striped dolphins (off the coast of Costa Rica in waters ~2000 m deep) was made in February–March 2008 (Holst and Smultea 2008), but none were observed in November–December 2004 (Holst et al. 2005b). None were observed during L-DEO seismic surveys in the Hess Deep ~1100 km west of the Galapagos Islands in July 2003 (Smultea and Holst 2003) or 1600–1950 km west of the proposed survey area in April–August 2008 (Hauser et al. 2008).

Fraser's Dolphin (*Lagenodelphis hosei*)

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

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

Fraser's dolphin may occasionally occur in the proposed study area, although its expected numbers are low based on available data. Pitman and Ballance (1992) reported its occurrence in the ETP, and Smith and Whitehead (1999) reported one sighting of 300 individuals in the Galápagos Islands. Off Costa Rica, May-Collado et al. (2005) reported only one sighting of 158 Fraser's dolphins during 1979–2001. Rodríguez-Fonseca (2001) identified Isla del Cocos as an important area in Pacific Costa Rican waters for the species. No Fraser's dolphins were reported during July–December ETP surveys in 2006 (Jackson et al. 2008) or during eight years of surveys from 1996 to 2003 off Costa Rica and from 2001 to 2003 off Panama (Rasmussen et al. 2004).

No Fraser's dolphins were detected during L-DEO seismic surveys off Costa Rica or Nicaragua in November–December 2004 or February–March 2008 (Holst et al. 2005b; Holst and Smultea 2008), in the Hess Deep ~1100 km west of the Galapagos Islands in July 2003 (Smultea and Holst 2003), or 1600–1950 km west of the proposed survey area in April–August 2008 (Hauser et al. 2008).

Short-beaked Common Dolphin (*Delphinus delphis*)

Common dolphins are found in tropical and temperate oceans around the world (Evans 1994). There are two species of common dolphin, the more coastal long-beaked dolphin (*Delphinus capensis*) and the more offshore short-beaked dolphin (*D. delphis*). The short-beaked common dolphin is widely distributed compared to the long-beaked common dolphin (Heyning and Perrin 1994). Only the short-beaked common dolphin is expected to occur in the ETP. Three stocks of *D. delphis* are recognized in the ETP: northern, central, and southern (Perrin et al. 1985; Perryman and Lynn 1993). Individuals present in the proposed study area would likely be from the central and southern stocks.

Gerrodette et al. (2005) reported an abundance estimate for short-beaked common dolphins of 1.1 million for 2003. However, abundance estimates of common dolphins have fluctuated from <1 million to >3 million from 1986 to 2000 (Gerrodette and Forcada 2002). The abundance estimate for 2006 was 3,127,203 (Gerrodette et al. 2008).

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

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

This species is expected to be the most abundant cetacean in the study area; based on the SWFSC surveys and model used to calculate densities in the study area (see § IV[3]), they are the first-ranked species there, more than three times more abundant than the second-ranked species. Jackson et al. (2008) reported numerous sightings of common dolphins near the study area during July–December surveys in 2006, with the highest concentrations of sightings occurring off the coasts of Costa Rica and Panama. Three sightings were also recorded to the south of the Galápagos Islands (Jackson et al. 2008). May-Collado et al. (2005) reported 82 sightings of 17,875 individuals during 1979–2001 off Costa Rica, mostly in oceanic waters. Rasmussen et al. (2004) reported one sighting of common dolphins in eight years of surveys from 1996 to 2003 off Costa Rica and from 2001 to 2003 off Panama.

During L-DEO seismic surveys off Costa Rica and Nicaragua, one group of 45 common dolphins (off Costa Rica in waters ~2000 m deep) and six groups of 360 common dolphins (all off Costa Rica in waters ≥2000 m deep) were identified in November–December 2004 and February–March 2008, respectively (Holst et al. 2005b; Holst and Smultea 2008). None were observed during an L-DEO seismic survey in the Hess Deep ~1100 km west of the Galapagos Islands in July 2003 (Smultea and Holst 2003), and 2 groups of 50 were sighted during L-DEO seismic surveys 1600–1950 km west of the proposed survey area in April–August 2008 (Hauser et al. 2008).

Risso's Dolphin (*Grampus griseus*)

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

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

Risso's dolphins are very common in the proposed survey area; based on the SWFSC surveys and model used to calculate densities in the study area (see § IV[3]), they are the fifth-ranked species there. Eight Risso's dolphins were reported during July–December ETP surveys in 2006 (Jackson et al. 2008). Six of these sightings were reported off the coasts of Costa Rica and Panama, at various depths, and two were reported in offshore waters between Ecuador and the Galápagos Islands. No Risso's dolphins were reported during eight years of surveys from 1996 to 2003 off Costa Rica and from 2001 to 2003 off Panama (Rasmussen et al. 2004).

During L-DEO seismic surveys off Costa Rica and Nicaragua, one sighting of 25 Risso's dolphins (off the coast of Costa Rica in waters ~2000 m deep) was made in November–December 2004 (Holst et al. 2005b), but none were observed in February–March 2008 (Holst and Smultea 2008). None were observed during an L-DEO seismic survey in the Hess Deep ~1100 km west of the Galapagos Islands in July 2003 (Smultea and Holst 2003), and 1 group of 20 was sighted during L-DEO seismic surveys 1600–1950 km west of the proposed survey area in April–August 2008 (Hauser et al. 2008).

Melon-headed Whale (*Peponocephala electra*)

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

Melon-headed whales are oceanic and occur in offshore areas (Perryman 2002), as well as around oceanic islands. Mullin et al. (1994) reported that they are usually sighted in water >500 m deep, and away from the continental shelf. Melon-headed whales tend to travel in groups of 100–500, but have also been seen in groups of 1500–2000. Ferguson et al. (2006b) reported the mean group size in the ETP as 257.7.

Off Costa Rica, May-Collado et al. (2005) reported two sightings of 445 animals in the period 1979–2000. Three melon-headed whale strandings occurred on the Pacific coast during 1966–1999; >200 individuals stranded at Nicoya Peninsula in 1976, and two individual strandings occurred on the northern coast in 1970 (Rodríguez-Fonseca and Cubero-Pardo 2001). No melon-headed whales were reported near the proposed study area during July–December ETP surveys in 2006 (Jackson et al. 2008) or during eight years of surveys from 1996 to 2003 off Costa Rica and from 2001 to 2003 off Panama (Rasmussen et al. 2004).

During L-DEO seismic surveys off Costa Rica and Nicaragua, two sightings of 55 melon-headed whales were reported off the coast of Costa Rica in waters >3000 m deep in February–March 2008 (Holst and Smultea 2008). None were observed there in November–December 2004 (Holst et al. 2005b), or during L-DEO seismic surveys in the Hess Deep ~1100 km west of the Galapagos Islands in July 2003 (Smultea and Holst 2003) and 1600–1950 km west of the proposed survey area in April–August 2008 (Hauser et al. 2008).

Pygmy Killer Whale (*Feresa attenuata*)

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

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

Pygmy killer whales are uncommon in the study area. Jackson et al. (2008) reported one sighting of pygmy killer whales in the study area, about 200 km south of the coast of Panama, during July–December surveys in 2006. However, none were reported during eight years of surveys from 1996 to 2003 off Costa Rica and from 2001 to 2003 off Panama (Rasmussen et al. 2004). Off Costa Rica, May-Collado et al. (2005) also reported no sightings of this species in 1979–2000. There has been a report of a stranding on the coast of Ecuador (Félix et al. 1995).

During L-DEO seismic surveys off Costa Rica and Nicaragua, one sighting of 10 pygmy killer whales (~150 km off the coast of Costa Rica) was reported in February–March 2008 (Holst and Smultea 2008), but none were observed in November–December 2004 (Holst et al. 2005b). None were observed during an L-DEO seismic survey in the Hess Deep ~1100 km west of the Galapagos Islands in July 2003 (Smultea and Holst 2003), and 2 groups of 28 were sighted 1600–1950 km west of the proposed survey area in April–August 2008 (Hauser et al. 2008).

False Killer Whale (*Pseudorca crassidens*)

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

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

False killer whales are uncommon in the proposed study area. Jackson et al. (2008) reported one sighting in the study area, to the southwest of the Galápagos Islands, during July–December surveys in 2006. Off Costa Rica, May-Collado et al. (2005) reported nine sightings of 253 animals in 1979–2000. Martínez-Fernandez et al. (2005) observed four groups off Costa Rica during monthly strip-transect surveys during December 2004–June 2005. Rasmussen et al. (2004) reported eight sightings of false killer whales in eight years of surveys (1996–2003) off Costa Rica and in 2001–2003 off Panama. Rodríguez-Fonseca (2001) identified Isla del Cocos as one of four important areas in Pacific Costa Rican waters for the species, although the study of May-Collado et al. (2005) “did not show patterns to support” the importance of the island.

During L-DEO seismic surveys off Costa Rica and Nicaragua, one sighting of 12 false killer whales (off the coast of Nicaragua in waters <2000 m deep) in November–December 2004 (Holst et al. 2005b), but none were observed in February–March 2008 (Holst and Smultea 2008). None were observed during L-DEO seismic surveys in the Hess Deep ~1100 km west of the Galapagos Islands in July 2003 (Smultea and Holst 2003) or 1600–1950 km west of the proposed survey area in April–August 2008 (Hauser et al. 2008).

Killer Whale (*Orcinus orca*)

The killer whale is cosmopolitan and globally abundant; it has been observed in all oceans of the world (Ford 2002). Killer whales are segregated socially, genetically, and ecologically into three distinct groups: resident, transient, and offshore animals. Offshore whales do not appear to mix with the other types of killer whales (Black et al. 1997; Dahlheim and Heyning 1999). The abundance of killer whales in the ETP was estimated at 8500 (Ford 2002).

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

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

Killer whales are uncommon in the study area. Jackson et al. (2008) reported four sighting of killer whales near the study area during July–December surveys in 2006; one sighting was ~100 south of Panama and the other three sightings were in the offshore waters of central Peru, to the southwest of the Galápagos Islands. Off Costa Rica, May-Collado et al. (2005) reported seven sightings of 25 animals in offshore oceanic waters in 1979–2000. Rasmussen et al. (2004) reported three sightings in eight years of surveys (1996–2003) off Costa Rica and in 2001–2003 off Panama. A group of 20–22 was seen preying on a blue whale calf in the CRD in 2003, ~230 km west of Nicaragua (Gilpatrick et al. 2005).

No killer whales were detected during L-DEO seismic surveys off Costa Rica or Nicaragua in November–December 2004 or February–March 2008 (Holst et al. 2005b; Holst and Smultea 2008), in the Hess Deep ~1100 km west of the Galapagos Islands in July 2003 (Smultea and Holst 2003), or 1600–1950 km west of the proposed survey area in April–August 2008 (Hauser et al. 2008).

Short-finned Pilot Whale (*Globicephala macrorhynchus*)

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

Pilot whales have a wide distribution throughout the ETP, but are most abundant in cold waters where upwelling occurs (Wade and Gerrodette 1993). Polacheck (1987) reported that encounter rates for pilot whales in the ETP were highest inshore; offshore concentrations may also occur, but at lower densities. Pilot whales are usually seen in groups of 20–90, although groups of several hundred are also seen (Olson and Reilly 2002; Jefferson et al. 2008). For the ETP, Wade and Gerrodette (1993) and Ferguson et al. (2006b) reported a mean group size of 18, and Jackson et al. (2008) reported a mean group size of 18.0 (n = 57). Off Costa Rica, May-Collado et al. (2005) reported a mean group size of 14.2. Pilot whales outfitted with time-depth recorders dove to depths of up to 828 m, although most of their time was spent above depths of 7 m (Heide-Jørgensen et al. 2002). The species' maximum recorded dive depth is 971 m (Baird pers. comm. *in* DoN 2005).

Short-finned pilot whales are common in the proposed survey area. Jackson et al. (2008) reported numerous sightings of short-finned pilot whales in the study area during July–December surveys in 2006, with the highest concentrations of sightings occurring off the coasts of Costa Rica, Panama, and Peru at various depths, including deep oceanic waters. May-Collado et al. (2005) reported 68 sightings of 967 animals off Costa Rica in 1979–2001; sightings were made primarily in offshore oceanic waters, but a fair number also occurred in neritic waters.

During L-DEO seismic surveys off Costa Rica and Nicaragua, four group of 30 short-finned pilot whales (off Costa Rica and Nicaragua) and three groups of 26 common dolphins (one off Costa Rica in waters <2000 m deep and two off Nicaragua in waters ~3500 m deep) were identified in November–December 2004 and February–March 2008, respectively (Holst et al. 2005b; Holst and Smultea 2008). None were observed during an L-DEO seismic survey in the Hess Deep ~1100 km west of the Galapagos Islands in July 2003 (Smultea and Holst 2003), and there were 12 sightings of 106 short-finned pilot whales in and during transit to L-DEO seismic survey areas 1600–1950 km west of the proposed survey area in April–August 2008 (Hauser et al. 2008).

Pinnipeds

Six species of pinnipeds are known to occur within the ETP: the California sea lion (*Zalophus californianus*), South American sea lion (*Otaria flavescens*), Galápagos sea lion (*Zalophus wollebaeki*), Galápagos fur seal (*Arctocephalus galapagoensis*), Guadalupe fur seal (*A. townsendi*), and South American fur seal (*A. australis*). Of the six species, four have the potential to occur within the survey area, although any occurrence is likely to be rare as they are mainly coastal species. The ranges of the other two species, the Guadalupe fur seal and the California sea lion, are considerably north of the proposed survey area; Guadalupe fur seals occur only off California and Baja California, and California sea lions are distributed from southern Mexico north to southwestern Canada, although the species has been documented off the coast of Costa Rica on several occasions (Acevedo-Gutiérrez 1994, 1996; Cubero-Pardo and Rodríguez 2000; Rodríguez-Herrera et al. 2002). Although encounters with the species are possible in the proposed study area, it is unlikely that they would be seen there because their rarity that far south of their normal ranges.

Galápagos sea lions and Galápagos fur seals, both listed as ***Endangered*** on the 2010 IUCN Red List of Threatened Species (IUCN 2010) and listed in CITES Appendix II (UNEP-WCMC 2009), occur around the Galápagos Islands. However, Galápagos sea lions are seen occasionally along the coasts of Colombia and Ecuador and as far north as Isla del Coco, Costa Rica, an island 500 km southwest of Costa Rica (Acevedo-Gutiérrez 1994; Capella et al. 2002; Palacios 1996b; Palacios et al. 1997). A few Galápagos fur seals have also been reported along the coast of South America (D. Palacios, Oregon State University, pers. comm. to LGL Ltd.). Galápagos fur seals are not known to occur in Costa Rican waters (Rodríguez-Fonseca 2001). Jackson et al. (2008) did not encounter any Galápagos sea lions or fur seals during surveys in the ETP. Similarly, Galápagos sea lions or fur seals were not encountered during L-DEO seismic surveys in the ETP (Smultea and Holst 2003; Holst et al. 2005b; Holst and Smultea 2008; Hauser et al. 2008). Based on available survey data, it is unlikely that these two species would occur in the survey area, although encounters could occur, especially in areas in or close to the Galápagos Islands EEZ.

South American sea lions and South American fur seals are distributed along the coast of South America. The northernmost breeding colony of South American sea lions occurs on the Peruvian coast (Vaz-Ferreira 1981), but vagrant individuals have been seen along the coast of Colombia (Capella et al. 2002) and as far north as Panama (Méndez and Rodriguez 1984). The northernmost sighting of the South American fur seal was recorded off the Colombian coast (Capella et al. 2002). Jackson et al. (2008) did not encounter either of these species in offshore waters of the proposed survey area, but did encounter South American seal lions near the Peruvian coast. South American sea lions and fur seals were not encountered during L-DEO seismic surveys in the ETP (Smultea and Holst 2003; Holst et al. 2005b; Holst and Smultea 2008; Hauser et al. 2008). Campagna et al. (2001) used satellite tracking to examine the foraging behaviour of lactating females and pre-breeding males in the southwest Atlantic Ocean. Although mean foraging trips covered an average of 206 km in the case of females and 591 km in the case of males, tagged animals remained on the continental shelf and never ventured in waters deeper than 150 m. As the survey area is mainly well offshore of their most common coastal habitat, sightings in the study area are not expected, although rare encounters could occur.

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.

SIO requests an IHA pursuant to Section 101 (a) (5) (D) of the MMPA for incidental take by harassment during its planned seismic surveys in the ETP during October–November 2010.

The operations outlined in § I have the potential to take marine mammals by harassment. Sounds will be generated by the GI airguns used during the surveys, two echosounders, and general vessel operations. "Takes" by harassment potentially will result when marine mammals near the activities are exposed to the pulsed sounds generated by the seismic sources or echosounders. The effects will depend on the species of cetacean or pinniped, the behavior of the animal at the time of reception of the stimulus, and received level of the sound (see § VI/VII). Disturbance reactions are likely by some of the marine mammals in the general vicinity of 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 MAY 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 Sections 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 Sections 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 Section VII. A more comprehensive review of the relevant background information appears in Appendix A of the Environmental Assessment (EA) that supports this IHA application. That Appendix is similar to corresponding parts of previous EAs and associated IHA applications concerning other L-DEO seismic surveys since 2003, updated in 2009.
- Then we discuss the potential impacts of operations by SIO's multibeam echosounder and sub-bottom profilers.
- Finally, we estimate the numbers of marine mammals that could be affected by the proposed activity in the ETP during October–November 2010. This section includes a description of the rationale for SIO's estimates of the potential numbers of harassment "takes" during the planned survey, as called for in Section 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). With the possible exception of some cases of temporary threshold shift in harbor seals and perhaps some other seals, 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 A (3) of the supporting 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 A (5) of the EA. That is often true even in cases when the pulsed sounds must be readily audible to the animals based on measured received levels and the hearing sensitivity of that mammal group. Although various baleen whales, toothed whales, and (less frequently) pinnipeds have been shown to react behaviorally to airgun pulses under some conditions, at other times mammals of all three types have shown no overt reactions. In general, pinnipeds usually seem to be more tolerant of exposure to airgun pulses than are cetaceans, with the relative responsiveness of baleen and toothed whales being variable.

Masking

Masking effects of pulsed sounds (even from large arrays of airguns) on marine mammal calls and other natural sounds are expected to be limited, although there are very few specific data on this. Because of the intermittent nature and low duty cycle of seismic pulses, animals can emit and receive sounds in the relatively quiet intervals between pulses. However, in 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 sperm whales 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 A (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, and on ringed seals. Less detailed data are available for some other species of baleen whales, small toothed whales, and sea otters, but for many species there are no data on responses to marine seismic surveys.

Baleen Whales.—Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to pulses from large arrays of airguns at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, as reviewed in Appendix A (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 pulses in the 160–170 dB re 1 μPa_{rms} range 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 4.5 to 14.5 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 A (5) of the EA have shown that some species of baleen whales, notably bowhead and humpback whales, at times show strong avoidance at received levels lower than 160–170 dB re 1 μPa_{rms}.

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

Humpback whales on their summer feeding grounds in southeast Alaska did not exhibit persistent avoidance when exposed to seismic pulses from a 1.64-L (100-in^3) airgun (Malme et al. 1985). Some humpbacks seemed “startled” at received levels of 150–169 dB re 1 μPa. Malme et al. (1985) concluded that there was no clear evidence of avoidance, despite the possibility of subtle effects, at received levels up to 172 re 1 μPa on an approximate rms basis.

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

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

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

Various species of *Balaenoptera* (blue, sei, fin, and minke whales) have occasionally been seen in areas ensonified by airgun pulses (Stone 2003; MacLean and Haley 2004; Stone and Tasker 2006), and calls from blue and fin whales have been localized in areas with airgun operations (e.g., McDonald et al. 1995; Dunn and Hernandez 2009). Sightings by observers on seismic vessels off the United Kingdom from 1997 to 2000 suggest that, during times of good sightability, sighting rates for mysticetes (mainly fin and sei whales) were similar when large arrays of airguns were shooting vs. silent (Stone 2003; Stone and Tasker 2006). However, these whales tended to exhibit localized avoidance, remaining significantly further (on average) from the airgun array during seismic operations compared with non-seismic periods (Stone and Tasker 2006). In a study off Nova Scotia, Moulton and Miller (2005) found little difference in sighting rates (after accounting for water depth) and initial sighting distances of balaenopterid whales when airguns were operating vs. silent. However, there were indications that these whales were more likely to be moving away when seen during airgun operations. Similarly, ship-based monitoring studies of blue, fin, sei and minke whales offshore of Newfoundland (Orphan Basin and Laurentian Sub-basin) found no more than small differences in sighting rates and swim directions during seismic vs. non-seismic periods (Moulton et al. 2005, 2006a,b).

Data on short-term reactions by cetaceans to impulsive noises are not necessarily indicative of long-term or biologically significant effects. It is not known whether impulsive sounds affect reproductive rate or distribution and habitat use in subsequent days or years. However, gray whales have continued to migrate annually along the west coast of North America with substantial increases in the population over recent years, despite intermittent seismic exploration (and much ship traffic) in that area for decades (Appendix A *in* Malme et al. 1984; Richardson et al. 1995; Angliss and Allen 2009). The western Pacific gray whale population did not seem affected by a seismic survey in its feeding ground during a previous year (Johnson et al. 2007). Similarly, bowhead whales have continued to travel to the eastern Beaufort Sea each summer, and their numbers have increased notably, despite seismic exploration in their summer and autumn range for many years (Richardson et al. 1987; Angliss and Allen 2009).

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 A of the EA have been reported for toothed whales. However, there are recent systematic studies on sperm whales (e.g., Gordon et al. 2006; Madsen et al. 2006; Winsor and Mate 2006; Jochens et al. 2008; Miller et al. 2009). There is an increasing amount of information about responses of various odontocetes to seismic surveys based on monitoring studies (e.g., Stone 2003; Smultea et al. 2004; Moulton and Miller 2005; Bain and Williams 2006; Holst et al. 2006; Stone and Tasker 2006; Potter et al. 2007; Hauser et al. 2008; Holst and Smultea 2008; Weir 2008; Barkaszi et al. 2009; Richardson et al. 2009).

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

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

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

Most studies of sperm whales exposed to airgun sounds indicate that the sperm whale shows considerable tolerance of airgun pulses (e.g., Stone 2003; Moulton et al. 2005, 2006a; Stone and Tasker 2006; Weir 2008). In most cases the whales do not show strong avoidance, and they continue to call (see Appendix A 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). In any event, it is likely that most beaked whales would also show strong avoidance of an approaching seismic vessel, although this has not been documented explicitly.

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

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

Pinnipeds.—Pinnipeds are not likely to show a strong avoidance reaction to the airgun array. Visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds, and only slight (if any) changes in behavior—see Appendix A (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). Even if reactions of any pinnipeds that might be encountered in the present study area are as strong as those evident in the telemetry study, reactions are expected to be confined to relatively small distances and durations, with no long-term effects on pinniped individuals or populations. As for delphinids, a ≥170 dB disturbance criterion is considered appropriate for pinnipeds, which tend to be less responsive than many cetaceans.

Additional details on the behavioral reactions (or the lack thereof) by all types of marine mammals to seismic vessels can be found in Appendix A (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, and TTS has been demonstrated and studied in certain captive odontocetes and pinnipeds exposed to strong sounds (reviewed in Southall et al. 2007). However, there has been no specific documentation of TTS let alone permanent hearing damage, i.e., permanent threshold shift (PTS), in free-ranging marine mammals exposed to sequences of airgun pulses during realistic field conditions. Current

NMFS policy regarding exposure of marine mammals to high-level sounds is that cetaceans and pinnipeds should not be exposed to impulsive sounds with received levels ≥180 and 190 dB re 1 μPa_{rms}, respectively (NMFS 2000). Those criteria have been used in establishing the exclusion (=shut-down) zones planned for the proposed seismic survey. However, those criteria were established before there was any information about minimum received levels of sounds necessary to cause auditory impairment in marine mammals. As discussed in Appendix A (6) of the EA and summarized here,

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

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

Several aspects of the planned monitoring and mitigation measures for this project are designed to detect marine mammals occurring near the airguns, and to avoid exposing them to sound pulses that might, at least in theory, cause hearing impairment (see § XI, "MITIGATION MEASURES"). In addition, many cetaceans and (to a limited degree) pinnipeds 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 could (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, permanent threshold shift (PTS), and non-auditory physical effects.

Temporary Threshold Shift (TTS).—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). Given the available data, the received energy level of a single seismic pulse (with no frequency weighting) might need to be ~186 dB re 1 $\mu Pa^2 \cdot s$ (i.e., 186 dB SEL or ~196–201 dB re 1 μPa_{rms}) in order to produce brief, mild TTS[2]. Exposure to several strong seismic pulses that each have received levels near 190 dB re 1 μPa_{rms} might result in cumulative exposure of ~186 dB SEL and thus slight TTS in a small odontocete, assuming the TTS threshold is (to a first approximation) a function of the total received pulse energy. The distances from the *Melville*'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 15 m (Table 1). For an odontocete closer to the surface, the maximum radius with ≥190 dB re 1 μPa_{rms} would be smaller.

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

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

---

[2] If the low frequency components of the watergun sound used in the experiments of Finneran et al. (2002) are downweighted as recommended by J. Miller et al. (2005) and Southall et al. (2007) using their Mmf-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).

(Southall et al. 2007), which would be equivalent to a single pulse with received level ~181–186 dB re 1 μPa_{rms}, or a series of pulses for which the highest rms values are a few dB lower. Corresponding values for California sea lions and northern elephant seals are likely to be higher (Kastak et al. 2005).

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

Permanent Threshold Shift (PTS).—When PTS occurs, there is physical damage to the sound receptors in the ear. In severe cases, there can be total or partial deafness, while in other cases, the animal or human 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 A (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, p. 441-4) estimated that received levels would need to exceed the TTS threshold by at least 15 dB for there to be risk of PTS. Thus, for cetaceans they estimate that the PTS threshold might be an M-weighted SEL (for the sequence of received pulses) of ~198 dB re 1 $\mu Pa^2 \cdot s$ (15 dB higher than the TTS threshold for an impulse), 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) estimated that the PTS threshold could be a cumulative M_{pw}-weighted SEL of ~186 dB re 1 $\mu Pa^2 \cdot s$ in the harbor seal exposed to impulse sound. The PTS threshold for the California sea lion and northern elephant seal the PTS threshold would probably be higher, given the higher TTS thresholds in those species.

Southall et al. (2007) also note that, regardless of the SEL, there is concern about the possibility of PTS if a cetacean or pinniped received one or more pulses with peak pressure exceeding 230 or 218 dB re

1 μPa (peak), respectively. Thus, PTS might be expected upon exposure of cetaceans to either SEL ≥198 dB re 1 $\mu Pa^2 \cdot s$ or peak pressure ≥230 dB re 1 μPa. Corresponding proposed dual criteria for pinnipeds (at least harbor seals) are ≥186 dB SEL and ≥ 218 dB peak pressure (Southall et al. 2007). These estimates are all first approximations, given the limited underlying data, assumptions, species differences, and evidence that the "equal energy" model is not be entirely correct. A peak pressure of 230 dB re 1 μPa (3.2 bar · m, 0-pk) would only be found within less than a meter from a GI gun, which has a peak pressure of 224.6 dB re 1μPa · m. 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, ramp ups, 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.

Strandings and Mortality.—Marine mammals close to underwater detonations of high explosives can be killed or severely injured, and the auditory organs are especially susceptible to injury (Ketten et al. 1993; Ketten 1995). However, explosives are no longer used for marine seismic research or commercial seismic surveys, and have been replaced entirely by airguns or related non-explosive pulse generators. Airgun pulses are less energetic and have slower rise times, and there is no specific evidence that they can cause serious injury, death, or stranding even in the case of large airgun arrays. However, the association of mass strandings of beaked whales with naval exercises and, in one case, an L-DEO seismic survey (Malakoff 2002; Cox et al. 2006), has raised the possibility that beaked whales exposed to strong "pulsed" sounds may be especially susceptible to injury and/or behavioral reactions that can lead to stranding (e.g., Hildebrand 2005; Southall et al. 2007). Appendix A (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. However, there are increasing indications that gas-bubble disease (analogous to "the bends"), induced in supersaturated tissue by a behavioral response to acoustic exposure, could be a pathologic mechanism for the strandings and mortality of some deep-diving cetaceans exposed to sonar. The evidence for this remains circumstantial and associated with exposure to naval mid-frequency sonar, not seismic surveys (Cox et al. 2006; Southall et al. 2007).

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

There is no conclusive evidence of cetacean strandings or deaths at sea as a result of exposure to seismic surveys, but a few cases of strandings in the general area where a seismic survey was ongoing have led to speculation concerning a possible link between seismic surveys and strandings. Suggestions that there was a link between seismic surveys and strandings of humpback whales in Brazil (Engel et al. 2004) were not well founded (IAGC 2004; IWC 2007). In 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 (Gentry 2002) and direct noise-induced bubble formation (Crum et al. 2005) are not expected in the case of an impulsive source like an airgun array. If seismic surveys disrupt diving patterns of deep-diving species, this might perhaps result in bubble formation and a form of "the bends", as speculated to occur in beaked whales exposed to sonar. However, there is no specific evidence of this upon exposure to airgun pulses.

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

Possible Effects of Multi-beam Echosounder Signals

The Kongsberg EM 122 12-kHz MBES will be operated from the source vessel at some times during the planned study. Information about this equipment was provided in § I. Sounds from the MBES are very short pings, occurring for 2–15 ms once every 5–20 s, depending on water depth; at depths>2600 m, FM chirp pulses up to 100 ms long are used. Most of the energy in the sound pulses emitted by this MBES is at frequencies near 12 kHz, and the maximum source level is 242 dB re 1 μPa_{rms}. The beam is narrow (1º) 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 100-ms chirp (or two pulses or chirps 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 longer pulse durations 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 Navy sonar. During SIO'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 echosounder signals (12 kHz) do not overlap with the predominant frequencies in the calls, which would avoid any significant masking.

Behavioral Responses

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

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

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

Hearing Impairment and Other Physical Effects

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

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

Possible Effects of Sub-bottom Profiler Signals

A sub-bottom profiler will be operated from the source vessel during the planned study. Details about this equipment were provided in § I. Sounds from the sub-bottom profiler are very short pulses, occurring for 6–24 ms once every second or so. Most of the energy in the sound pulses emitted by the sub-bottom profiler is at 3.5 kHz, and the beam is directed downward. The sub-bottom profiler on the R/V *Melville* has a maximum source level of 211 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, and—even for an SBP more powerful than those on the R/V *Melville*—if the animal was in the area, it would have to pass the transducer at close range and in order to be subjected to sound levels that could cause TTS.

Masking

Marine mammal communications will not be masked appreciably by the sub-bottom profiler signals given their directionality and the brief period when an individual mammal is likely to be within their beams. Furthermore, in the case of most baleen whales, the sub-bottom profiler 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 sub-bottom profilers likely would be similar to those for other pulsed sources if received at the same levels. However, the pulsed signals from the sub-bottom profilers 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 sub-bottom profilers produce 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 sub-bottom profilers are 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 sub-bottom profilers. 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 sub-bottom profiler.

Numbers of Marine Mammals that could be Exposed to Various Received Sound Levels

All anticipated takes would be “takes by harassment” as described in § I, involving temporary changes in behavior. The mitigation measures to be applied will minimize the possibility of injurious takes. (However, as noted earlier and in Appendix A of the EA, 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 consideration of the number of marine mammals that could be disturbed appreciably by ~5475 km of seismic surveys in the ETP. The main sources of distributional and numerical data used in deriving the estimates are described in the next subsection.

It is assumed that, during simultaneous operations of the seismic sources and the other sources, any marine mammals close enough to be affected by the MBES or SBPs would already be affected by the seismic sources. However, whether or not the seismic sources 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 SBPs given their characteristics (e.g., narrow downward-directed beam) and other considerations described in § I and VII(b and c), above. Such reactions are not considered to constitute “taking” (NMFS 2001). Therefore, no additional allowance is included for animals that might be affected by sound sources other than the seismic sources.

Basis for Estimating Exposure to Various Received Sound Levels

Extensive systematic ship-based surveys have been conducted by NMFS SWFSC for marine mammals in the ETP. We used densities from two sources: (1) SWFSC has recently developed habitat modeling as a method to estimate cetacean densities on a finer spatial scale than traditional line-transect analyses by using a continuous function of habitat variables, e.g., sea surface temperature, depth, distance from shore, and prey density (Barlow et al. 2009). For the ETP, the models are based on data from 12 SWFSC ship-based cetacean and ecosystem assessment surveys conducted during July–December from

1986 to 2006. The models have been incorporated into a web-based Geographic Information System (GIS) developed by Duke University's Department of Defense Strategic Environmental Research and Development Program (SERDP) team in close collaboration with the SWFSC SERDP team (Read et al. 2009). We used the GIS to obtain densities for the 11 cetacean species in the model in each 8 areas: the four proposed survey areas shown in Figure 1, and corridors 1° wide and centered on the tracklines between the survey areas and from the southernmost survey area to the EEZ of Peru. Those areas included 4061 km of survey effort. (2) For species sighted in SWFSC surveys whose sample sizes were too small to model density, we used densities from the surveys conducted during summer and fall 1986–1996, as summarized by Ferguson and Barlow (2001). Densities were calculated from Ferguson and Barlow (2003) for 5° x 5° blocks that include the proposed survey areas and corridors: Blocks 139, 159, 160, 200, 201, 202, 212, 213, and 219. Those blocks included 27,275 km of survey effort in Beaufort sea states 0–5, and 2564 km of survey effort in Beaufort sea states 0–2. Densities were obtained for an additional 8 species that were sighted in one or more of those blocks.

For two endangered species for which there are only unconfirmed sightings in the region, the sei and fin whales, arbitrary low densities (equal to the density of the species with the lowest calculated density) were assigned.

Oceanographic conditions, including occasional El Niño and La Niña events, influence the distribution and numbers of marine mammals present in the ETP, resulting in considerable year-to-year variation in the distribution and abundance of many marine mammal species (e.g., Escorza-Treviño 2009). Thus, for some species the densities derived from recent surveys may not be representative of the densities that will be encountered during the proposed seismic survey.

Table 3 gives the estimated densities for each cetacean species likely to occur in the study area, i.e., species for which we obtained or assigned densities. The densities have been corrected for both detectability and availability bias by the authors. Detectability bias is associated with diminishing sightability with increasing lateral distance from the trackline [$f(0)$]. Availability bias refers to the fact that there is less-than-100% probability of sighting an animal that is present along the survey trackline, and it is measured by $g(0)$.

There is some uncertainty about the representativeness of the data and the assumptions used in the calculations below. However, the approach used here is believed to be the best available approach. Also, to provide some allowance for these uncertainties, "maximum estimates" as well as "best estimates" of the densities present and numbers potentially affected have been derived. Best estimates of density are the mean densities weighted by effort in the eight survey areas or corridors from Read et al. (2009) or the nine 5° x 5° blocks from Ferguson and Barlow (2001, 2003), whereas maximum estimates of density are the highest densities in any of those survey areas/corridors or blocks.

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

It should be noted that the following estimates of exposures to various sound levels assume that the surveys will be fully completed; in fact, the planned number of line-kilometers has been increased by 25% to accommodate lines that may need to be repeated, equipment testing, etc. As is typical during 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

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

	Density (#/1000 km^2)		
Species[1]	**Best (mean)**	**Maximum**	**Source**
Mysticetes			
Bryde's whale	0.53	1.15	Read et al. (2009)
Sei whale	*0.01*	*0.01*	Arbitrary low
Fin whale	*0.01*	*0.01*	Arbitrary low
Blue whale	*0.13*	*0.23*	Read et al. (2009)
Odontocetes			
Sperm whale	*3.95*	*15.20*	Ferguson and Barlow (2003)
Pygmy and dwarf sperm whales	0.01	0.02	Read et al. (2009)
Cuvier's beaked whale	1.83	3.70	Ferguson and Barlow (2003)
Mesoplodon spp.	0.21	0.37	Read et al. (2009)
Rough-toothed dolphin	1.60	2.34	Read et al. (2009)
Bottlenose dolphin	15.14	23.09	Read et al. (2009)
Pantropical spotted dolphin	12.43	22.53	Read et al. (2009)
Spinner dolphin	3.81	5.74	Read et al. (2009)
Striped dolphin	35.23	53.67	Read et al. (2009)
Fraser's dolphin	1.03	5.60	Ferguson and Barlow (2003)
Short-beaked common dolphin	143.21	242.80	Read et al. (2009)
Risso's dolphin	10.21	37.40	Ferguson and Barlow (2003)
Melon-headed Whale	2.80	9.30	Ferguson and Barlow (2003)
Pygmy killer whale	0.60	1.80	Ferguson and Barlow (2003)
False killer whale	0.39	2.10	Ferguson and Barlow (2003)
Killer whale	0.85	4.00	Ferguson and Barlow (2003)
Short-finned pilot whale	6.29	11.74	Read et al. (2009)

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

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 expose to 160- or 170-dB re 1 μPa$_{rms}$ sounds are precautionary, and probably overestimate the actual numbers of marine mammals that might be involved. These estimates assume that there will be no weather, equipment, or mitigation delays, which is highly unlikely.

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

Number of Cetaceans that could be Exposed to ≥160 dB.—The number of different individuals that could be exposed to GI-airgun sounds with received levels ≥160 dB re 1 μPa$_{rms}$ on one or more occasions can be estimated by considering the total marine area that would be within the 160-dB radius around the operating seismic source on at least one occasion, along with the expected density of animals in the area. The proposed seismic lines do not run parallel to each other in close proximity, which minimizes the number of times an individual mammal may be exposed during the survey; in this case, an individual could be exposed 1.01 times on average.

The numbers of different individuals potentially exposed to ≥160 dB re 1 μPa_{rms} were calculated by multiplying the expected species density, either "mean" (i.e., best estimate) or "maximum", times the anticipated area to be ensonified to that level during GI-airgun operations.

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

Applying the approach described above, ~4340 km^2 would be within the 160-dB isopleth on one or more occasions during the surveys, not including the 25% contingeny added before calculating estimated numbers exposed. Because this approach does not allow for turnover in the mammal populations in the study area during the course of the survey, the actual number of individuals exposed may be underestimated, although the conservative (i.e., probably overestimated) line-kilometer distances used to calculate the area may offset this. Also, the approach assumes that no cetaceans will move away or toward the trackline as the R/V *Melville* approaches in response to increasing sound levels prior to the time the levels reach 160 dB. Another way of interpreting the estimates that follow is that they represent the number of individuals that are expected (in the absence of a seismic program) to occur in the waters that will be exposed to ≥160 dB re 1 μPa_{rms}.

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

The best estimate of the number of individual cetaceans that could be exposed to seismic sounds with received levels ≥160 dB re 1 μPa_{rms} during the survey is 1304 (Table 4). That total includes 22 ***endangered*** whales: 1 blue whale (0.05%), and 21 sperm whales (0.08%) (Table 4). Most (97.2%) of the cetaceans potentially exposed are delphinids; short-beaked common, striped, pantropical spotted, bottlenose, and Risso's dolphins and short-finned pilot whales are estimated to be the most common species in the area, with best estimates of 777 (0.02% of the regional population), 191 (0.02%), 67 (0.01%), 82 (0.02%), 55 (0.05%), and 34 (0.01%) exposed to ≥160 dB re 1 μPa_{rms}, respectively. However, a more meaningful estimate is the one for sound levels ≥170 dB (see below).

Number of Delphinids that could be Exposed to ≥170 dB.—The 160-dB criterion, on which the preceding estimates are based, was derived from studies of baleen whales. Odontocete hearing at low frequencies is relatively insensitive, and delphinids generally appear to be more tolerant of strong low-frequency sounds than are many baleen whales. As summarized in Appendix A (5) of the EA, delphinids commonly occur within distances where received levels would be expected to exceed 160 dB re 1 μPa_{rms}. There is no generally accepted alternative "take" criterion for delphinids and Dall's porpoises exposed to airgun sounds. However, the estimates in this subsection assume that only those individuals exposed to

TABLE 4. Estimates of the possible numbers of different individuals that might be exposed, during SIO's proposed seismic survey in ETP in October–November 2010. The proposed sound source consists of a pair of 45-in3 GI airguns. Received levels of seismic sounds are expressed in dB re 1 µPa (rms, averaged over pulse duration), consistent with NMFS' practice. Not all marine mammals will change their behavior when exposed to these sound levels, but some may alter their behavior when levels are lower (see text). Delphinids are unlikely to react to levels below 170 dB. Species in italics are listed under the ESA as endangered or threatened. The column of numbers in boldface shows the numbers of "takes" for which authorization is requested.

	Number of Individuals Exposed to Sound Levels >160 dB (>170 dB, Delphinids)					
	Best Estimate[1]					
Species	**Number**		**% of Regional Pop'n[2]**	**Maximum Estimate[1]**		**Requested Take Authorization**
Balaenopteridae						
Bryde's whale	*3*		0.02	6		**3**
Sei whale	*0*		*NA*	*0*		***0***
Fin whale	*0*		*0.00*	*0*		***0***
Blue whale	*1*		*0.05*	*1*		***2***
Physeteridae						
Sperm whale	*21*		*0.08*	*82*		***21***
Pygmy/dwarf sperm whales	0		0.00	0		**0**
Ziphiidae						
Cuvier's beaked whale	10		0.05	20		**10**
Mesoplodon sp. (unidentified)	1		<0.01	2		**1**
Delphinidae						
Rough-toothed dolphin	9	(3)	0.01	13	(4)	**15**
Bottlenose dolphin	82	(26)	0.02	125	(39)	**82**
Pantropical spotted dolphin	67	(21)	0.01	122	(38)	**131**
Spinner dolphin	21	(6)	<0.01	31	(10)	**109**
Striped dolphin	191	(60)	0.02	291	(92)	**191**
Fraser's dolphin	6	(2)	<0.01	30	(10)	**440**
Short-beaked common dolphin	777	(244)	0.02	1317	(414)	**777**
Risso's dolphin	55	(17)	0.05	203	(64)	**55**
Melon-headed Whale	15	(5)	0.03	50	(16)	**258**
Pygmy killer whale	3	(1)	0.01	10	(3)	**30**
False killer whale	2	(1)	0.01	11	(4)	**11**
Killer whale	5	(1)	0.05	22	(7)	**5**
Short-finned pilot whale	34	(11)	0.01	64	(20)	**34**

[1] Best and maximum estimates are based on densities from Table 3, and therefore takes are not anticipated for humpback, minke, and Longman's beaked whale.

[2] Regional population size estimates are from Table 2; NA means not available.

≥170 dB re 1 µPa$_{rms}$, on average, would be affected sufficiently to be considered "taken by harassment". ("On average" means that some individuals might react significantly upon exposure to levels somewhat <170 dB, but others would not do so even upon exposure to levels somewhat >170 dB.) The area ensonified by levels ≥170 dB was determined (as described above for levels ≥160 dB) and was multiplied by the marine mammal density in order to obtain best and maximum estimates.

The area ensonified by levels ≥170 dB was estimated to be 1365 km^2 (as described above for levels ≥160 dB), and the estimated area, including overlap, is 1377 km^2. Thus, an average individual marine mammal could be exposed to ≥170 dB slightly more than once during the survey. The best and maximum estimates of the numbers of delphinids that could be exposed to ≥170 dB during the surveys are 399 and 720, respectively (Table 4), and the corresponding estimates for the short-beaked common dolphin are 244 and 414 (Table 4). The estimates are based on the predicted 170-dB radii around the seismic source to be used during the study and are considered to be more realistic estimates of the number of individual delphinids that could be affected.

Conclusions

The proposed seismic project will involve towing a pair of GI airguns that introduce pulsed sounds into the ocean, along with, at times, simultaneous operation of an MBES and an SBP. Routine vessel operations, other than the proposed seismic 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 § VII(b and c), 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 low.

Odontocete reactions to seismic pulses, or at least the reactions of delphinids and Dall’s porpoises, are expected to extend to lesser distances than are those of mysticetes. Odontocete low-frequency hearing is less sensitive than that of mysticetes, and delphinids are often seen from seismic vessels. In fact, there are documented instances of dolphins approaching active seismic vessels. However, delphinids as well as some other types of odontocetes sometimes show avoidance responses and/or other changes in behavior near operating seismic vessels.

Taking into account the mitigation measures that are planned (see § XI), effects on cetaceans are generally expected to be limited to avoidance of the area around the seismic operation and short-term changes in behavior, falling within the MMPA definition of “Level B harassment”. Furthermore, the estimated numbers of animals potentially exposed to sound levels sufficient to cause appreciable disturbance are generally low percentages of the regional population sizes. The best estimate of the number of individuals that would be exposed to sounds ≥160 dB re 1 μPa_{rms} represent, for all species, <0.1% of the regional populations. For only one species (the long-beaked common dolphin), >1% of the regional populations were estimated to be exposed (Table 4).

Varying estimates of the numbers of marine mammals that could be exposed to strong seismic sounds during the proposed program have been presented, depending on the specific exposure criteria (≥160 or ≥170 dB) and density criterion used (best or maximum). The requested “take authorization” for each species is based on the estimated best number of individuals that could be exposed to ≥160 dB re 1 μPa_{rms}. That figure likely overestimates (in most cases by a large margin) the actual number of animals that will be exposed to and will react to the seismic sounds. The reasons for that conclusion are outlined above. The relatively short-term exposures are unlikely to result in any long-term negative consequences for the individuals or their populations.

The many cases of apparent tolerance by cetaceans of seismic exploration, vessel traffic, and some other human activities show that co-existence is possible. Mitigation measures such as controlled speed, course alternation, look outs, non-pursuit, shut downs when marine mammals are seen within defined ranges, and special measures for species of particular concern should further reduce short-term reactions, and avoid or minimize any auditory effects. In all cases, the effects are expected to be short-term, with no lasting biological consequence.

Pinnipeds.—It is not expected that any pinnipeds would occur in the study area.

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.

Costa Rica, Panama, Ecuador, and Peru are members of the International Whaling Commission; Columbia is not a member (IWC 2010). None of those nations are whaling countries that take part in commercial whaling. However, subsistence whaling of several species of small cetaceans, including the bottlenose dolphin, takes place in territorial coastal waters of Peru (Read et al. 1998). This hunt is mainly for human consumption and uses gill nets, purse seines, and harpoons. Read et al. (1998) estimated that approximately 10,000 dolphins and porpoises were landed in Peru in 1985. Because the seismic surveys are in offshore waters, 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 surveys 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 § VI/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 very limited (see Appendix C 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 potentially could 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. 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 aspect of potential impacts relates to how exposure to seismic survey sound affects marine fish populations and their viability, including their availability to fisheries.

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

Pathological Effects

The potential for pathological damage to hearing structures in fish depends on the energy level of the received sound and the physiology and hearing capability of the species in question (see Appendix C of the EA). For a given sound to result in hearing loss, the sound must exceed, by some specific 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 is unknown; however, it likely depends 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 valid papers with proper experimental methods, controls, and careful pathological investigation implicating sounds produced by actual seismic survey airguns with 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 fishes from the Mackenzie River Delta. This study found that broad whitefish (*Coregonus nasus*) that received a sound exposure level of 177 dB re 1 $\mu Pa^2 \cdot s$ showed no hearing loss. During both studies, the repetitive exposure to sound was greater than would have occurred during a typical seismic survey. However, the substantial low-frequency energy produced by the airgun arrays [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).

Except for these two studies, at least with airgun-generated sound treatments, most contributions rely on rather subjective assays such as fish "alarm" or "startle response" or changes in catch rates by fishers. These observations are important in that they attempt to use the levels of exposures that are likely to be encountered by most free-ranging fish in actual survey areas. However, the associated sound stimuli are often poorly described, and the biological assays are varied (Hastings and Popper 2005).

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

Some studies have reported, some equivocally, that mortality of fish, fish eggs, or larvae can occur close to seismic sources (Kostyuchenko 1973; Dalen and Knutsen 1986; Booman et al. 1996; Dalen et al. 1996). Some of the reports claimed seismic effects from treatments quite different from actual seismic survey sounds or even reasonable surrogates. 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; McCauley et al. 2000a, 2000b). 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 C of the EA).

Behavioral Effects

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

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

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

Effects on Invertebrates

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

Pathological Effects

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

Some studies have suggested that seismic survey sound has a limited pathological impact on early developmental stages of crustaceans (Pearson et al. 1994; Christian et al. 2003; DFO 2004). However, the impacts appear to be either temporary or insignificant compared to what occurs under natural conditions. Controlled field experiments on adult crustaceans (Christian et al. 2003, 2004; DFO 2004) and adult cephalopods (McCauley et al. 2000a,b) exposed to seismic survey sound have not resulted in any significant pathological impacts on the animals. It has been suggested that exposure to commercial seismic survey activities has injured giant squid (Guerra et al. 2004), but there is no evidence to support such claims.

Physiological Effects

Physiological effects refer mainly to biochemical responses by marine invertebrates to acoustic stress. Such stress potentially could affect invertebrate populations by increasing mortality or reducing reproductive success. 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). 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).

Because of the reasons noted above, the operations are not expected to cause significant impacts on habitats used by marine mammals, or on the food sources that marine mammals use.

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 effects of the planned activity on marine mammal habitats and food resources are expected to be negligible, as described above. 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.

During the proposed survey, marine mammals will be distributed according to their habitat preferences, in pelagic waters with depths >1000 m in the vicinity of offshore islands. Concentrations of marine mammals and/or marine mammal prey species are not expected in or near the proposed study area, and there are no critical feeding, breeding, or migrating areas for any of the species that are found there at the time of the proposed survey.

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 at the various sites 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, seismic operations will be conducted in accordance with regulations by the National Marine Fisheries Service (NMFS) under the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA), including obtaining permission for incidental harassment or incidental 'take' of marine mammals and other endangered species. The proposed seismic activities will take place in International Waters and the EEZs of Costa Rica, Panama, Colombia, and Ecuador.

The following subsections provide more detailed information about the monitoring and mitigation measures that are an integral part of the planned activities. The procedures described here are based on protocols used during previous SIO 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).

Vessel-based observers will watch for marine mammals near the seismic sources when they are in use. Mitigation and monitoring measures proposed to be implemented for the proposed seismic survey have been developed and refined in cooperation with NMFS during previous SIO and L-DEO seismic studies and associated EAs, IHA applications, and IHAs. The mitigation and monitoring measures described herein represent a combination of the procedures required by past IHAs for other SIO and L-DEO projects. The measures are described in detail below.

The number of individual animals expected to be approached closely during the proposed activity will be small in relation to regional population sizes. With the proposed monitoring and shut-down provisions (see below), any effects on individuals are expected to be limited to behavioral disturbance. That is expected to have negligible impacts on the species and stocks.

The following subsections provide more detailed information about the mitigation measures that are an integral part of the planned activity.

Proposed Exclusion Zones

Received sound levels have been modeled by Lamont-Doherty Earth Observatory of Columbia University (L-DEO) for a number of airgun configurations, including two 45-in^3 Nucleus G. Guns, in relation to distance and direction from the airguns (Fig. 2). The model does not allow for bottom interactions, and is most directly applicable to deep water. Based on the modeling, estimates of the maximum distances from the GI airguns where sound levels of 190, 180, 170, and 160 dB re 1 μPa (rms) are predicted to be received in deep (>1000-m) water are shown in Table 1. Because the model results are for G. Guns, which have more energy than GI airguns of the same size, those distances overestimate the distances for the 45-in^3 GI airguns.

Empirical data concerning the 180-, 170-, and 160-dB distances have been acquired based on measurements during the acoustic verification study conducted by L-DEO in the northern Gulf of Mexico from 27 May to 3 June 2003 (Tolstoy et al. 2004). Although the results are limited, the data showed that radii around the airguns where the received level would be 180 dB re 1 μPa (rms), the safety criterion applicable to cetaceans (NMFS 2000), vary with water depth. Similar depth-related variation is likely in the 190-dB distances applicable to pinnipeds. Correction factors were developed for water depths 100–1000 m and <100 m. The proposed survey will occur in depths ~1000–4800 m, so the correction factors for shallow water are not relevant here. All of seismic operations will be in depths >1000 m.

The empirical data indicate that, for ***deep water*** (>1000 m), the L-DEO model tends to overestimate the received sound levels at a given distance (Tolstoy et al. 2004). However, to be precautionary pending acquisition of additional empirical data, it is proposed that safety radii during airgun operations in deep water will be the values predicted by L-DEO's model (Table 1). Therefore, the assumed 180- and 190-dB radii are 40 m and 10 m, respectively.

The seismic source will be shut down immediately when cetaceans or sea turtles are detected within or about to enter the 180-dB re 1 μPa_{rms} radius, or when pinnipeds are detected within or about to enter the 190-dB re 1 μPa_{rms} radius. The 180- and 190-dB shut-down criteria are consistent with guidelines listed for cetaceans and pinnipeds, respectively, by NMFS (2000) and other guidance by NMFS.

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

Mitigation During Operations

Mitigation measures that will be adopted will include (1) vessel speed or course alteration, provided that doing so will not compromise operational safety requirements, (2) GI-gun shut down within calculated exclusion zones, (3) ramp-up procedures. Although power-down procedures are often standard operating practice for seismic surveys, they will not be used here because powering down from two airguns to one airgun would make only a small difference in the 180- or 190-dB radius—probably not enough to allow continued one-airgun operations if a mammal or turtle came within the safety radius for two airguns.

Speed or Course Alteration

If a marine mammal or turtle is detected outside the EZ but is likely to enter it based on relative movement of the vessel and the animal, then if safety and scientific objectives allow, the vessel speed and/or course will be adjusted to minimize the likelihood of the animal entering the EZ. Major course and speed adjustments are often impractical when towing long seismic streamers and large source arrays, but are possible in this case because only a small source and short streamers will be used.

Shut-down Procedures

If a marine mammal or turtle is detected outside the exclusion zone but is likely to enter the exclusion zone, and if the vessel's speed and/or course cannot be changed to avoid having the animal enter the exclusion zone, the seismic source will be shut down before the animal is within the exclusion zone. Likewise, if a mammal or turtle is already within the safety zone when first detected, the seismic source will be shut down immediately.

Following a shut down, seismic activity will not resume until the marine mammal or turtle has cleared the exclusion zone. The animal will be considered to have cleared the exclusion zone if it

- is visually observed to have left the exclusion zone, or
- has not been seen within the zone for 15 min in the case of small odontocetes and pinnipeds, or

- has not been seen within the zone for 30 min in the case of mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, and beaked whales, or
- the vessel has moved outside the exclusion zone for turtles, i.e., i.e., <1 min based on the length of time it would take the vessel to leave the modeled exclusion zones of 40 m with speeds of 11–18.5 km/h.

Ramp-up Procedures

A ramp-up procedure will be followed when the GI airguns begin operating after a specified period without GI airgun operations. It is proposed that, for the present cruise, this period would be ~1–2 min. This period is based on the 180-dB radii for the GI airguns (see Table 1) in relation to the planned speed of the *Melville* while shooting (see above).

Ramp up will begin with a single GI airgun (45 in^3). The second GI airgun (45 in^3) will be added after 5 min. During ramp up, the MMOs will monitor the exclusion zone, and if marine mammals or turtles are sighted, a shut down will be implemented as though both GI airguns were operational.

If the complete exclusion zone 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. If one GI airgun has operated, 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 GI airgun and could move away if they choose. A ramp up from a shut down may occur at night, but only where the safety radius is small enough to be visible. Ramp up of the GI airguns will not be initiated if a sea turtle or marine mammal is sighted within or near the applicable exclusion zones during 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 International Waters and the EEZs of Costa Rica, Panama, Colombia, and Ecuador, 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...

SIO 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 Incidental Harassment Authorization.

SIO's proposed Monitoring Plan is described below. SIO 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. SIO 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

Vessel-based marine mammal visual observers (MMVOs) will be based on board the seismic source vessel, and they will watch for marine mammals and turtles near the vessel during seismic operations. MMVOs will also watch for marine mammals and turtles near the seismic vessel for at least 30 minutes prior to the start of seismic operations after an extended shutdown. When feasible, MMVOs will also make observations during daytime periods when the seismic system is not operating for comparison of animal abundance and behavior. Based on MMVO observations, the seismic source will be shut down when marine mammals are observed within or about to enter a designated exclusion zone (EZ) [see Section (e) below]. The EZ is a region in which a possibility exists of adverse effects on animal hearing or other physical effects.

MMVOs will be appointed by the academic institution conducting the research cruise, with NMFS Office of Protected Resources concurrence. At least one MMVO will monitor the EZ during seismic operations. MMVOs will normally work in shifts of 4-hour duration or less. The vessel crew will also be instructed to assist in detecting marine mammals and turtles.

Standard equipment for marine mammal observers will be 7 x 50 reticule binoculars and optical range finders. At night, night-vision equipment will be available. The observers will be in wireless communication with ship's officers on the bridge and scientists in the vessel's operations laboratory, so they can advise promptly of the need for avoidance maneuvers or seismic source shut down.

MMVO Data and Documentation

MMVOs will record data to estimate the numbers of marine mammals and turtles exposed to various received sound levels and to document apparent disturbance reactions or lack thereof. Data will be used to estimate numbers of animals potentially 'taken' by harassment (as defined in the MMPA).

They will also provide information needed to order a shutdown of the seismic source when a marine mammal or sea turtles 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 seismic source 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, as well as information regarding seismic source shutdown, will be recorded in a standardized format. Data accuracy will be verified by the MMVOs at sea, and preliminary reports will be prepared during the field program and summaries forwarded to the operating institution's shore facility and to NSF weekly or more frequently. MMVO observations will provide the following information:

1. The basis for decisions about shutting down the seismic source.
2. Information needed to estimate the number of marine mammals potentially 'taken by harassment'. These data will be reported to NMFS and/or USFWS per terms of MMPA authorizations or regulations.
3. Data on the occurrence, distribution, and activities of marine mammals and turtles in the area where the seismic study is conducted.
4. Data on the behavior and movement patterns of marine mammals and turtles seen at times with and without seismic activity.

A report will be submitted to NMFS 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 be submitted to NMFS, providing 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 amount and nature of potential "take" 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.

Scripps Institution of Oceanography will coordinate the planned marine mammal monitoring program associated with the seismic survey in the ETP (as summarized in § XI and XIII) with other parties that may have interest in the area and/or be conducting marine mammal studies in the same region during the proposed seismic survey. On behalf of SIO, the U.S. State Department will seek authorization from those governments for clearance to work in their EEZs.

XV. LITERATURE CITED

Marine Mammals and Acoustics

Acevedo, A. and M.A. Smultea. 1995. First records of humpback whales including calves at Golfo Dulce and Isla del Coco, Costa Rica, suggesting geographical overlap of northern and southern hemisphere populations. **Mar. Mamm. Sci**. 11(4):554-560.

Acevedo-Gutiérrez, A. 1994. First record of a sea lion, *Zalophus californianus*, at Isla del Coco, Costa Rica. **Mar. Mamm. Sci.** 10(4):484-485.

Acevedo-Gutierrez, A. 1996. Lista de mamíferos marinos en Golfo Dulce e Isla del Coco, Costa Rica. **Rev. Biol.Trop.** 44:933-934.

Acevedo, A. and M.A. Smultea. 1995. First records of humpback whales including calves at Golfo Dulce and Isla del Coco, Costa Rica, suggesting geographical overlap of northern and southern hemisphere populations. **Mar. Mamm. Sci**. 11(4):554-560.

ACS (American Cetacean Society). 2007. American Cetacean Society fact sheet: spinner dolphin, S*tenella longirostris*. Accessed on 7 May 2010 at http://www.acsonline.org/factpack/SpinnerDolphin.htm

Aguayo, A.L. 1974. Baleen whales off continental Chile. p. 209-217 *In:* W.E. Schevill (ed.), The whale problem: a status report. Harvard University Press, Cambridge, MA.

Aguayo, A., J. Cárdenas, and D. Torres. 1992. Análisis de los avistamientos de Eubalaena australis (Desmoulins, 1822) en aguas chilenas, desde 1983 hasta 1989. **Seri. Cient. Inst. Antárt. Chileno** 42:77-91.

Alava, J.J. and S. Salazar. 2006. Status and conservation of otariids in Ecuador and the Galápagos Islands. p. 495-519 *In*: Sea lions of the world. Alaska Sea Grant College Program, AK-SG-06-01.

Allen, R.L. 1985. Dolphins and the purse-seine fishery for yellowfin tuna. p. 236-252 *In*: J.R. Beddington, R.J.H. Beverton, and D.M. Lavigne (eds.), Marine mammals and fisheries. George Allen & Unwin, London, U.K. 354 p.

Archer, F.I., II and W.F. Perrin. 1999. *Stenella coeruleoalba*. **Mamm. Species** 603:1–9.

Arnbom, T. and H. Whitehead. 1989. Observations on the composition and behaviour of groups of female sperm whale near the Galápagos Islands. **Can. J. Zool.** 67(1):1-7.

Au, D.K.W. and W.L. Perryman. 1985. Dolphin habitats in the eastern tropical Pacific. **Fish. Bull.** 83(4):623-643.

Bailey, H., B.R. Mate, D.M. Palacios, L. Irvine, S.J. Bograd and D.P. Costa. 2009. Behavioural estimation of blue whale movements in the Northeast Pacific from state-space model analysis of satellite tracks. **Endang. Species Res**. 10:93-106.

Bain, D.E. and R. Williams. 2006. Long-range effects of airgun noise on marine mammals: responses as a function of received sound level and distance. Working Pap. SC/58/E35. Int. Whal. Comm., Cambridge, U.K. 13 p.

Baird, R.W., A.D. Ligon, and S.K. Hooker. 2000. Sub-surface and night-time behavior of humpback whales off Maui, Hawaii: a preliminary report. Rep. prepared under Contract #40ABNC050729 from the Hawaiian Islands Humpback Whale National Marine Sanctuary, Kihei, HI, to the Hawaii Wildlife Fund, Paia, HI.

Baird, R.W. 2002a. Risso's dolphin. p. 1037-1039 *In:* W.F. Perrin, B. Würsig and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals. Academic Press, San Diego, CA. 1414 p.

Baird, R.W. 2002b. False killer whale. p. 411-412 *In:* W.F. Perrin, B. Würsig and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals. Academic Press, San Diego, CA. 1414 p.

Baird, R.W., M.B. Hanson, E.A. Ashe, M.R. Heithaus, and G.J. Marshall. 2003. Studies of foraging in "southern resident" killer whales during July 2002: Dive depths, bursts in speed, and the use of a "Crittercam" system for examining sub-surface behavior. Rep. for the National Marine Fisheries Service, National Marine Mammal Laboratory, Seattle, WA.

Baird, R.W., D.L. Webster, D.J. McSweeney, A.D. Ligon, G.S. Schorr, and J. Barlow. 2006. Diving behaviour of Cuvier's (*Ziphius cavirostris*) and Blainville's (*Mesoplodon densirostris*) beaked whales in Hawai'i. **Can. J. Zool.** 84:1120-1128.

Balcomb, K.C., III and D.E. Claridge. 2001. A mass stranding of cetaceans caused by naval sonar in the Bahamas. **Bahamas J. Sci.** 8(2):2-12.

Barkaszi, M.J., D.M. Epperson, and B. Bennett. 2009. Six-year compilation of cetacean sighting data collected during commercial seismic survey mitigation observations throughout the Gulf of Mexico, USA. p. 24-25 *In*: Abstr. 18th Bienn. Conf. Biol. Mar. Mamm., Québec, Canada, Oct. 2009. 306 p.

Barlow, J. and K.A. Forney. 2007. Abundance and population density of cetaceans in the California Current eco-system. **Fish. Bull.** 105(4):509-526.

Barlow, J. and R. Gisner. 2006. Mitigating, monitoring and assessing the effects of anthropogenic sound on beaked whales. **J. Cetac. Res. Manage.** 7(3):239-249.

Barros, N.B., D.A. Duffield, P.H. Ostrom, D.K. Odell, and V.R. Cornish. 1998. Nearshore vs. offshore ecotype differentiation of *Kogia breviceps* and *K. simus* based on hemoglobin, morphometric and dietary analyses. Abstr. World Mar. Mamm. Sci. Conf., Monaco, 20–24 January 1998.

Barlow, J., M.C. Ferguson, E.A. Becker, J.V. Redfern, K.A. Forney, I.L. Vilchis, P.C. Fiedler, T. Gerrodette, and L.T. Ballance. 2009. Predictive modeling of marine mammal densities in the eastern Pacific Ocean. NOAA Tech. Memo. NOAA-TMNMFS-SWFSC-444. Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, CA. 206 p.

Baumgartner, M.F. 1997. The distribution of Risso's dolphin (*Grampus griseus*) with respect to the physiography of the Northern Gulf of Mexico. **Mar. Mamm. Sci.** 13(4):614-638.

Berzin, A.A. 1978. Whale distribution in tropical eastern Pacific waters. **Rep. Int. Whal. Comm.** 28:173-177.

Best, P.B. 1979. Social organization in sperm whales, *Physeter macrocephalus*. p. 227-289 *In:* H.E. Winn and B.L. Olla (eds.), Behavior of marine animals, Vol. 3. Plenum, New York, NY.

Black, N.A., A. Schulman-Janiger, R.L. Ternullo, and M. Guerrero-Ruiz. 1997. Killer whales of California and western Mexico: A catalog of photo-identified individuals. NOAA Tech. Memo. NMFS-SWFSC-247. Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, CA. 174 p.

Bowles, A.E., M. Smultea, B. Würsig, D.P. DeMaster, and D. Palka. 1994. Relative abundance and behavior of marine mammals exposed to transmissions from the Heard Island Feasibility Test. **J. Acoust. Soc. Am.** 96(4):2469-2484.

Branch, T.A., D.M. Palacios, K.M. Stafford, C. Allison, J.L. Bannister, C.L.K. Burton, K.C.S. Jenner, M-N.M. Jenner, B. Maughan, T. Miyashita, M.G. Morrice, V.J. Sturrock, R.C. Anderson, A.N. Baker, P.B. Best, P. Borsa, S. Childerhouse, K.P. Findlay, A.D. Ilangakoon, M. Joergensen, B. Kahn, B. Maughan, Y.A. Mikhalev, Oman Whale and Dolphin Research Group, D. Thiele, D. Tormosov, K. Van Waerebeek, and R.M. Warneke. 2006. Past and present distribution of blue whales in the Southern Hemisphere and northern Indian Ocean. Working Pap. SC/58/SH16. Int. Whal. Comm., Cambridge, U.K. 27 p.

Brownell, R.L., Jr. and P.J. Clapham. 1999. Burmeister's porpoise *Phocoena spinipinnis* Burmeister, 1865. p. 393-410 *In:* S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 6. The second book of dolphins and the porpoises. Academic Press, San Diego, CA. 486 p.

Burkhardt, E., O. Boebel, H. Bornemann, and C. Ruholl. 2008. Risk assessment of scientific sonars. **Bioacoustics** 17:235-237.

Calambokidis, J. and S.D. Osmek. 1998. Marine mammal research and mitigation in conjunction with air gun operation for the USGS 'SHIPS' seismic surveys in 1998. Rep. by Cascadia Research, Olympia, WA, for U.S. Geol. Surv., Nat. Mar. Fish. Serv., and Minerals Manage. Serv.

Calambokidis, J., G.H. Steiger, J.M. Straley, L.M. Herman, S. Cerchio, D.R. Salden, J. Urbán R., J.K. Jacobsen, O. von Ziegesar, K.C. Balcomb, C.M. Gabriele, M.E. Dahlheim, S. Uchida, G. Ellis, Y. Miyamura, P. Ladrón de Guevara P., M. Yamaguchi, F. Sato, S.A. Mizroch, L. Schlender, K. Rasmussen, J. Barlow, and T.J. Quinn II. 2001. Movements and population structure of humpback whales in the North Pacific. **Mar. Mamm. Sci.** 17:769–794.

Calambokidis, J. E. Oleson, M. McDonald, W. Burgess, J. Francis, and J. Hildebrand. 2003. Feeding and vocal behavior of blue whales determined through suction-cup attached tags. Environmental Consequences of Underwater Sound (ECOUS) Symposium. 12–16 May 2003, San Antonio, Texas.

Calambokidis, J., A. Gouglas, and F. Garita. 2010. Summary of 2010 humpback whale research along the Osa Peninsula, Costa Rica. Oceanic Society Research Expeditions, Exploritas and Cascadia Research Collective. Accessed on 11 May 2010 at http://www.cascadiaresearch.org/costarica/Summary%20of%20Southern%20Costa%20Rica%20Jan-Feb%20mm%20surveys-FINAL-2010.pdf

Campagna, C. 2008a. *Otaria flavescens*. *In*: IUCN 2010. IUCN Red List of Threatened Species. Version 2010.1. <www.iucnredlist.org>. Accessed on 11 May 2010 at www.iucnredlist.org.

Campagna, C. 2008b. *Arctocephalus australis*. *In*: IUCN 2010. IUCN Red List of Threatened Species. Version 2010.1. <www.iucnredlist.org>. Accessed on 11 May 2010 at www.iucnredlist.org.

Capella J.J., L. Flórez-González, P. Falk-Fernández, and D.M. Palacios. 2002. Regular appearance of otariid pinnipeds along the Colombian Pacific coast. **Mar. Mamm. Sci.** 28(1):67-72.

Carretta, J.V., K.A. Forney, M.S. Lowry, J. Barlow, J. Baker, D. Johnston, B. Hanson, R.L Brownell Jr., J. Robbins, D.K. Mattila, K. Ralls, M.M. Muto, D. Lynch, and L. Carswell. 2010. U.S. Pacific marine mammal stock assessments: 2009. NOAA Tech. Memo. NMFS-SWFSC-453. Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, CA. 336 p.

Chandler, T.E. and J. Calambokidis. 2004. Costa Rica Dome blue whale cruise report. Unpublished report, 6 p. Accessed on 11 May 2010 at http://www.cascadiaresearch.org/reports/CRUISE%20REPORT.pdf.

Clapham, P.J. and D.K. Mattila. 1990. Humpback whale songs as indicators of migration routes. **Mar. Mamm. Sci.** 6:155160.

Clapham P.J and J.G. Mead. 1999. *Megaptera novaeangliae*. **Mamm. Spec.** 604:1-9.

Claridge, D.E. 2003. Examining distribution and habitat preferences of deep-diving cetaceans, including beaked whales, in Northwest Providence Channel, the Bahamas, using geographic information system (GIS) mapping techniques. Presentation at the 15th Bienn. Conf. Biol. Mar. Mamm., Greensboro, NC.

Clark, C.W. and W.T. Ellison. 2004. Potential use of low-frequency sounds by baleen whales for probing the environment: evidence from models and empirical measurements. p. 564-582 *In:* Thomas, J.A., C.F. Moss and M. Vater (eds.) Echolocation in bats and dolphins. Univ. Chicago Press, Chicago, IL.

Clark, C.W. and G.C. Gagnon. 2006. Considering the temporal and spatial scales of noise exposures from seismic surveys on baleen whales. Working Pap. SC/58/E9. Int. Whal. Comm., Cambridge, U.K. 9 p.

Cox, T.M., T.J. Ragen, A.J. Read, E. Vos, R.W. Baird, K. Balcomb, J. Barlow, J. Caldwell, T. Cranford, L. Crum, A. D'Amico, G. D'Spain, A. Fernández, J. Finneran, R. Gentry, W. Gerth, F. Gulland, J. Hildebrand, D. Houser, T. Hullar, P.D. Jepson, D. Ketten, C.D. MacLeod, P. Miller, S. Moore, D.C. Mountain, D. Palka, P. Ponganis, S. Rommel, T. Rowles, B. Taylor, P. Tyack, D. Wartzok, R. Gisiner, J. Mead, and L. Benner.

2006. Understanding the impacts of anthropogenic sound on beaked whales. **J. Cetac. Res. Manage.** 7(3):177-187.

Croll, D.A., A. AcevedoGutierrez, B.R. Tershy and J. UrbanRamirez. 2001. The diving behavior of blue and fin whales: is dive duration shorter than expected based on oxygen stores? **Comp. Biochem. Physiol. A** 129:797-809.

Crum, L.A., M.R. Bailey, J. Guan, P.R. Hilmo, S.G. Kargl, and T.J. Matula. 2005. Monitoring bubble growth in supersaturated blood and tissue ex vivo and the relevance to marine mammal bioeffects. **Acoustic Res. Lett. Online** 6(3):214-220.

Cubero-Pardo, P. and J. Rodríguez F. 2000. *Zalophus californianus* (Pinnipedia:Otariidae) en Costa Rica. **Rev. Biol. Trop.** 48(1):273.

Culik, B.M. 2002. Review on small cetaceans: distribution, behaviour, migration and threats. Compiled for the Convention on Migratory Species (CMS). Bonn, Germany.

Culik, B.M. 2010. Odontocetes: the toothed whales: *Mesoplodon grayi*. UNEP/CMS Secretariat, Bonn, Germany. Accessed on 10 May 2010 at http://www.cms.int/reports/small_cetaceans/index.htm.

Cummings, W. C. 1985. Bryde's whale. p. 137–154 *In:* S.H. Ridgway and R.J. Harrison (eds.), Handbook of marine mammals, Vol. 3. The sirenians and baleen whales. Academic Press, London, U.K. 362 p.

Dahlheim, M.E. and J.E. Heyning. 1999. Killer whale *Orcinus orca* (Linnaeus, 1758). p. 281-322 *In:* S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 6. The second book of dolphins and the porpoises. Academic Press, San Diego, CA. 486 p.

Dahlheim, M.E., S. Leatherwood, and W.F. Perrin. 1982. Distribution of killer whales in the warm temperate and tropical eastern Pacific. **Rep. Int. Whal. Comm.** 32:647-653.

Dalebout, M.L., G.J.B. Ross, C.S. Baker, R.C. Anderson, P.B. Best, V.G. Cockcroft, H.L. Hinsz, V. Peddemors, and R.L. Pitman. 2003. Appearance, distribution, and genetic distinctiveness of Longman's beaked whale, *Indopacetus pacificus*. **Mar. Mamm. Sci.** 19(3):421-461.

Davis, R.W., G.S. Fargion, N. May, T.D. Leming, M. Baumgartner, W.E. Evans, L.J. Hansen, and K. Mullin. 1998. Physical habitat of cetaceans along the continental slope in the north-central and western Gulf of Mexico. **Mar. Mamm. Sci.** 14(3):490-507.

Dietz, R., J. Teilmann, M.-P.H. Jørgensen, and M.V. Jensen. 2002. Satellite tracking of humpback whales in West Greenland. Roskilde, Denmark: National Environmental Research Institute Technical Report 411.

Dizon, A.E., S.O. Southern, and W.F. Perrin. 1991. Molecular analysis of mtDNA types in exploited populations of spinner dolphins (*Stenella longirostris*). **Rep. Int. Whal. Comm. Spec. Iss.** 13:183-202.

Dolar, M.L.L. 2002. Fraser's dolphin—*Lagenodelphis hosei*. p. 485-487 *In:* W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals. Academic Press, San Diego, CA. 1414 p.

Dolphin, W.F. 1987. Ventilation and dive patterns of humpback whales, *Megaptera novaeangliae*, on their Alaskan feeding grounds. **Can. J. Zool.** 65(1): 83-90.

DoN (Department of the Navy). 2005. Marine resource assessment for the Northeast Operating Areas: Atlantic City, Narragansett Bay, and Boston. Naval Facilities Engineering Command, Atlantic; Norfolk, VA. Contract No. N62470-02-D-9997, Task Order No. 0018. Prepared by GeoMarine, Inc., Newport News, VA.

Donovan, G.P. 1984. Blue whales off Peru, December 1982, with special reference to pygmy blue whales. **Rep. Int. Whal. Comm.** 34:473-476.

Donovan, G.P. 1991. A review of IWC stock boundaries. **Rep. Int. Whal. Comm. Spec. Iss.** 13:39-68.

Dufault, S. and H. Whitehead. 1995. The geographic stock structure of female and immature sperm whales in the South Pacific. **Rep. Int. Whal. Comm.** 45:401-405.

Duffield, D.A., S.H. Ridgway, and L.H. Cornell. 1983. Hematology distinguishes coastal and offshore forms of dolphins (*Tursiops*). **Can. J. Zool.** 61(4):930-933.

Engel, M.H., M.C.C. Marcondes, C.C.A. Martins, F.O. Luna, R.P. Lima, and A. Campos. 2004. Are seismic surveys responsible for cetacean strandings? An unusual mortality of adult humpback whales in Abrolhos Bank, northeastern coast of Brazil. Working Paper SC/56/E28. Int. Whal. Comm., Cambridge, U.K. 8 p.

Escorza-Treviño, S. 2009. North Pacific marine mammals. p. 781-788 *In:* W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd edit. 1414 p.

Evans, W.E. 1994. Common dolphin, white-bellied porpoise *Delphinus delphis* Linnaeus, 1758. p. 191-224 *In:* S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 5. The first Book of dolphins. Academic Press, San Diego, CA. 416 p.

Félix F. and B. Haase. 2005. Distribution of humpback whales along the coast of Ecuador and management implications**. J. Cetacean Res. Manage**. 7:21–31.

Félix, F., B. Haase, and J. Samaniego. 1995. [First record of pygmy killer whale Feresa attenuata (Cetacea, Delphinidae) and dwarf sperm whale *Kogia simus* (Cetacea, Physeteridae) on the Ecuadorean continental coast]. Estud. Oceanol. 14:77-85. [In Spanish].

Félix, F., C. Castro, B. Haase and M. Scheidat. 2005. New estimate of the Southeastern Pacific Humpback Whale Stock. Abstr. 16th Bienn. Conf. Biol. Mar. Mamm., December 2005, San Diego, CA.

Ferguson, M.C. and J. Barlow. 2001. Spatial distribution and density of cetaceans in the Eastern Tropical Pacific Ocean based on summer/fall research vessel surveys in 1986–96. Admin. Rep. LJ-01-04, Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, CA. 61 p.

Ferguson, M.C. and J. Barlow. 2003. Addendum: Spatial distribution and density of cetaceans in the Eastern Tropical Pacific Ocean based on summer/fall research vessel surveys in 1986–96. Admin. Rep. LJ-01-04, Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, CA. 120 p.

Ferguson, M.C., J. Barlow, S.B. Reilly, and T. Gerrodette. 2006a. Predicting Cuvier's (*Ziphius cavirostris*) and *Mesoplodon* beaked whale population density from habitat characteristics in the Eastern Tropical Pacific Ocean. **J. Cetacean Res. Manage.** 7(3): 287-299

Ferguson, M.C., J. Barlow, P. Fiedler, S.B. Reilly, and T. Gerrodette. 2006b. Spatial models of delphinid (family Delphinidae) encounter rate and group size in the eastern tropical Pacific Ocean. **Ecol. Model.** 193(3-4):645-662.

Fernández, A., M. Arbelo, R. Deaville, I.A.P. Patterson, P. Castro, J.R. Baker, E. Degollada, H.M. Ross, P. Herráez, A.M. Pocknell, E. Rodríguez, F.E. Howie, A. Espinosa, R.J. Reid, J.R. Jaber, V. Martin, A.A. Cunningham, and P.D. Jepson. 2004. Pathology: whales, sonar and decompression sickness (reply). **Nature** 428(6984):1.

Fernández, A., J.F. Edwards, F. Rodriquez, A.E. de los Monteros, P. Herráez, P. Castro, J.R. Jaber, V. Martin, and M. Arbelo. 2005. "Gas and fat embolic syndrome" involving a mass stranding of beaked whales (Family Ziphiidae) exposed to anthropogenic sonar signals. **Vet. Pathol.** 42(4):446-457.

Finneran, J.J. and C.E. Schlundt. 2004. Effects of intense pure tones on the behavior of trained odontocetes. TR 1913, SSC San Diego, San Diego, CA.

Finneran, J.J., C.E. Schlundt, D.A. Carder, J.A. Clark, J.A. Young, J.B. Gaspin, and S.H. Ridgway. 2000. Auditory and behavioral responses of bottlenose dolphins (*Tursiops truncatus*) and beluga whale (*Delphinapterus leucas*) to impulsive sounds resembling distant signatures of underwater explosions. **J. Acoust. Soc. Am.** 108(1):417-431.

Finneran, J.J., C.E. Schlundt, R. Dear, D.A. Carder, and S.H. Ridgway. 2002. Temporary shift in masked hearing thresholds in odontocetes after exposure to single underwater impulses from a seismic watergun. **J. Acoust. Soc. Am.** 111(6):2929-2940.

Finneran, J.J., D.A. Carder, C.E. Schlundt, and S.H. Ridgway. 2005. Temporary threshold shift in bottlenose dolphins (*Tursiops truncatus*) exposed to mid-frequency tones. **J. Acoust. Soc. Am.** 118(4):2696-2705.

Ford, J.K.B. 2002. Killer whale. p. 669-675 *In:* W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals. Academic Press, San Diego, CA. 1414 p.

Frankel, A.S. 2005. Gray whales hear and respond to a 21–25 kHz high-frequency whale-finding sonar. Abstr. 16th Bienn. Conf. Biol. Mar. Mamm., 12–16 Dec. 2005, San Diego, CA.

Frantzis, A. 1998. Does acoustic testing strand whales? **Nature** 392(6671):29.

Gailey, G., B. Würsig, and T.L. McDonald. 2007. Abundance, behavior, and movement patterns of western gray whales in relation to a 3-D seismic survey, northeast Sakhalin Island, Russia. **Environ. Monit. Assess.** 134(1-3):75-91. doi: 10.1007/s10661-007-9812-1.

Gallardo, V.A., D. Arcos, M. Salamanca, and L. Pastene. 1983. On the occurrence of Bryde's Whales (*Balaenoptera edeni* Anderson, 1878) in an upwelling area off central Chile. **Rep. Int. Whal. Comm.** 33:481-488.

Gallo, J. P. 1994. Factors affecting the population status of Guadalupe fur seal, Arctocephalus townsendi (Merriam, 1897), at Isla de Guadalupe, Baja California, Mexico. Ph.D. Thesis, University of California, Santa Cruz. 199 p.

Gambell, R. 1976. World whale stocks. **Mamm. Rev.** 6:41-53.

Gambell, R. 1985a. Sei whale *Balaenoptera borealis* Lesson, 1828. p. 155-170 *In:* S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 3. The sirenians and baleen whales. Academic Press, London, U.K. 362 p.

Gambell, R. 1985b. Fin whale *Balaenoptera physalus* (Linnaeus, 1758). p. 171-192 *In:* S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 3. The sirenians and baleen whales. Academic Press, London, U.K. 362 p.

Gannier, A. 2000. Distribution of cetaceans off the Society Islands (French Polynesia) as obtained from dedicated surveys. **Aquat. Mamm.** 26(2):111-126.

Gedamke, J., S. Frydman, and N. Gales. 2008. Risk of baleen whale hearing loss from seismic surveys: preliminary results from simulations accounting for uncertainty and individual variation. Working Pap. SC/60/E9. Int. Whal. Comm., Cambridge, U.K. 10 p.

Gentry, R. (ed). 2002. Report of the workshop on acoustic resonance as a source of tissue trauma in cetaceans. 24-25 April, NMFS, Silver Spring, MD. 19 p. Accessed on 11 May 2010 at: http://www.nmfs.noaa.gov/pr/pdfs/acoustics/cetaceans.pdf.

Gerrodette, T., and J. Forcada. 2002. Estimates of abundance of northeastern offshore spotted, coastal spotted, and eastern spinner dolphins in the eastern tropical Pacific Ocean. Admin. Rep. LJ-02-06, Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, CA. 43 p.

Gerrodette, T. and J. Forcada. 2005. Non-recovery of two spotted and spinner dolphin populations in the eastern tropical Pacific Ocean. **Mar. Ecol. Prog. Ser.** 291:1-21.

Gerrodette, T. and J. Pettis. 2005. Responses of tropical cetaceans to an echosounder during research vessel Surveys. p. 104 *In:* Abstr. 16th Bien. Conf. Biol. Mar. Mamm., 12–16 Dec. 2005, San Diego, CA.

Gerrodette, T., G. Watters, W. Perryman and L. Balance. 2008. Estimates of 2006 dolphin abundance in the Eastern Tropical Pacific, with revised estimates from 1986-2003. Tech. Memo. NOAA-TM-NMFS-SWFSC-422. Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, CA. 39p.

Gilpatrick, J.W., Jr., R.L. Pitman, L.T. Ballance, R. LeDuc, and H. Fearnbach. 2005. Killer whales prey upon a blue whale calf on the Costa Rica Dome: genetics, morphometrics and composition of the herd. Abstr. 16th Bienn. Conf. Biol. Mar. Mamm., 12–16 Dec. 2005, San Diego, CA.

Goold, J.C. 1996a. Acoustic assessment of common dolphins off the west Wales coast, in conjunction with 16th round seismic surveying. Rep. from School of Ocean Sciences, Univ. Wales, Bangor, Wales, for Chevron UK Ltd, Repsol Explor. (UK) Ltd., and Aran Energy Explor. Ltd. 22 p.

Goold, J.C. 1996b. Acoustic assessment of populations of common dolphin *Delphinus delphis* in conjunction with seismic surveying. **J. Mar. Biol. Assoc. U.K.** 76:811-820.

Goold, J.C. 1996c. Acoustic cetacean monitoring off the west Wales coast. Rep. from School of Ocean Sciences, Univ. Wales, Bangor, Wales, for Chevron UK Ltd, Repsol Explor. (UK) Ltd, and Aran Energy Explor. Ltd. 20 p.

Gordon, J., D. Gillespie, J. Potter, A. Frantzis, M.P. Simmonds, R. Swift, and D. Thompson. 2004. A review of the effects of seismic surveys on marine mammals. **Mar. Technol. Soc. J.** 37(4):16-34.

Gordon, J., R. Antunes, N. Jaquet, and B. Würsig. 2006. An investigation of sperm whale headings and surface behaviour before, during and after seismic line changes in the Gulf of Mexico. Working Pap. SC/58/E45. Int. Whal. Comm., Cambridge, U.K. 10 p.

Gosselin, J.-F. and J. Lawson. 2004. Distribution and abundance indices of marine mammals in the Gully and two adjacent canyons of the Scotian Shelf before and during nearby hydrocarbon seismic exploration programmes in April and July 2003. Res. Doc. 2004/133. Can. Sci. Advis. Secretariat, Fisheries & Oceans Canada. 24 p. Accessed on 11 May 2010 at www.dfo-mpo.gc.ca/csas/Csas/DocREC/2004/RES2004_133_e.pdf.

Greene, C.R., Jr. 1997. Physical acoustics measurements. p. 3-1 to 3-63 *In:* W.J. Richardson (ed.) Northstar marine mammal monitoring program, 1996: marine mammal and acoustical monitoring of a seismic program in the Alaskan Beaufort Sea. LGL Rep. 2121-2. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Explor. (Alaska) Inc., Anchorage, AK, and Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 245 p.

Greene, C.R., Jr., N.S. Altman, and W.J. Richardson. 1999a. Bowhead whale calls. p. 6-1 to 6-23 *In*: Richardson, W.J. (ed.) Marine mammal and acoustical monitoring of Western Geophysical's open-water seismic program in the Alaskan Beaufort Sea, 1998. LGL Rep. TA2230-3. Rep. by LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for Western Geophysical, Houston, TX, and U.S. Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 390 p.

Greene, C.R., Jr., N.S. Altman, and W.J. Richardson. 1999b. The influence of seismic survey sounds on bowhead whale calling rates. **J. Acoust. Soc. Am.** 106(4, Pt. 2):2280 (Abstract).

Gregr, E.J. and A.W. Trites. 2001. Predictions of critical habitat for five whale species in the waters of coastal British Columbia. **Can. J. Fish. Aquat. Sci.** 58: 1265-1285.

Haase, B. and F. Félix. 1994. A note on the incidental mortality of sperm whales (*Physeter macrocephalus*) in Ecuador. **Rep. Int. Whal. Comm. Spec. Iss.** 15:481-483.

Hall, M.A. and S.D. Boyer. 1989. Estimates of incidental mortality of dolphins in the eastern Pacific fishery for tropical tunas in 1987. **Rep. Int. Whal. Comm.** 39:321-322.

Hansen, L.J., K.D. Mullin, and C.L. Roden. 1994. Preliminary estimates of cetacean abundance in the U.S. Atlantic Exclusive Economic Zone from 1992 vessel surveys. Southeast Fisheries Science Center, Miami Laboratory. Contribution No. MIA-93/94-58.

Harris, R.E., G.W. Miller, and W.J. Richardson. 2001. Seal responses to airgun sounds during summer seismic surveys in the Alaskan Beaufort Sea. **Mar. Mamm. Sci.** 17(4):795-812.

Harris, R.E., T. Elliot, and R.A. Davis. 2007. Results of mitigation and monitoring program, Beaufort Span 2-D marine seismic program, open water season 2006. LGL Ltd. LGL Rep. TA4319-1. Rep. from LGL Ltd., King City, Ont., for GX Technol., Houston, TX. 48 p.

Hastie, G.D. and V.M. Janik. 2007. Behavioural responses of grey seals to multibeam imaging sonars. *In:* Abstr. 17th Bien. Conf. Biol. Mar. Mamm., 29 Nov–3 Dec., Cape Town, South Africa.

Hauser, D.D.W., M. Holst, and V.D. Moulton. 2008. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program in the Eastern Tropical Pacific, April-August 2008. LGL Rep. TA4656/7-1. Rep. from LGL Ltd., King City, Ont., and St. John's, Nfld, for Lamont-Doherty Earth Observatory, Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 98 p.

Heide-Jørgensen, M.P., D. Bloch, E. Stefansson, B. Mikkelsen, L.H. Ofstad, and R. Dietz. 2002. Diving behaviour of long-finned pilot whales *Globicephala melas* around the Faroe Islands. Wildl. Biol. 8:307-313.

Heyning, J.E. 1989. Cuvier's beaked whale *Ziphius cavirostris* G. Cuvier, 1823. p. 289-308 *In:* S.H. Ridgway and R.J. Harrison (eds.), Handbook of marine mammals, Vol. 4. River dolphins and the larger toothed whales. Academic Press, San Diego, CA. 444 p.

Heyning, J.E. and W.F. Perrin. 1994. Evidence for two species of common dolphins (genus *Delphinus*) from the Eastern North Pacific. **Contribut. Sci.** 442:1-35.

Hildebrand, J.A. 2005. Impacts of anthropogenic sound. p. 101-124 *In:* J.E. Reynolds, W.F. Perrin, R.R. Reeves, S. Montgomery, and T. Ragen (eds.), Marine mammal research: conservation beyond crisis. Johns Hopkins Univ. Press, Baltimore, MD. 223 p.

Hoelzel, A.R., C.W. Potter, and P.B. Best. 1998. Genetic differentiation between parapatric 'nearshore' and 'offshore' populations of the bottlenose dolphin. **Proc. R. Soc Lond. B** 265:1177-1183.

Hogarth, W.T. 2002. Declaration of William T. Hogarth in opposition to plaintiff's motion for temporary restraining order, 23 October 2002. Civ. No. 02-05065-JL. U.S. District Court, Northern District of California, San Francisco Div.

Holst, M. and J. Beland. 2008. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's seismic testing and calibration study in the northern Gulf of Mexico, November 2007–February 2008. LGL Rep. TA4295-2. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 77 p.

Holst, M. and M.A. Smultea. 2008. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program off Central America, February–April 2008. LGL Rep. TA4342-3. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 133 p.

Holst, M., M.A. Smultea, W.R. Koski, and B. Haley. 2005a. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program off the Northern Yucatán Peninsula in the Southern Gulf of Mexico, January–February 2005. LGL Rep. TA2822-31. Rep. by LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 96 p.

Holst, M., M.A. Smultea, W.R. Koski, and B. Haley. 2005b. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program in the Eastern Tropical Pacific Ocean off Central America, November–December 2004. LGL Rep. TA2822-30. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 125 p.

Holst, M., W.J. Richardson, W.R. Koski, M.A. Smultea, B. Haley, M.W. Fitzgerald, and M. Rawson. 2006. Effects of large and small-source seismic surveys on marine mammals and sea turtles. Abstract. Presented at Am. Geophys. Union - Soc. Explor. Geophys. Joint Assembly on Environ. Impacts from Marine Geophys. & Geological Studies - Recent Advances from Academic & Industry Res. Progr., Baltimore, MD, May 2006.

Horwood, J. 1987. The sei whale: population biology, ecology, and management. Croom Helm, Beckenham, Kent, U.K. 375 p.

IAGC (International Association of Geophysical Contractors). 2004. Further analysis of 2002 Abrolhos Bank, Brazil humpback whale strandings coincident with seismic surveys. Int. Assoc. Geophys. Contr., Houston, TX.

Ireland, D., M. Holst, and W.R. Koski. 2005. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic program off the Aleutian Islands, Alaska, July–August 2005. LGL Report TA4089-3. Rep. by LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD.

IUCN (The World Conservation Union). 2010. IUCN Red List of Threatened Species, Version 2010.1. Accessed on 11 May 2010 at http://www.iucnredlist.org.

IWC (International Whaling Commission). 2007. Report of the standing working group on environmental concerns. Annex K to Report of the Scientific Committee. **J. Cetac. Res. Manage.** 9 (Suppl.):227-260.

IWC (International Whaling Commission). 2010. IWC members and commissioners. Accessed on 11 May 2010 at http://www.iwcoffice.org/commission/members.htm.

Jackson, A., T. Gerrodette, S. Chivers, M. Lynn, S. Rankin, and S. Mesnick. 2008. Marine mammal data collected during a survey in the Eastern Tropical Pacific Ocean aboard the NOAA ships *David Starr Jordan* and *MacArthur II*, July 28–December 7 2006. NOAA Tech. Memo. TM-NMFS-SWFSC-421. Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, CA. 45 p.

Jacquet, N. and H. Whitehead. 1996. Scale-dependent correlation of sperm whale distribution with environmental features and productivity in the South Pacific. **Mar. Ecol. Prog. Ser.** 135(1-3):1-9.

Jefferson, T.A., M.A. Webber, and R.L. Pitman. 2008. Marine mammals of the world—A comprehensive guide to their identification. Elsevier, Academic Press, Amsterdam, Holland. 573 p.

Jepson, P.D., M. Arbelo, R. Deaville, I.A.P. Patterson, P. Castro, J.R. Baker, E. Degollada, H.M. Ross, P. Herráez, A.M. Pocknell, F. Rodríguez, F.E. Howie, A. Espinosa, R.J. Reid, J.R. Jaber, V. Martin, A.A. Cunningham, and A. Fernández. 2003. Gas-bubble lesions in stranded cetaceans. **Nature** 425(6958):575-576.

Jochens, A., D. Biggs, K. Benoit-Bird, D. Engelhaupt, J. Gordon, C. Hu, N. Jaquet, M. Johnson, R. Leben, B. Mate, P. Miller, J. Ortega-Ortiz, A. Thode, P. Tyack, and B. Würsig. 2008. Sperm whale seismic study in the Gulf of Mexico: synthesis report. OCS Study MMS 2008-006. Rep. from Dep. Oceanogr., Texas A & M Univ., College Station, TX, for U.S. Minerals Manage. Serv., Gulf of Mexico OCS Reg., New Orleans, LA. 341 p.

Johnson, M., P.T. Madsen, W.M.X. Zimmer, N. Aguilar de Soto, and P.L. Tyack. 2004. Beaked whales echolocate on prey. **Proc. Royal Soc.Lond. Ser. B Suppl.** 04BL0042.S1-S4.

Johnson, S.R., W.J. Richardson, S.B. Yazvenko, S.A. Blokhin, G. Gailey, M.R. Jenkerson, S.K. Meier, H.R. Melton, M.W. Newcomer, A.S. Perlov, S.A. Rutenko, B. Würsig, C.R. Martin, and D.E. Egging. 2007. A western gray whale mitigation and monitoring program for a 3-D seismic survey, Sakhalin Island, Russia. **Environ. Monit. Assess.** 134(1-3):1-19. doi: 10.1007/s10661-007-9813-0.

Kastak, D., R.L. Schusterman, B.L. Southall, and C.J. Reichmuth. 1999. Underwater temporary threshold shift induced by octave-band noise in three species of pinnipeds. **J. Acoust. Soc. Am.** 106(2):1142-1148.

Kastak, D., B.L. Southall, R.J. Schusterman, and C. Reichmuth. 2005. Underwater temporary threshold shift in pinnipeds: effects of noise level and duration. **J. Acoust. Soc. Amer.** 118(5):3154-3163.

Kato, H. 2002. Bryde's whales. . p. 171-176 *In*: W. F. Perrin, B. Würsig, and H. G. M. Thewissen (eds.), Encyclopedia of marine mammals. Academic Press, San Diego, CA. 1414 p.

Kenney, R.D. and H.E. Winn. 1987. Cetacean high-use habitats of the northeast United States continental shelf. **Fish. Bull.** 84:345-357.

Ketten, D.R. 1995. Estimates of blast injury and acoustic trauma zones for marine mammals from underwater explosions. p. 391-407 *In:* Kastelein, R.A., J.A. Thomas, and P.E. Nachtigall (eds.), Sensory systems of aquatic mammals. De Spil Publ., Woerden, Netherlands. 588 p.

Ketten, D.R., J. Lien, and S. Todd. 1993. Blast injury in humpback whale ears: evidence and implications. **J. Acoust. Soc. Am.** 94(3, Pt. 2):1849-1850.

Ketten, D.R., J. O'Malley, P.W.B. Moore, S. Ridgway, and C. Merigo. 2001. Aging, injury, disease, and noise in marine mammal ears. **J. Acoust. Soc. Am.** 110(5, Pt. 2):2721.

Kinzey, D., T. Gerrodette, J. Barlow, A. Dizon, W. Perryman, P. Olson, and A. Von Saunder. 1999. Marine mammal data collected during a survey in the eastern tropical Pacific Ocean aboard the NOAA ships *McArthur* and *David Starr Jordan* and the UNOLS ship *Endeavor* July 31-December 9, 1998. NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-283. Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, CA. 113 p.

Kinzey, D., T. Gerrodette, J. Barlow, A. Dizon, W. Perryman, and P. Olson. 2000. Marine mammal data collected during a survey in the eastern tropical Pacific Ocean aboard the NOAA ships *McArthur* and *David Starr Jordan*, July 28-December 9, 1998. NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-293. Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, CA. 89 p.

Kinzey, D., T. Gerrodette, A. Dizon, W. Perryman, P. Olson, and S. Rankin. 2001. Marine mammal data collected during a survey in the eastern tropical Pacific Ocean aboard the NOAA ships *McArthur* and *David Starr Jordan*, July 28-December 9, 2000. NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-303. Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, CA. 100 p.

Klatsky, L.J., R.S. Wells, and J.C. Sweeney. 2007. Offshore bottlenose dolphins (*Tursiops truncatus*): Movement and dive behavior near the Bermuda Pedestal**. J. Mamm.** 88:59-66.

Kremser, U., P. Klemm, and W.D. Kötz. 2005. Estimating the risk of temporary acoustic threshold shift, caused by hydroacoustic devices, in whales in the Southern Ocean. **Antarctic Sci.** 17(1):3-10.

Kruse, S., D.K. Caldwell, and M.C. Caldwell. 1999. Risso's dolphin *Grampus griseus* (G. Cuvier, 1812). p. 183-212 *In:* S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 6. The mecond book of dolphins and the porpoises. Academic Press, San Diego, CA. 486 p.

Kryter, K.D. 1985. The effects of noise on man, 2nd ed. Academic Press, Orlando, FL. 688 p.

Lagerquist, B.A., K.M. Stafford, and B.R. Mate. 2000. Dive characteristics of satellite-monitored blue whales (*Balaenoptera musculus*) off the central California coast. **Mar. Mamm. Sci.** 16(2):375-391.

Laist, D.W., A.R. Knowlton, J.G. Mead, A.S. Collet, and M. Podesta. 2001. Collisions between ships and whales. **Mar. Mamm. Sci.** 17:35–75.

Laurinolli, M.H. and N.A. Cochrane. 2005. Hydroacoustic analysis of marine mammal vocalization data from ocean bottom seismometer mounted hydrophones in the Gully. p. 89-95 *In:* K. Lee, H. Bain and G.V. Hurley (eds.) Acoustic monitoring and marine mammal surveys in The Gully and Outer Scotian Shelf before and during active seismic surveys. Environ. Stud. Res. Funds Rep. 151. 154 p. Published 2007.

Leatherwood, S. and R.R. Reeves. 1983. The Sierra Club handbook of whales and dolphins. Sierra Club, San Francisco, CA.

Leatherwood, S., R.R. Reeves, W.F. Perrin, and W.E. Evans. 1988. Whales, dolphins and porpoises of the eastern North Pacific and adjacent arctic waters. Dover Publications, New York, NY. 245 p.

Leatherwood, S., J.S. Grove, and A.E. Zuckerman. 1991. Dolphins of the genus *Lagenorhynchus* in the tropical South Pacific. **Mar. Mamm. Sci.** 7(2):194-197.

Lee, T. 1993. Summary of cetacean survey data collected between the years of 1974 and 1985. NOAA Tech. Memo. NMFS-SWFSC-181. National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, CA. 184 p.

Ljungblad, D.K., B. Würsig, S.L. Swartz, and J.M. Keene. 1988. Observations on the behavioral responses of bowhead whales (*Balaena mysticetus*) to active geophysical vessels in the Alaskan Beaufort Sea. **Arctic** 41(3):183-194.

Lockyer, C.H. and S.G. Brown. 1981. The migration of whales. p. 105-137 *In*: D.J. Aidley (ed.), Animal migration. Soc. Exp. Biol. Sem. Ser. 13, Cambridge University Press, London, U.K.

Lucke, K., U. Siebert, P.A. Lepper, and M.-A. Blanchet. 2009. Temporary shift in masked hearing thresholds in a harbor porpoise (*Phocoena phocoena*) after exposure to seismic airgun stimuli. **J. Acoust. Soc. Am.** 125(6):4060-4070.

Lusseau, D. and L. Bejder. 2007. The long-term consequences of short-term responses to disturbance experience from whalewatching impact assessment. **Intern. J. Comp. Psych.** 20(2-3):228-236.

Mackintosh, N.A. 1965. The stocks of whales. Fishing News, London.

Mackintosh, N.A. 1966. The distribution of southern blue and fin whales. p. 125-144 *In:* K.S. Norris (ed.), Whales, dolphins and porpoises. University of California Press, Berkeley and Los Angeles, CA. 789 p.

MacLean, S.A. and B. Haley. 2004. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic study in the Støregga Slide area of the Norwegian Sea, August–September 2003. LGL Rep. TA2822-20. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory, Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 59 p.

MacLean, S.A. and W.R. Koski. 2005. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic program in the Gulf of Alaska, August–September 2004. LGL Rep. TA2822-28. Rep. by LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 102 p.

MacLeod, C.D. and A. D'Amico. 2006. A review of beaked whale behaviour and ecology in relation to assessing and mitigating impacts of anthropogenic noise. **J. Cetacean Res. Manage.** 7(3): 211-221

MacLeod, C.D. and G. Mitchell. 2006. Known key areas for beaked whales around the world. **J. Cetacean Res. Manage.** 7: 309-320.

MacLeod, C.D. and A.F. Zuur. 2005. Habitat utilization by Blainville's beaked whales off Great Abaco, northern Bahamas, in relation to seabed topography. **Mar. Biol.** 147:1-11.

MacLeod, C.D., N. Hauser, and H. Peckham. 2004. Diversity, relative density and structure of the cetacean community in summer months east of Great Abaco, Bahamas. **J. Mar. Biol. Assoc. U.K.** 84:469-474.

Madsen, P.T., B. Møhl, B.K. Nielsen, and M. Wahlberg. 2002. Male sperm whale behavior during exposures to distant seismic survey pulses. **Aquat. Mamm.** 28(3):231-240.

Madsen, P.T., M. Johnson, P.J.O. Miller, N. Aguilar de Soto, J. Lynch, and P.L. Tyack. 2006. Quantitative measures of air gun pulses recorded on sperm whales (*Physeter macrocephalus*) using acoustic tags during controlled exposure experiments. **J. Acoust. Soc. Am.** 120(4):2366–2379.

Malakoff, D. 2002. Suit ties whale deaths to research cruise. **Science** 298(5594):722-723.

Malme, C.I. and P.R. Miles. 1985. Behavioral responses of marine mammals (gray whales) to seismic discharges. p. 253-280 *In*: G.D. Greene, F.R. Engelhardt, and R.J. Paterson (eds.), Proc. workshop on effects of explosives use in the marine environment, Jan. 1985, Halifax, N.S. Tech. Rep. 5. Can. Oil & Gas Lands Admin., Environ. Prot. Br., Ottawa, Ont. 398 p.

Malme, C.I., P.R. Miles, C.W. Clark, P. Tyack, and J.E. Bird. 1984. Investigations of the potential effects of underwater noise from petroleum industry activities on migrating gray whale behavior/Phase II: January 1984 migration. BBN Rep. 5586. Rep. by Bolt Beranek & Newman Inc., Cambridge, MA, for U.S. Minerals Manage. Serv., Anchorage, AK. Var. pag. NTIS PB86-218377.

Malme, C.I., P.R. Miles, P. Tyack, C.W. Clark, and J.E. Bird. 1985. Investigation of the potential effects of underwater noise from petroleum industry activities on feeding humpback whale behavior. BBN Rep. 5851; OCS Study MMS 85-0019. Rep. by BBN Labs Inc., Cambridge, MA, for U.S. Minerals Manage. Serv., Anchorage, AK. Var. pag. NTIS PB86-218385.

Malme, C.I., B. Würsig, J.E. Bird, and P. Tyack. 1986. Behavioral responses of gray whales to industrial noise: feeding observations and predictive modeling. Outer Cont. Shelf Environ. Assess. Progr., Final Rep. Princ. Invest., NOAA, Anchorage, AK 56(1988):393-600. BBN Rep. 6265. 600 p. OCS Study MMS 88-0048; NTIS PB88-249008.

Malme, C.I., B. Würsig, J.E. Bird, and P. Tyack. 1988. Observations of feeding gray whale responses to controlled industrial noise exposure. p. 55-73 *In*: Sackinger, W.M., M.O. Jeffries, J.L. Imm, and S.D. Treacy (eds.), Port and ocean engineering under arctic conditions, Vol. II. Geophysical Inst., Univ. Alaska, Fairbanks, AK. 111 p.

Martínez-Fernández, D., A. Montero-Cordero and L. May-Collado. 2005. Occurrence of Pseudorca crassidens in the pacific coastal waters of Costa Rica. Poster presentation. 16th Bien. Conf. Biol. Mar. Mamm., 12–16 December 2005, San Diego, CA.

Mate, B.R., B.A. Lagerquist, and J. Calambokidis. 1999. Movements of North Pacific blue whales during the feeding season off southern California and their southern fall migration. **Mar. Mamm. Sci.** 15(4):1246-1257.

May-Collado, L., T. Gerrodette, J. Calambokidis, K. Rasmussen, and I. Sereg. 2005. Patterns of cetacean sighting distribution in the Pacific Exclusive Economic Zone of Costa Rica based on data collected from 1979-2001. **Rev Biol. Trop.** 53:249-263.

McAlpine, D.F. 2002. Pygmy and dwarf sperm whales *Kogia breviceps* and *K. sima*. p. 1007-1009 *In*: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals. Academic Press, San Diego, CA. 1414 p.

McCauley, R.D., M.-N. Jenner, C. Jenner, K.A. McCabe, and J. Murdoch. 1998. The response of humpback whales (*Megaptera novaeangliae*) to offshore seismic survey noise: preliminary results of observations about a working seismic vessel and experimental exposures. **APPEA (Austral. Petrol. Product. Explor. Assoc.) J.** 38:692-707.

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch, and K. McCabe. 2000a. Marine seismic surveys: analysis of airgun signals; and effects of air gun exposure on humpback whales, sea turtles, fishes and squid. Rep. from Centre for Marine Science and Technology, Curtin Univ., Perth, W.A., for Austral. Petrol. Prod. Assoc., Sydney, N.S.W. 188 p.

McCauley, R.D., J. Fewtrell, A.J. Duncan, M.-N. Jenner, C. Jenner, R.I.T. Prince, A. Adhitya, K. McCabe, and J. Murdoch. 2000b. Marine seismic surveys – a study of environmental implications. **APPEA (Austral. Petrol. Product. Explor. Assoc.) J.** 40:692-708.

McDonald, M.A., J.A. Hildebrand, and S.C. Webb. 1995. Blue and fin whales observed on a seafloor array in the Northeast Pacific. **J. Acoust. Soc. Am.** 98(2 Pt.1):712-721.

Mead, J.G. 1989. Beaked whales of the genus *Mesoplodon*. p. 349-430 *In:* S.H. Ridgway and R.J. Harrison (eds.), Handbook of marine mammals, Vol. 4, River dolphins and the larger toothed whales. Academic Press, San Diego, CA. 416 p.

Miller, G.W., R.E. Elliott, W.R. Koski, V.D. Moulton, and W.J. Richardson. 1999. Whales. p. 5-1 to 5-109 *In*: Richardson, W.J. (ed.) Marine mammal and acoustical monitoring of Western Geophysical's open-water seismic program in the Alaskan Beaufort Sea, 1998. LGL Rep. TA2230-3. Rep. by LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for Western Geophysical, Houston, TX, and U.S. Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 390 p.

Miller, G.W., V.D. Moulton, R.A. Davis, M. Holst, P. Millman, A. MacGillivray, and D. Hannay. 2005. Monitoring seismic effects on marine mammals—southeastern Beaufort Sea, 2001–2002. p. 511-542 *In*: Armsworthy, S.L., P.J. Cranford, and K. Lee (eds.) Offshore oil and gas environmental effects monitoring/Approaches and technologies. Battelle Press, Columbus, OH.

Miller, P.J.O., M.P. Johnson, P.T. Madsen, N. Biassoni, M. Quero, and P.L. Tyack. 2009. Using at-sea experiments to study the effects of airguns on the foraging behavior of sperm whales in the Gulf of Mexico. **Deep-Sea Res. I** 56(7):1168-1181.

Miyazaki, N. and W.F. Perrin. 1994. Rough-toothed dolphin *Steno bredanensis* (Lesson, 1828). p. 1-21 *In*: S.H. Ridgway and R.J. Harrison (eds.), Handbook of marine mammals, Vol. 5: The first book of dolphins. Academic Press, San Diego, CA. 416 p.

Mizroch, S.A., D.W. Rice, and J.M. Breiwick. 1984. The blue whale, *Balaenoptera musculus*. **Mar. Fish. Rev.** 46(4)15-19.

Moore, S.E. and J.T. Clarke. 2002. Potential impact of offshore human activities on gray whales. J. Cetac. Res. Manage. 4(1):19-25.

Moulton, V.D. and J.W. Lawson. 2002. Seals, 2001. p. 3-1 to 3-48 *In*: Richardson, W.J. (ed.), Marine mammal and acoustical monitoring of WesternGeco's open water seismic program in the Alaskan Beaufort Sea, 2001. LGL Rep. TA2564-4. Rep. by LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for WesternGeco, Houston, TX, and Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD.

Moulton, V.D. and G.W. Miller. 2005. Marine mammal monitoring of a seismic survey on the Scotian Slope, 2003. p. 29-40 *In*: Lee, K., H. Bain, and G.V. Hurley (eds.), Acoustic monitoring and marine mammal surveys in the Gully and Outer Scotian Shelf before and during active seismic programs. Env. Stud. Res. Funds Rep. No. 151. 154 p. + xx.

Moulton, V.D., B.D. Mactavish, and R.A. Buchanan. 2005. Marine mammal and seabird monitoring of Chevron Canada Resources' 3-D seismic program on the Orphan Basin, 2004. LGL Rep. SA817. Rep. by LGL Ltd., St. John's, Nfld., for Chevron Canada Resources, Calgary, Alb., ExxonMobil Canada Ltd., St. John's, Nfld., and Imperial Oil Resources Ventures Ltd., Calgary, Alb. 90 p. + appendices.

Moulton, V.D., B.D. Mactavish, R.E. Harris, and R.A. Buchanan. 2006a. Marine mammal and seabird monitoring of Chevron Canada Limited's 3-D seismic program on the Orphan Basin, 2005. LGL Rep. SA843. Rep. by LGL Ltd., St. John's, Nfld., for Chevron Canada Resources, Calgary, Alb., ExxonMobil Canada Ltd., St. John's, Nfld., and Imperial Oil Resources Ventures Ltd., Calgary, Alb. 111 p. + appendices.

Moulton, V.D., B.D. Mactavish, and R.A. Buchanan. 2006b. Marine mammal and seabird monitoring of Conoco-Phillips' 3-D seismic program in the Laurentian Sub-basin, 2005. LGL Rep. SA849. Rep. by LGL Ltd., St. John's, Nfld., for ConocoPhillips Canada Resources Corp., Calgary, Alb. 97 p. + appendices.

Mullin, K.D., T.A. Jefferson, L.J. Hansen, and W. Hoggard. 1994. First sightings of melon-headed whales (*Peponocephala electra*) in the Gulf of Mexico. **Mar. Mamm. Sci.** 10(3):342-348.

Muñoz-Hincapié, M.F., D.M. Mora-Pinto, D.M. Palacios, E.R. Secchi, and A.A. Mignucci-Giannoni. 1998. First osteological record of the dwarf sperm whale in Colombia, with notes on the zoogeography of Kogia in South America. **Revista Acad. Colomb. Cien.** 22(84):433-444.

NatureServe. 2009. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. Accessed on 11 May 2010 at http://www.natureserve.org/explorer.

Nieukirk, S.L., K.M. Stafford, D.K. Mellinger, R.P. Dziak, and C.G. Fox. 2004. Low-frequency whale and seismic airgun sounds recorded in the mid-Atlantic Ocean. **J. Acoust. Soc. Am.** 115(4):1832-1843.

NMFS (National Marine Fisheries Service). 1995. Small takes of marine mammals incidental to specified activities; offshore seismic activities in southern California. **Fed. Regist.** 60(200, 17 Oct.):53753-53760.

NMFS (National Marine Fisheries Service). 1998. Recovery plan for the blue whale (*Balaenoptera musculus*). Prepared by R.R. Reeves, P.J. Clapham, R.L. Brownell, Jr., and G.K. Silber for the National Marine Fisheries Service, Silver Spring, MD. 42 p.

NMFS (National Marine Fisheries Service). 2000. Small takes of marine mammals incidental to specified activities; marine seismic-reflection data collection in southern California/Notice of receipt of application. **Fed. Regist.** 65(60, 28 Mar.):16374-16379.

NMFS (National Marine Fisheries Service). 2001. Small takes of marine mammals incidental to specified activities; oil and gas exploration drilling activities in the Beaufort Sea/Notice of issuance of an incidental harassment authorization. **Fed. Regist.** 66(26, 7 Feb.):9291-9298.

NMFS (National Marine Fisheries Service). 2005. Endangered fish and wildlife; notice of intent to prepare an environmental impact statement. **Fed. Regist.** 70(7, 11 Jan.):1871-1875.

NOAA and USN (National Oceanographic and Atmospheric Administration and U.S. Navy). 2001. Joint interim report: Bahamas marine mammal stranding event of 15–16 March 2000. U.S. Dep. Commer., Nat. Oceanic Atmos. Admin., Nat. Mar. Fish. Serv., Sec. Navy, Assist. Sec. Navy, Installations and Environ. 51 p. Accessed on 11 May 2010 at http://www.nmfs.noaa.gov/pr/pdfs/health/stranding_bahamas2000.pdf.

Norris, T.F., M. McDonald, and J. Barlow. 1999. Acoustic detections of singing humpback whales (*Megaptera novaeangliae*) in the eastern North Pacific during their northbound migration. **J. Acoust. Soc. Am.** 106(1):506-514.

Nowacek, D.P., L.H. Thorne, D.W. Johnston, and P.L. Tyack. 2007. Responses of cetaceans to anthropogenic noise. **Mamm. Rev.** 37(2):81-115.

NRC (National Research Council). 2005. Marine mammal populations and ocean noise/Determining when noise causes biologically significant effects. U.S. Nat. Res. Counc., Ocean Studies Board, Committee on Characterizing Biologically Significant Marine Mammal Behavior (Wartzok, D.W., J. Altmann, W. Au, K. Ralls, A. Starfield, and P.L. Tyack). Nat. Acad. Press, Washington, DC. 126 p.

Odell, D.K. and K.M. McClune. 1999. False killer whale *Pseudorca crassidens* (Owen, 1846). p. 213-243 *In:* S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals. Vol. 6. The second Book of dolphins and the porpoises. Academic Press, San Diego, CA. 486 p.

Olson, P.A. and S. B. Reilly. 2002. Pilot whales. p. 898-893 *In:* W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals. Academic Press, San Diego, CA. 1414 p.

Palacios, D.M. 1996a. On the specimen of the ginkgo-toothed beaked whale, *Mesoplodon ginkgodens*, from the Galápagos Islands. **Mar. Mamm. Sci.** 12(3):444-446.

Palacios, D.M. 1996b. Earlier observations of presumed Galápagos sea lions, *Zalophus californianus wollebaeki*, from coastal Ecuador [letter]. **Mar. Mamm. Sci.** 12(3):497.

Palacios, D.M. 1999. Blue whale (*Balaenoptera musculus*) occurrence off the Galápagos Islands, 1978-1995. **J. Cetac. Res. Manage.** 1(1):41-51.

Palacios, D.M., F. Félix, L. Flórez-González, J.J. Cappela, D. Chiluiza, and B.J.M. Haase. 1997. Sightings of Galápagos sea lions (*Zalophus californianus wollebaeki*) on the coasts of Colombia and Ecuador. **Mammalia** 61(1):114-116.

Palacios, D.M. K.M. Stafford, and F.B. Schwing. 2005. Temporal variations in blue whale acoustic detections in relation to environmental conditions in the northeastern tropical Pacific, 1996-2002. Abstr. 16th Bienn. Conf. Biol. Mar. Mamm., 12–16 December 2005, San Diego, CA.

Panigada, S., M. Zanardelli, S. Canese and M. Jahoda. 1999. How deep can baleen whales dive? **Mar. Ecol. Prog. Ser.** 187:309–311.

Papastavrou, V., S.C. Smith, and H. Whitehead. 1989. Diving behaviour of the sperm whale, *Physeter macrocephalus*, off the Galápagos Islands. **Can. J. Zool.** 67(4):839-846.

Parente, C.L., M.C.C. Marcondes, and M.H. Engel. 2006. Humpback whale strandings and seismic surveys in Brazil from 1999 to 2004. Working Pap. SC/58/E41. Int. Whal. Comm., Cambridge, U.K. 16 p.

Perrin, W.F. 1990. Subspecies of *Stenella longirostris* (Mammalia: Cetacea, Delphinidae). **Proc. Biol. Soc. Wash.** 103(2):453-463.

Perrin, W.F. and J.W. Gilpatrick, Jr. 1994. Spinner dolphin. p. 99-128 *In:* S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 5. The first book of dolphins. Academic Press, San Diego, CA. 416 p.

Perrin, W.F. and A.A. Hohn. 1994. Pantropical spotted dolphin *Stenella attenuat*a. p. 71-98 *In:* S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 5. The first book of dolphins. Academic Press, San Diego, CA. 416 p.

Perrin, W.F. and W.A. Walker. 1975. The rough-toothed porpoise, *Steno bredanensis*, in the eastern tropical Pacific. **J. Mammal.** 56:905-907.

Perrin, W.F., M.D. Scott, G.J. Walker, and V.L. Cass. 1985. Review of geographical stocks of tropical dolphins (*Stenella* spp. and *Delphinus delphis*) in the eastern Pacific. NOAA Tech. Rep. NMFS 28. 28 p.

Perrin, W.F., C.E. Wilson, and F.I. Archer II. 1994a. Striped dolphin *Stenella coeruleoalba* (Meyen, 1833). p. 129-159 *In:* S. H. Ridgway and R. J. Harrison (eds.), Handbook of marine mammals, Vol. 5. The first book of dolphins. Academic Press, San Diego, CA. 416 p.

Perrin, W.F., S. Leatherwood, and A. Collet. 1994b. Fraser's dolphin *Lagenodelphis hosei* Fraser, 1956. p. 225-240 *In:* S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 5. The first book of dolphins. Academic Press, London, U.K. 416 p.

Perry, S.L., D.P. DeMaster, and G.K. Silber. 1999. The great whales: history and status of six species listed as endangered under the U.S. Endangered Species Act of 1973. **Mar. Fish. Rev.** 61:1-74.

Perryman, W.L. 2002. Melon-headed whale—*Peponocephala electra*. p. 733-735 *In:* W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals. Academic Press, San Diego, CA. 1414 p.

Perryman, W.L. and T.C. Foster. 1980. Preliminary report of predation by small whales, mainly the false killer whale, *Pseudorca crassidens*, on dolphins (*Stenella* spp. and *Delphinus delphis*) in the eastern tropical Pacific. Admin. Rep. LJ-80-05. Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, CA. 9 p.

Perryman, W.L. and M.S. Lynn. 1993. Identification of geographic forms of common dolphin (*Delphinus delphis*) from aerial photogrammetry. **Mar. Mamm. Sci.** 9(2):119-137.

Perryman, W.L., D.W.K. Au, S. Leatherwood, and T.A. Jefferson. 1994. Melon-headed whale *Peponocephala electra* Gray, 1846. p. 363-386 *In*: S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 5. The first book of dolphins. Academic Press, London, U.K. 416 p.

Pierson, M.O., J.P. Wagner, V. Langford, P. Birnie, and M.L. Tasker. 1998. Protection from, and mitigation of, the potential effects of seismic exploration on marine mammals. Chapter 7 *In*: Tasker, M.L. and C. Weir (eds.), Proceedings of the seismic and marine mammals workshop, 23–25 June 1998, London, U.K.

Pitman, R.L. 2002. Mesoplodont whales *Mesoplodon spp.* p. 738-742 *In*: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals. Academic Press, San Diego, CA. 1414 p.

Pitman, R.L. and L.T. Ballance. 1992. Parkinson's petrel distribution and foraging ecology in the eastern tropical Pacific: Aspects of an exclusive feeding relationships with dolphins. **Condor** 94(4):825-835.

Pitman, R.L. and M.S. Lynn. 2001. Biological observations of an unidentified Mesoplodont whale in the eastern tropical Pacific and probable identity: *Mesoplodon peruvianus*. **Mar. Mamm. Sci.** 17(3): 648-657.

Pitman, R.L., A. Aguayo L., and J. Urbán R. 1987. Observations of an unidentified beaked whale (*Mesoplodon* sp.) in the eastern tropical Pacific. **Mar. Mamm. Sci.** 3(4):345-352.

Pitman, R.L., D.M. Palacios, P.L.R. Brennan, B.J. Brennan, K.C. Balcomb, III, and T. Miyashita. 1999. Sightings and possible identity of a bottlenose whale in the tropical Indo-Pacific: *Indopacetus pacificus*? **Mar. Mamm. Sci.** 15(2): 513-518.

Polacheck, T. 1987. Relative abundance, distribution and inter-specific relationship of cetacean schools in the Eastern Tropical Pacific. **Mar. Mamm. Sci.** 3(1):54-77.

Potter, J.R., M. Thillet, C. Douglas, M.A. Chitre, Z. Doborzynski, and P.J. Seekings. 2007. Visual and passive acoustic marine mammal observations and high-frequency seismic source characteristics recorded during a seismic survey. **IEEE J. Oceanic Eng.** 32(2):469-483.

Rasmussen, K., J. Calambokidis, and G.H. Steiger. 2004. Humpback whales and other marine mammals off Costa Rica and surrounding waters, 1996-2003. Report of the Oceanic Society 2003 field season in cooperation with elderhostel volunteers. Cascadia Research, Olympia, WA. 24 p.

Rasmussen, K., D.M. Palacios, J. Calambokidis, M.T. Saborio, L. Dalla Rosa, E.R. Secchi, G.H. Steiger, J.M. Allen, and G.S. Stone. 2007. Southern Hemisphere humpback whales wintering off Central America: insights from water temperature into the longest mammalian migration. **Biol. Lett.** 3:302-305.

Read, A.J., K. Van Waerebeek, J.C. Reyes, J.S. McKinnon, and L.C. Lehman. 1998. The exploitation of small cetaceans in coastal Peru. **Biol. Conserv.** 46:53-70.

Read, A.J., P.N. Halpin, L.B. Crowder, B.D. Best, and E. Fujioka (eds.). 2009. OBIS-SEAMAP: Mapping marine mammals, birds and turtles. World Wide Web electronic publication. Accessed on 17 April 2010 at http://seamap.env.duke.edu/prod/serdp/serdp_map.php.

Reeves, R.R., B.S. Stewart, P.J. Clapham, and J.A. Powell. 2002. Guide to marine mammals of the world. Chanticleer Press, New York, NY. 527 p.

Reilly, S.B. 1990. Seasonal changes in distribution and habitat differences among dolphins in the eastern tropical Pacific. **Mar. Ecol. Prog. Ser.** 66(1-2):1-11.

Reilly, S.B. and V.G. Thayer. 1990. Blue whale (*Balaenoptera musculus*) distribution in the eastern tropical Pacific. **Mar. Mamm. Sci.** 6:265-277.

Reilly, S.B. and P.C. Fiedler. 1994. Interannual variability of dolphin habitats in the eastern tropical Pacific. I: Research vessel surveys, 1986–1990. **Fish. Bull.** 92(2):434-450.

Rendell, L.E. and J.C.D. Gordon. 1999. Vocal response of long-finned pilot whales (*Globicephala melas*) to military sonar in the Ligurian Sea. **Mar. Mamm. Sci.** 15(1):198-204.

Reyes, J.C., J.G. Mead, and K. Van Waerebeek. 1991. A new species of beaked whale *Mesoplodon peruvianus* sp. n. (Cetacea: Ziphiidae) from Peru. **Mar. Mamm. Sci.** 7(1):1-24.

Rice, D.W. 1989. Sperm whale *Physeter macrocephalus* Linnaeus, 1758. p. 177-233 *In:* S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 4. River dolphins and the larger toothed whales. Academic Press, San Diego, CA. 444 p.

Rice, D.W. 1998. Marine mammals of the world, systematics and distribution. Spec. Publ. 4. Soc. Mar. Mammal., Allen Press, Lawrence, KS. 231 p.

Richardson, W.J., B. Würsig, and C.R. Greene. 1986. Reactions of bowhead whales, *Balaena mysticetus*, to seismic exploration in the Canadian Beaufort Sea. **J. Acoust. Soc. Am.** 79(4):1117-1128.

Richardson, W.J., R.A. Davis, C.R. Evans, D.K. Ljungblad, and P. Norton. 1987. Summer distribution of bowhead whales, *Balaena mysticetus*, relative to oil industry activities in the Canadian Beaufort Sea, 1980–84. **Arctic** 40(2):93-104.

Richardson, W.J., C.R. Greene, Jr., C.I. Malme, and D.H. Thomson. 1995. Marine mammals and noise. Academic Press, San Diego. 576 p.

Richardson, W.J., G.W. Miller, and C.R. Greene, Jr. 1999. Displacement of migrating bowhead whales by sounds from seismic surveys in shallow waters of the Beaufort Sea. **J. Acoust. Soc. Am.** 106(4, Pt. 2):2281 (Abstract).

Richardson, W.J., M. Holst, W.R. Koski and M. Cummings. 2009. Responses of cetaceans to large-source seismic surveys by Lamont-Doherty Earth Observatory. p. 213 *In*: Abstr. 18th Bienn. Conf. Biol. Mar. Mamm., October 2009, Québec City, Que. 306 p.

Ritter, F. and B. Brederlau. 1999. Behavioural observations of dense beaked whales (*Mesoplodon densirostris*) off La Gomera, Canary Islands (1995–1997). **Aquat. Mamm.** 25(2):55-61.

Rodríguez-Fonseca, J. 2001. Diversity and distribution of Costa Rica's cetaceans (Cetacea: Delphinidae, Physeteridae, Ziphiidae and Balaenopteridae). **Rev. Biol. Trop.** 49, Suppl. 2:135-143. (Spanish, Engl. summ.)

Rodríguez-Fonseca, J. and P. Cubero-Pardo. 2001. Cetacean strandings in Costa Rica (1966-1999). **Rev. Biol. Trop**. 49(2):667-672.

Rodríguez-Herrera, B., F.A. Chinchilla, and L.J. May-Collado. 2002. Lista de especies, endemismo y conservación de los de mamiferos de Costa Rica. **Rev. Mex. Mastozoologia** 6:19-41.

Romero, A., A.I. Agudo, S.M. Green, and G. Notarbartolo di Sciara. 2001. Cetaceans of Venezuela: their distribution and conservation status. NOAA Tech. Rep. NMFS 151. U.S. Dep. Comm., Seattle, WA. 60 p.

Rosales, M.L. and S. Escorza-Trefiño. 2005. Population structure and sex biased dispersal of spotted dolphins (*Stenella attenuata*) in the eastern tropical Pacific. 2005. Abstr. 16th Bienn. Conf. Biol. Mar. Mamm., 12–16 December 2005, San Diego, CA.

Ross, G. J.B. and S. Leatherwood. 1994. Pygmy killer whale *Feresa attenuata* Gray, 1874. p. 387-404 *In:* S.H. Ridgway and R.J. Harrison (eds.), Handbook of marine mammals, Vol. 5. The first book of dolphins. Academic Press, San Diego, CA. 416 p.

Santillán L., M. Roca, M. Apaza, L. Rosa de Oliveira, and K. Ontón. 2004. New record of mother-calf pair of southern right whale, *Eubalaena australis*, off the Peruvian coast. LAJAM 3: 83-84.

Schlundt, C.E., J.J. Finneran, D.A. Carder, and S.H. Ridgway. 2000. Temporary shift in masking hearing thresholds of bottlenose dolphins, *Tursiops truncatus*, and white whales, *Delphinapterus leucas*, after exposure to intense tones. **J. Acoust. Soc. Am.** 107(6):3496-3508.

Scott, M.D. and S.J. Chivers. 1990. Distribution and herd structure of bottlenose dolphins in the eastern tropical Pacific Ocean. p. 387-402. *In:* S. Leatherwood and R.R. Reeves (eds.), The bottlenose dolphin. Academic Press, San Diego, CA. 653 p.

Scott, M.D., A.A. Hohn, A.J. Westgate, J.R. Nicolas, B.R. Whitaker, and W.B. Cambell. 2001. A note on the release and tracking of a rehabilitated pygmy sperm whale (*Kogia breviceps*). **J. Cetac. Res. Manage**. 3:87-94.

Sergeant, D.E. 1977. Stocks of fin whales *Balaenoptera physalus* L. in the North Atlantic Ocean. **Rep. Int. Whal. Comm.** 27:460-473.

Shane, S.H., R.S. Wells, and B. Würsig. 1986. Ecology, behavior and social organization of the bottlenose dolphin: a review. **Mar. Mamm. Sci.** 2:34-63.

Simard, Y., F. Samaran, and N. Roy. 2005. Measurement of whale and seismic sounds in the Scotian Gully and adjacent canyons in July 2003. p. 97-115 *In:* K. Lee, H. Bain, and C.V. Hurley (eds.), Acoustic monitoring and marine mammal surveys in The Gully and Outer Scotian Shelf before and during active seismic surveys. Environ. Stud. Res. Funds Rep. 151. 154 p (Published 2007).

Simmonds, M. P. and L.F. Lopez-Jurado. 1991. Whales and the military. **Nature** 351(6326):448.

Smith, S.D. and H. Whitehead. 1999. Distribution of dolphins in Galápagos waters. **Mar. Mam. Sci.** 15(2):550-555.

Smith, S.C. and H. Whitehead. 2000. The diet of Galápagos sperm whales *Physeter macrocephalus* as indicated by fecal sample analysis. **Mar. Mamm. Sci.** 16(2):315-325.

Smith, T.D. 1983. Changes in size of three dolphin (*Stenella* spp.) populations in the eastern tropical Pacific. **Fish. Bull.** 81(1):1-13.

Smultea, M.A. and M. Holst. 2003. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic study in the Hess Deep area of the Eastern Equatorial Tropical Pacific, July 2003. LGL Rep. TA2822-16. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory, Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 68 p.

Smultea, M.A., M. Holst, W.R. Koski, and S. Stoltz. 2004. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic program in the Southeast Caribbean Sea and adjacent Atlantic Ocean, April–June 2004. LGL Rep. TA2822-26. Rep. by LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 106 p.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene Jr., D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J. Richardson, J.A. Thomas, and P.L. Tyack. 2007. Marine mammal noise exposure criteria: initial scientific recommendations. **Aquat. Mamm.** 33(4):411-522.

Stafford, K.M. 2003. Two types of blue whale calls recorded in the Gulf of Alaska. **Mar. Mamm. Sci.** 19(4):682-693.

Stafford, K.M., S.L. Nieukirk, and C.G. Fox. 1999a. Low-frequency whale sounds recorded on hydrophones moored in the eastern tropical Pacific. **J. Acoust. Soc. Am.** 106(6):3687-3698.

Stafford, K.M., S.L. Nieukirk, and C.G. Fox. 1999b. An acoustic link between blue whales in the eastern tropical Pacific and the Northeast Pacific. **Mar. Mamm. Sci**. 15(4):1258-1268.

Stafford, K.M., S.L. Nieukirk, and C.G. Fox. 2001. Geographic and seasonal variation of blue whale calls in the North Pacific. **J. Cetac. Res. Manage.** 3(1):65-76

Stafford, K.M., D.K. Mellinger, S.E. Moore, and C.G. Fox. 2007. Seasonal variability and detection range modeling of baleen whale calls in the Gulf of Alaska, 1999–2002. **J. Acoust. Soc. Am.** 122(6):3378-3390.

Stewart, B.S. and S. Leatherwood. 1985. Minke whale *Balaenoptera acutorostrata* Lacépède, 1804. p. 91-136 *In:* S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 3. The sirenians and baleen whales. Academic Press, London, U.K. 362 p.

Stone, C.J. 2003. The effects of seismic activity on marine mammals in UK waters 1998–2000. JNCC Report 323. Joint Nature Conservancy, Aberdeen, Scotland. 43 p.

Stone, C.J. and M.L. Tasker. 2006. The effects of seismic airguns on cetaceans in UK waters. **J. Cetac. Res. Manage.** 8(3):255-263.

Swartz, S.L., T. Cole, M.A. McDonald, J.A. Hildebrand, E.M. Oleson, A. Martinez, P.J. Clapham, J. Barlow, and M. L. Jones. 2003. Acoustic and visual survey of humpback whale (*Megaptera novaeangliae*) distribution in the eastern and southeastern Caribbean Sea. **Caribb. J. Sci**. 39(2):195-208.

Teloni, V., P.M. Johnson, P.J.O. Miller, and P.T. Madsen. 2008. Shallow food for deep divers: dynamic foraging of male sperm whales. **J. Exp. Mar. Biol. Ecol.** 354(1):119-131.

Tershy B.R., J. Urbán- Ramírez, D. Breese, L. Rojas-B., and L.Y. Findley. 1993. Are fin whales resident to the Gulf of California? Univ. Auton. Baja Calif. Sur., **Rev. Invest. Cient.** 1:69–71.

Thompson, D., M. Sjöberg, E.B. Bryant, P. Lovell, and A. Bjørge. 1998. Behavioural and physiological responses of harbour (*Phoca vitulina*) and grey (*Halichoerus grypus*) seals to seismic surveys. Abstr. World Mar. Mamm. Sci. Conf., Monaco.

Tolstoy, M., J. Diebold, S. Webb, D. Bohnenstiehl, and E. Chapp. 2004a. Acoustic calibration measurements. Chapter 3 *In*: Richardson, W.J. (ed.), Marine mammal and acoustic monitoring during Lamont-Doherty Earth Observatory's acoustic calibration study in the northern Gulf of Mexico, 2003. Revised ed. Rep. by LGL Ltd., King City, ON, for Lamont-Doherty Earth Observ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD.

Tolstoy, M., J.B. Diebold, S.C. Webb, D.R. Bohenstiehl, E. Chapp, R.C. Holmes, and M. Rawson. 2004b. Broad-band calibration of R/V *Ewing* seismic sources. **Geophys. Res. Lett.** 31:L14310. doi: 10.1029/ 2004GL020234.

Tyack, P.L. 2009. Human-generated sound and marine mammals. **Phys. Today** 62(11, Nov.):39-44.

Tyack, P., M. Johnson, and P. Miller. 2003. Tracking responses of sperm whales to experimental exposures of airguns. p. 115-120 *In:* A.E. Jochens and D.C. Biggs (eds.), Sperm whale seismic study in the Gulf of Mexico/annual report: Year 1. OCS Study MMS 2003-069. Rep. by Texas A&M Univ., College Station, TX, for U.S. Minerals Manage. Serv., Gulf of Mexico OCS Reg., New Orleans, LA.

Tyack, P.L., M. Johnson, N. Aguilar Soto, A. Sturlese, and P.T. Madsen. 2006. Extreme diving of beaked whales. **J. Exp. Biol.** 209(21):4238-4253.

UNEP-WCMC (United Nations Environment Programme-World Conservation Monitoring Centre). 2009. Convention on International Trade in Endangered Species of Wild Flora and Fauna. Appendices I, II, and II. Valid from 22 May 2009. Accessed on 26 April 2010 at http://www.cites.org/eng/app/e-appendices.pdf.

Urbán-Ramírez, J. and D. Aurioles-Gamboa. 1992. First record of the pygmy beaked whale *Mesoplodon peruvianus* in the North Pacific. **Mar. Mamm. Sci.** 8(4):420-425.

Urick, R.J. 1983. Principles of underwater sound, 3rd Ed. McGraw-Hill, New York, NY. 423 p.

Van Waerebeek, K. and J.C. Reyes. 1988. First record of the pygmy killer whale, *Feresa attenuata* Gray, 1975 from Peru, with a summary of distribution in the eastern Pacific. **Z. Säugetierkunde** 53:253-255.

Van Waerebeek, K., J. Canto, J. Gonzalez, J. Oporto, and J.L. Brito. 1991. Southern right whale dolphins, *Lissodelphis peronii* off the Pacific coast of South America. **Z. Säugetierkunde** 56:284-295.

Wade, L.S. and G.L. Friedrichsen. 1979. Recent sightings of the blue whale, *Balaenoptera musculus*, in the northeastern tropical Pacific. **Fish. Bull.** 76(4):915-919.

Wade, P.R. and T. Gerrodette. 1993. Estimates of cetacean abundance and distribution in the eastern tropical Pacific. **Rep. Int. Whal. Comm.** 43:477-493.

Walker, J.L., C.W. Potter, and S.A. Macko. 1999. The diets of modern and historic bottlenose dolphin populations reflected through stable isotopes. **Mar. Mamm. Sci.** 15(2):335-350.

Wang, M.C., W.A. Walker, K.T. Shao, and L.S. Chou. 2002. Comparative analysis of the diets of pygmy sperm whales and dwarf sperm whales in Taiwanese waters. **Acta Zool. Taiwan.** 13(2):53-62.

Waring, G.T., T. Hamazaki, D. Sheehan, G. Wood, and S. Baker. 2001. Characterization of beaked whale (Ziphiidae) and sperm whale (*Physeter macrocephalus*) summer habitat in shelf-edge and deeper waters off the northeast U.S. **Mar. Mamm. Sci.** 17:703-717.

Wartzok, D., A.N. Popper, J. Gordon, and J. Merrill. 2004. Factors affecting the responses of marine mammals to acoustic disturbance. **Mar. Technol. Soc. J.** 37(4):6-15.

Watkins, W.A. and K.E. Moore. 1982. An underwater acoustic survey for sperm whales (*Physeter catodon*) and other cetaceans in the southeast Caribbean. **Cetology** 46:1-7.

Watkins, W.A., K.E. Moore, and P. Tyack. 1985. Sperm whale acoustic behaviors in the southeast Caribbean. **Cetology** 49:1-15.

Watkins, W.A., M.A. Daher, G.M. Reppucci, J.E. George, D.L. Martin, N.A. DiMarzio, and D.P. GWhitehead, H. 1989. Formations of foraging sperm whales, *Physeter macrocephalus*, off the Galápagos Islands. **Can. J. Zool.** 67(9):2131-2139.

Watkins, W.A., M.A. Daher, G.M. Reppucci, J.E. George, D. L. Martin, N.A. DiMarzio, and D.P. Gannon. 2000. Seasonality and distribution of whale calls in the North Pacific. **Oceanogr.** 13(1):62-67.

Weilgart, L.S. 2007. A brief review of known effects of noise on marine mammals. **Intern. J. Comp. Psychol.** 20:159-168.

Weir, C.R. 2008. Overt responses of humpback whales (*Megaptera novaeangliae*), sperm whales (*Physeter macrocephalus*), and Atlantic spotted dolphins (*Stenella frontalis*) to seismic exploration off Angola. **Aquat. Mamm.** 34(1):71-83.

Weir, C.R. and S.J. Dolman. 2007. Comparative review of the regional marine mammal mitigation guidelines implemented during industrial seismic surveys, and guidance towards a worldwide standard. **J. Int. Wildl. Law Policy** 10(1):1-27.

Whitehead, H. 1989. Formations of foraging sperm whales, *Physeter macrocephalus*, off the Galápagos Islands. **Can. J. Zool.** 67(9):2131-2139.

Whitehead, H. 2002. Estimates of the current global population size and historical trajectory for sperm whales. **Mar. Ecol. Prog. Ser.** 242:295-304.

Whitehead, H. 2003. Sperm whales: social evolution in the ocean. University of Chicago Press, Chicago, IL. 431 p.

Whitehead, H. and S. Waters. 1990. Social organization and population structure of sperm whales off the Galápagos Islands, Ecuador (1985–1987). **Rep. Int. Whal. Comm., Spec. Iss.** 12:249-257.

Whitehead, H., S. Waters, and T. Lyrholm. 1992. Population structure of female and immature sperm whales (*Physeter macrocephalus*) off the Galápagos Islands. **Can. J. Fish. Aquatic Sci.** 49(1):78-84.

Wieting, D. 2004. Background on development and intended use of criteria. p. 20 *In:* S. Orenstein, L. Langstaff, L. Manning, and R. Maund (eds.), Advisory Committee on Acoustic Impacts on Marine Mammals, final meet. summary. Second meet., April 28–30, 2004, Arlington, VA. Sponsored by the Mar. Mamm. Comm.

Willis, P.M. and R.W. Baird. 1998. Sightings and strandings of beaked whales on the west coast of Canada. **Aquat. Mamm.** 24:21-25.

Winsor, M.H. and B.R. Mate. 2006. Seismic survey activity and the proximity of satellite tagged sperm whales. Working Pap. SC/58/E16. Int. Whal. Comm., Cambridge, U.K. 8 p.

Würsig, B., S.K. Lynn, T.A. Jefferson, and K.D. Mullin. 1998. Behaviour of cetaceans in the northern Gulf of Mexico relative to survey ships and aircraft. **Aquat. Mamm.** 24(1):41-50.

Würsig, B.G., D.W. Weller, A.M. Burdin, S.H. Reeve, A.L Bradford, S.A. Blokhin, and R.L Brownell, Jr. 1999. Gray whales summering off Sakhalin Island, Far East Russia: July-October 1997. A joint U.S.-Russian scientific investigation. Final Report. Rep. from Texas A&M Univ., College Station, TX, and Kamchatka Inst. Ecol. & Nature Manage., Russian Acad. Sci., Kamchatka, Russia, for Sakhalin Energy Investment Co. Ltd and Exxon Neftegaz Ltd, Yuzhno-Sakhalinsk, Russia. 101 p.

Yazvenko, S.B., T.L. McDonald, S.A. Blokhin, S.R. Johnson, S.K. Meier, H.R. Melton, M.W. Newcomer, R.M. Nielson, V.L. Vladimirov, and P.W. Wainwright. 2007a. Distribution and abundance of western gray whales during a seismic survey near Sakhalin Island, Russia. **Environ. Monit. Assess.** 134(1-3):45-73. doi: 10.1007/s10661-007-9809-9.

Yazvenko, S.B., T.L. McDonald, S.A. Blokhin, S.R. Johnson, H.R. Melton, and M.W. Newcomer. 2007b. Feeding activity of western gray whales during a seismic survey near Sakhalin Island, Russia. **Environ. Monit. Assess**. 134(1-3): 93-106. doi: 10.1007/s10661-007-9810-3.

Yochem, P.K. and S. Leatherwood. 1985. Blue whale. p. 193-240 *In:* S.H. Ridgway and R Harrison (eds.), Handbook of marine mammals, Vol. 3. The sirenians and baleen whales. Academic Press, New York, NY. 362 p.

Yoder, J.A. 2002. Declaration of James A. Yoder in opposition to plaintiff's motion for temporary restraining order, 28 October 2002. Civ. No. 02-05065-JL. U.S. District Court, Northern District of California, San Francisco Division.

Fish and Invertebrates

Bjarti, T. 2002. An experiment on how seismic shooting affects caged fish. Faroese Fisheries Laboratory, University of Aberdeen. 41 p.

Booman, C., J. Dalen, H. Leivestad, A. Levsen, T. van der Meeren, and K. Toklum. 1996. Effecter av luftkanonshyting på egg, larver og yngel. Fisken og Havet 1996(3):1-83. (Norwegian with English summary).

Buchanan, R.A., J.R. Christian, V.D. Moulton, B. Mactavish, and S. Dufault. 2004. 2004 Laurentian 2-D seismic survey environmental assessment. Rep. from LGL Ltd., St. John's, Nfld., and Canning & Pitt Associates, Inc., St. John's, Nfld., for ConocoPhillips Canada Resources Corp., Calgary, Alta. 274 p.

Chapman, C.J. and A.D. Hawkins. 1969. The importance of sound in fish behaviour in relation to capture by trawls. **FAO Fish. Rep.** 62:717-729.

Christian, J.R., A. Mathieu, D.H. Thomson, D. White, and R.A. Buchanan. 2003. Effect of seismic energy on snow crab (*Chionoecetes opilio*). Environmental Studies Research Funds Report No. 144. Calgary. 106 p.

Christian, J.R., A. Mathieu, and R.A. Buchanan. 2004. Chronic effects of seismic energy on snow crab (*Chionoecetes opilio*). Environmental Studies Research Funds Report No. 158, March 2004. Calgary. 45 p.

Dalen, J. and G.M. Knutsen. 1986. Scaring effects in fish and harmful effects on eggs, larvae and fry by offshore seismic explorations. p. 93-102 *In*: H.M. Merklinger (ed.), Progress in underwater acoustics. Plenum, NY. 839 p.

Dalen, J. and A. Raknes. 1985. Scaring effects on fish from three dimensional seismic surveys. Inst. Mar. Res. Rep. FO 8504/8505, Bergen, Norway. [Norwegian, Engl. summ.]

Dalen, J., E. Ona, A.V. Soldal, and R. Saetre. 1996. Seismiske undersøkelser til havs: en vurdering av konsekvenser for fisk og fiskerier [Seismic investigations at sea; an evaluation of consequences for fish and fisheries]. Fisken og Havet 1996:1-26. (in Norwegian, with an English summary).

DFO (Fisheries and Oceans Canada). 2004. Potential impacts of seismic energy on snow crab. DFO Can. Sci. Advis. Sec. Habitat Status Rep. 2004/003.

Engås, A, S. Løkkeborg, E. Ona, and A.V. Soldal. 1996. Effects of seismic shooting on local abundance and catch rates of cod (*G. morhua*) and haddock (*M. aeglefinus*). **Can. J. Fish. Aquat. Sci.** 53:2238-2249.

Falk, M.R. and M.J. Lawrence. 1973. Seismic exploration: its nature and effect on fish. Fisheries and Marine Service, Resource Management Branch, Fisheries Operations Directorate: Technical Report CENT-73-9.

Guerra, A., A.F. González, and F. Rocha. A review of the records of giant squid in the north-eastern Atlantic and severe injuries in *Architeuthis dux* stranded after acoustic explorations. ICES CM 2004/CC: 29.

Hassel, A., T. Knutsen, J. Dalen, S. Løkkeborg, K. Skaar, Ø. Østensen, E.K. Haugland, M. Fonn, Å. Høines, and O.A. Misund. 2003. Reaction of sand eel to seismic shooting: a field experiment and fishery statistics study. Institute of Marine Research, Bergen, Norway.

Hastings, M.C. and A.N. Popper. 2005. Effects of sound on fish. Rep. by Jones & Stokes, Sacramento, CA, for California Department of Transportation, Sacramento, CA. 28 January.

Holliday, D.V., R.E. Piper, M.E. Clarke, and C.F. Greenlaw. 1987. The effects of airgun energy release on the eggs, larvae, and adults of the northern anchovy (*Engraulis mordax*). American Petroleum Institute, Washington, DC. Tracer Applied Sciences.

Kostyuchenko, L.P. 1973. Effects of elastic waves generated in marine seismic prospecting on fish eggs in the Black Sea. **Hydrobiol. J.** 9:45-48.

LaBella, G., C. Froglia, A. Modica, S. Ratti, and G. Rivas. 1996. First assessment of effects of air-gun seismic shooting on marine resources in the central Adriatic Sea. Society of Petroleum Engineers, Inc. International Conference on Health, Safety and Environment, New Orleans, Louisiana, U.S.A., 9–12 June 1996.

Løkkeborg, S. 1991. Effects of geophysical survey on catching success in longline fishing. **ICES CM B** 40:9 p.

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch, and K. McCabe. 2000a. Marine seismic surveys: analysis of airgun signals; and effects of air gun exposure on humpback whales, sea turtles, fishes and squid. Rep. from Centre for Marine Science and Technology, Curtin Univ., Perth, W.A., for Austral. Petrol. Prod. Assoc., Sydney, N.S.W. 188 p.

McCauley, R.D., J. Fewtrell, A.J. Duncan, M.-N. Jenner, M-N., C. Jenner, R.I.T. Prince, A. Adhitya, K. McCabe, and J. Murdoch. 2000b. Marine seismic surveys–a study of environmental implications. **APPEA J.** 40:692-708.

McCauley, R.D., J. Fewtrell, and A.N. Popper. 2003. High intensity anthropogenic sound damages fish ears. **J. Acoust. Soc. Am.** 113(1):638-642.

Payne, J.F., C.A. Andrews, L.L. Fancey, A.L. Cook, and J.R. Christian. 2007. Pilot study on the effects of seismic air gun noise on lobster (*Homarus americanus*). **Can. Tech. Rep. Fish. Aquatic Sci.** 2712.

Payne, J.F., C. Andrews, L. Fancey, D. White, and J. Christian. 2008. Potential effects of seismic energy on fish and shellfish: An update since 2003. Canadian Science Advisory Secretariat Research Document 2008/060.

Department of Fisheries and Oceans Canada. Accessed on 8 May 2010 at www.dfo-mpo.gc.ca/CSAS/Csas/Publications/ResDocs-DocRech/2008/2008_060_e.pdf. Lasted updated 26 November 2008. 16 p.

Payne, J.F., J. Coady, and D. White. 2009. Potential effects of seismic airgun discharges on monkfish eggs (*Lophius americanus*) and larvae. Environmental Studies Research Funds Report No. 170. St. John's, NL. 35 p.

Pearson, W.H., J.R. Skalski, and C.I. Malme. 1992. Effects of sounds from a geophysical survey device on behaviour of captive rockfish (*Sebastes* spp.). **Can. J. Fish. Aquat. Sci.** 49(7):1343-1356.

Pearson, W., J. Skalski, S. Sulkin, and C. Malme. 1994. Effects of seismic energy releases on the survival and development of zoeal larvae of Dungeness crab (*Cancer magister*). **Mar. Environ. Res**. 38: 93-113.

Pickett, G.D., D.R. Eaton, R.M.H. Seaby, and G.P. Arnold. 1994. Results of bass tagging in Poole Bay during 1992. Lab. Leafl., MAFF Direct. Fish. Res., Lowestoft, (74). 12 p.

Popper, A.N. 2005. A review of hearing by sturgeon and lamprey. Report by A.N. Popper, Environmental BioAcoustics, LLC, Rockville, MD, for U.S. Army Corps of Engineers, Portland District.

Popper, A.N., M. Salmon, and K.W. Horch. 2001. Acoustic detection and communication by decapod crustaceans. **J. Comp. Physiol. A** 187: 83-89.

Popper, A.N., M.E. Smith, P.A. Cott, B.W. Hanna, A.O. MacGillivray, M.E. Austin, and D.A. Mann. 2005. Effects of exposure to seismic airgun use on hearing of three fish species. **J. Acoust. Soc. Am.** 117:3958-3971.

Rogers, P. and M. Cox. 1988. Underwater sound as a biological stimulus. p. 131-149 *In*: J. Atema., R.R. Fay, A.N. Popper, and W.N. Tavolga (eds.), The sensory biology of aquatic animals. Springer-Verlag, New York, NY.

Saetre, R. and E. Ona. 1996. Seismike undersøkelser og på fiskeegg og -larver en vurdering av mulige effecter pa bestandsniva. [Seismic investigations and damages on fish eggs and larvae; an evaluation of possible effects on stock level]. **Fisken og Havet** 1996:1-17, 1-8. (in Norwegian, with an English summary).

Santulli, A., A. Modica, C. Messina, L. Ceffa, A. Curatolo, G. Rivas, G. Fabi, and V. D'Amelio. 1999. Biochemical responses of European sea bass (*Dicentrarchus labrax* L.) to the stress induced by off shore experimental seismic prospecting. **Mar. Pollut. Bull.** 38(12):1105-1114.

Skalski, J.R., W.H. Pearson, and C.I. Malme. 1992. Effects of sounds from a geophysical survey device on catch-per-unit-effort in a hook-and-line fishery for rockfish (*Sebastes* spp). **Can. J. Fish. Aquatic Sci.** 49:1357-1365.

Slotte, A., K. Hansen, J. Dalen, and E. Ona. 2004. Acoustic mapping of pelagic fish distribution and abundance in relation to a seismic shooting area off the Norwegian west coast. **Fish. Res.** 67:143-150.

Sverdrup, A., E. Kjellsby, P.G. Krüger, R. Fløysand, F.R. Knudsen, P.S. Enger, G. Serck-Hanssen, and K.B. Helle. 1994. Effects of experimental seismic shock on vasoactivity of arteries, integrity of the vascular endothelium and on primary stress hormones of the Atlantic salmon. **J. Fish Biol.** 45: 973-995.

Wardle, C.S., T.J. Carter, G.G. Urquhart, A.D.F. Johnstone, A.M. Ziolkowski, G. Hampson, and D. Mackie. 2001. Effects of seismic air guns on marine fish. **Cont. Shelf Res.** 21(8-10):1005-1027.