Request by Lamont-Doherty Earth Observatory for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during a Marine Geophysical Survey by the R/V *Marcus G. Langseth* in the Southwest Pacific Ocean, January–February 2009

submitted by

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

to

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

Application Prepared by

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

15 August 2008

LGL Report TA4686-2

TABLE OF CONTENTS

Request by Lamont-Doherty Earth Observatory for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during a Marine Geophysical Survey by the R/V *Marcus G. Langseth* in the Southwest Pacific Ocean, January–February 2009

SUMMARY

Lamont-Doherty Earth Observatory (L-DEO) plans to conduct a marine seismic survey in the Lau Basin of the Southwest Pacific Ocean (SWPO) during January–February 2009 as part of the National Science Foundation's (NSF) RIDGE 2000 program. The survey will take place in the Exclusive Economic Zone (EEZ) of Tonga, in water depths >1000 m. The seismic study will use a towed array of 36 airguns with a total discharge volume of ~6600 in^3, firing at relatively long intervals—once every 400 m (180 s). L-DEO requests that it be issued an Incidental Harassment Authorization (IHA) allowing non-lethal takes of marine mammals incidental to the planned seismic survey. This request is submitted pursuant to Section 101 (a) (5) (D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371 (a) (5).

Numerous species of marine mammals inhabit Lau Basin and the waters of Tonga. Several of these species are listed as ***endangered*** under the U.S. Endangered Species Act (ESA), including the sperm, humpback, sei, fin, and blue whales. Other listed species that could occur in the study area include the ***endangered*** leatherback and hawksbill turtles, and the ***threatened*** green, olive ridley, and loggerhead turtles. L-DEO is proposing a monitoring and mitigation program to minimize the impacts of the proposed activity on marine mammals and sea turtles present during conduct of the proposed research, and to document the nature and extent of any effects.

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

I. OPERATIONS TO BE CONDUCTED

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

Overview of the Activity

L-DEO plans to conduct a seismic survey in the SWPO as part of the Lau Integrated Studies Site (Lau ISS) initiative of NSF's RIDGE 2000 program. The survey will encompass the area 19°40'–21°30'S, 175°30'–176°50'W within the EEZ of Tonga (Fig. 1). The project is scheduled to occur ~14 January–21 February 2009.

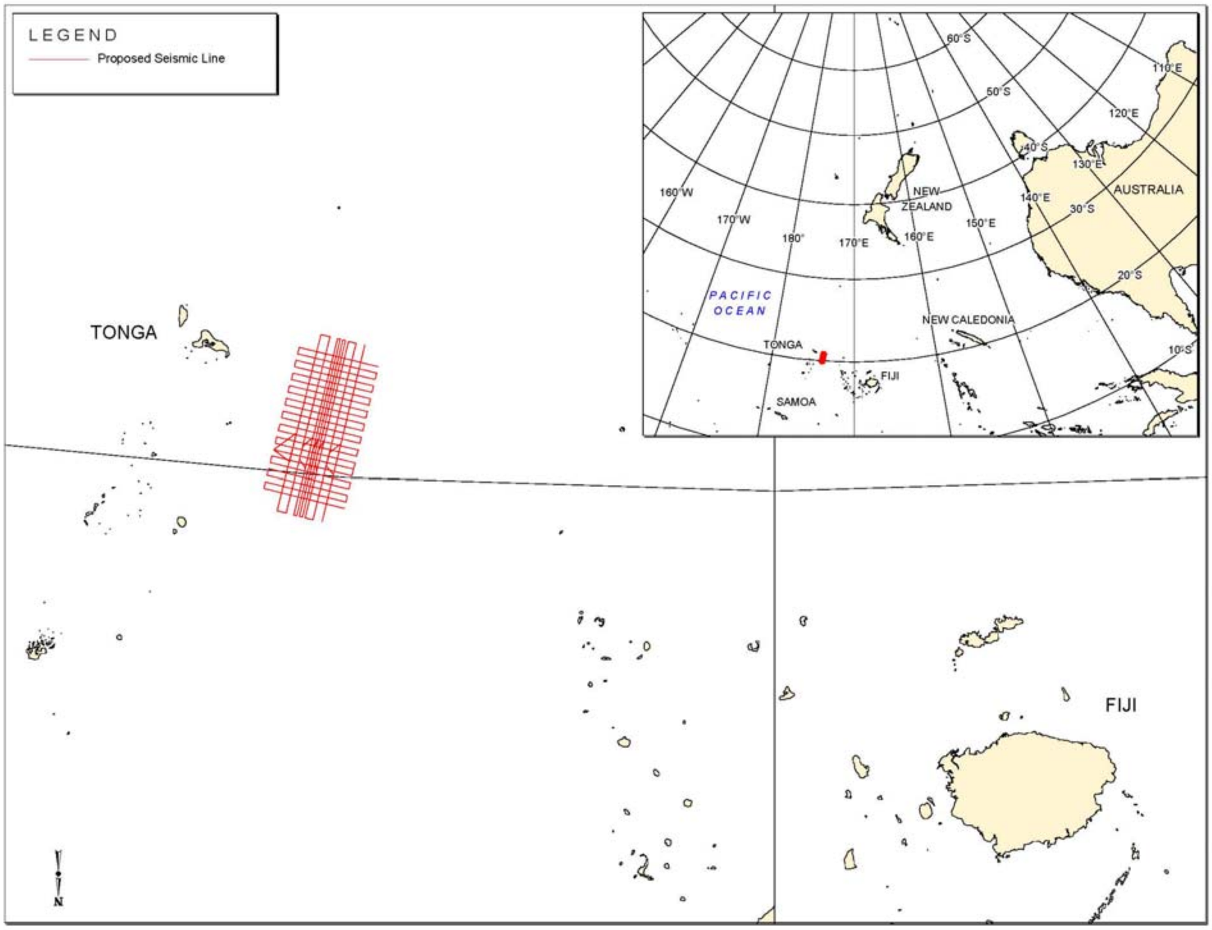

FIGURE 1. Study area and proposed seismic transect lines in the Lau Basin, Southwest Pacific Ocean.

The proposed survey will provide data integral to advancing scientific understanding of the Eastern Lau Spreading Center (ELSC) magma storage and thermal system. This study is part of NSF's RIDGE 2000 program, which was developed to facilitate the study of mid-ocean ridges and back-arc spreading centers. These areas mark the boundaries where oceanic plates separate from one another. Around the mid-ocean ridges, heat from the mantle drives vast hydrothermal systems that influence ocean water chemistry and nourish enormous ecosystems. By affecting the chemical and thermal make-up of our oceans, mid-ocean ridges may influence global climatic conditions. Understanding cycles of mass and energy flux through the mid-ocean ridge systems helps us understand the history of the planet and predict its future.

Within the RIDGE 2000 program, the Lau ISS initiative is an interdisciplinary research program focused on understanding the combined mass, fluid, thermal, and biological processes interacting within the ELSC. The proposed survey in the Lau Basin is part of the Lau ISS initiative, and the survey's main purpose is to image the magmatic systems and thermal structure at the ELSC. These images will increase our understanding of the magma supply and volcanic processes along the ridge and the source of heat for the hydrothermal systems that support the biological communities. This information can in turn be used to understand how mid-ocean ridges influence global climatic conditions, and to obtain improved locations and source properties of regional earthquakes. The information is vital to understanding plate tectonic processes and their effects on earthquake occurrence and distribution.

The source vessel, the R/V *Marcus G. Langseth*, will deploy an array of 36 airguns as an energy source at a tow depth of 9–12 m. The receiving system for the returning acoustic signals will consist of ~55–64 Ocean Bottom Seismometers (OBSs). A relatively short (up to 6-km) hydrophone streamer may also be used. As the airgun array is towed along the survey lines, the hydrophone streamer would receive the returning acoustic signals and transfer the data to the on-board processing system. The OBSs record the returning acoustic signals internally for later analysis.

The planned seismic survey will consist of ~3650 km of survey lines along the ELSC. All survey effort will take place in deep (>1000 m) water. To understand the ridge magma plumbing system and thermal structure of the ELSC, the delineation of lateral heterogeneity in physical properties at scales of several hundred meters to a few kilometers is needed. To achieve this, the proposed seismic transects (Fig. 2) will allow the tomographical imaging in three-dimensions of the physical properties of the crust and uppermost mantle of this area.

There will be additional operations associated with equipment testing, startup, line changes, and repeat coverage of any areas where initial data quality is sub-standard. In our calculations (see § VII), 25% has been added to the total planned line-length to allow for those additional operations. In addition to the operations of the airgun array, a multibeam echosounder (MBES) and a sub-bottom profiler (SBP) will be operated from the *Langseth* continuously throughout the ELSC cruise.

All planned geophysical data acquisition activities will be conducted by L-DEO with on-board assistance by the scientists who have proposed the study. The scientific team consists of Dr. Doug Wiens (Washington University), Dr. Robert Dunn (University of Hawaii), Dr. Donna Blackman (Scripps Institution of Oceanography), and Dr. Spahr Webb (L-DEO). The vessel will be self-contained, and the crew will live aboard the vessel for the entire cruise.

Vessel Specifications

The R/V *Marcus G. Langseth* will be used as the source vessel. The *Langseth* will tow the 36-airgun array along predetermined lines (Fig. 2). The *Langseth* will also deploy and retrieve the OBSs and, if used, a hydrophone streamer. If the *Langseth* is towing the airgun array as well as the hydrophone streamer, the turning rate of the vessel while the gear is deployed is limited to five degrees per minute. Thus, the maneuverability of the vessel is limited during operations with the streamer.

The *Langseth* has a length of 71.5 m, a beam of 17.0 m, and a maximum draft of 5.9 m. The *Langseth* was designed as a seismic research vessel, with a propulsion system designed to be as quiet as possible to avoid interference with the seismic signals. The ship is powered by two Bergen BRG-6 diesel engines, each producing 3550 hp, which drive the two propellers directly. Each propeller has four blades, and the shaft typically rotates at 750 revolutions per minute (rpm). The vessel also has an 800 hp bow-thruster, which is not used during seismic acquisition. The operation speed during seismic acquisition is typically 7.4–9.3 km/h. When not towing seismic survey gear, the *Langseth* can cruise at 20–24 km/h. The *Langseth* has a range of 25,000 km.

The *Langseth* will also serve as the platform from which vessel-based marine mammal (and sea turtle) observers (MMOs) will watch for animals before and during airgun operations, as described in § XIII, below.

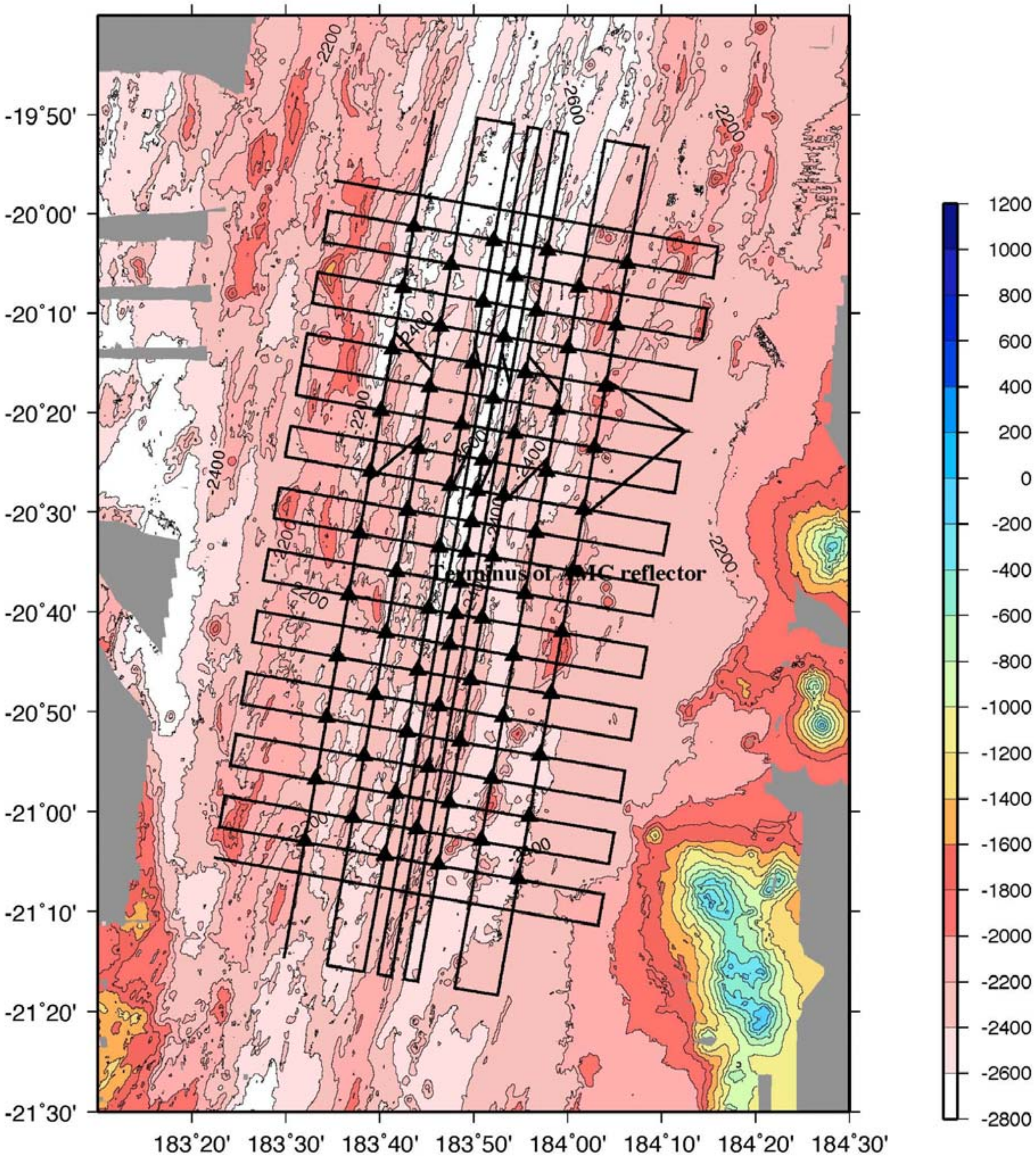

FIGURE 2. Study area and proposed seismic transect lines (solid black lines) in the Lau Basin, Southwest Pacific Ocean. Triangles represent OBS locations. The Axial Magma Chamber (AMC) reflector is a feature that sits ~2 km beneath the seafloor and is a sill filled with magma.

Other details of the *Langseth* include the following:

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

Airgun Description

During the survey, the airgun array to be used will consist of 36 airguns, with a total volume of ~6600 in^3. The airgun array will consist of a mixture of Bolt 1500LL and Bolt 1900LLX airguns. The airguns will be configured as four identical linear arrays or “strings” (Fig. 3). Each string will have ten airguns; the first and last airguns in the strings are spaced 16 m apart. Nine airguns in each string will be fired simultaneously, whereas the tenth is kept in reserve as a spare, to be turned on in case of failure of another airgun. The four airgun strings will be distributed across an area of ~24×16 m behind the *Langseth* and will be towed ~50–100 m behind the vessel. The airgun array will fire every ~400 m (180 s) for OBS refraction data. The firing pressure of the array is 1900 psi. During firing, a brief (~0.1 s) pulse of sound is emitted. The airguns will be silent during the intervening periods.

The tow depth of the array will typically be 9 m, but the tow-depth may, at times, be adjusted to 12 m. The depth at which the source is towed (particularly a large source) affects the maximum near-field output and the shape of its frequency spectrum. If the source is towed at 12 m, the effective source level for sound propagating in near-horizontal directions is higher than if the array is towed at shallow depths (see Fig. 4–6 and Table 1, later). However, the nominal source levels of the array (or the estimates of the sound that would be measured from a theoretical point source emitting the same total energy as the airgun array) at various tow depths are nearly identical. In our calculations, we have assumed a tow depth of 12 m at all times.

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

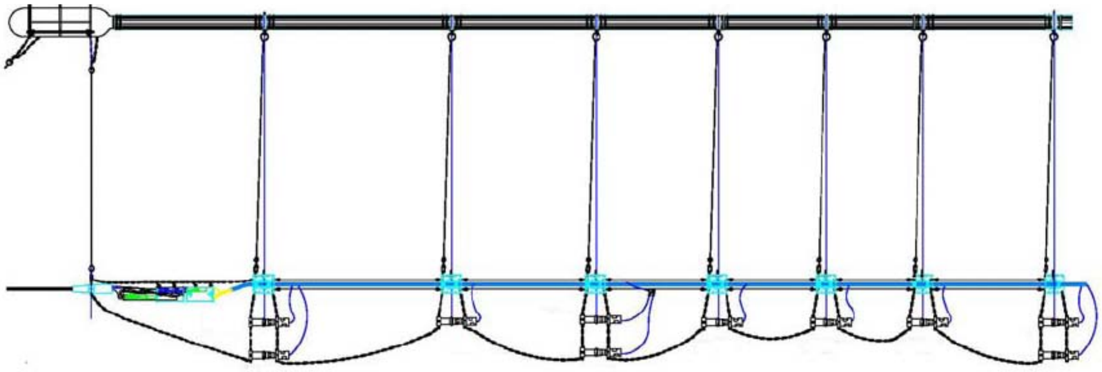

FIGURE 3. One linear airgun array or string with ten airguns, nine of which would be operating.

36-Airgun Array Specifications

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

Acoustic Measurement Units

Received sound levels have been predicted by L-DEO, in relation to distance and direction from the airguns, for the 36-airgun array (Fig. 4 and 5) and for a single 1900LL 40-in^3 airgun, which will be used during power downs (Fig. 6). The maximum relevant depth shown on the Figures by the straight dashed line is the maximum assumed dive depth for deep-diving marine mammals and is relevant for predicting exclusion zones (EZ) in deep water (see below). A detailed description of the modeling effort is provided in Appendix A of the Environmental Assessment (EA).

The predicted sound contours are shown as sound exposure levels (SEL) in decibels (dB) re 1 $\mu\text{Pa}^2 \cdot \text{s}$. SEL is a measure of the received energy in the pulse and represents the sound pressure level (SPL) that would be measured if the pulse energy were spread evenly across a 1-s period. Because actual seismic pulses are less than 1 s in duration in most situations, this means that the SEL value for a given pulse is usually lower than the SPL calculated for the actual duration of the pulse (see Appendix B of the EA). The advantage of working with SEL is that the SEL measure accounts for the total received energy in the pulse, and biological effects of pulsed sounds are believed to depend mainly on pulse energy (Southall et al. 2007). In contrast, SPL for a given pulse depends greatly on pulse duration. A pulse with a given SEL can be long or short depending on the extent to which propagation effects have “stretched” the pulse duration. The SPL will be low if the duration is long and higher if the duration is short, even though the pulse energy (and presumably the biological effects) are the same.

Although SEL is now believed to be a better measure than SPL when dealing with biological effects of pulsed sound, SPL is the measure that has been most commonly used in studies of marine mammal reactions to airgun sounds and in NMFS guidelines concerning levels above which “taking” might occur. SPL is often referred to as rms or “root mean square” pressure, averaged over the pulse duration. As noted above, the rms received levels that are used as impact criteria for marine mammals are not directly comparable to pulse energy (SEL). At the distances where rms levels are 160–190 dB re 1 μPa, the difference between the SEL and SPL values for the same pulse measured at the same location usually average ~10–15 dB, depending on the propagation characteristics of the location (Greene 1997; McCauley et al. 1998, 2000a; see Appendix B of the EA). Here, we assume that rms pressure levels of received seismic pulses will be 10 dB higher than the SEL values predicted by L-DEO’s model. Thus, we assume that 170 dB SEL $\approx$ 180 dB re 1 $\mu\text{Pa}_{\text{rms}}$.

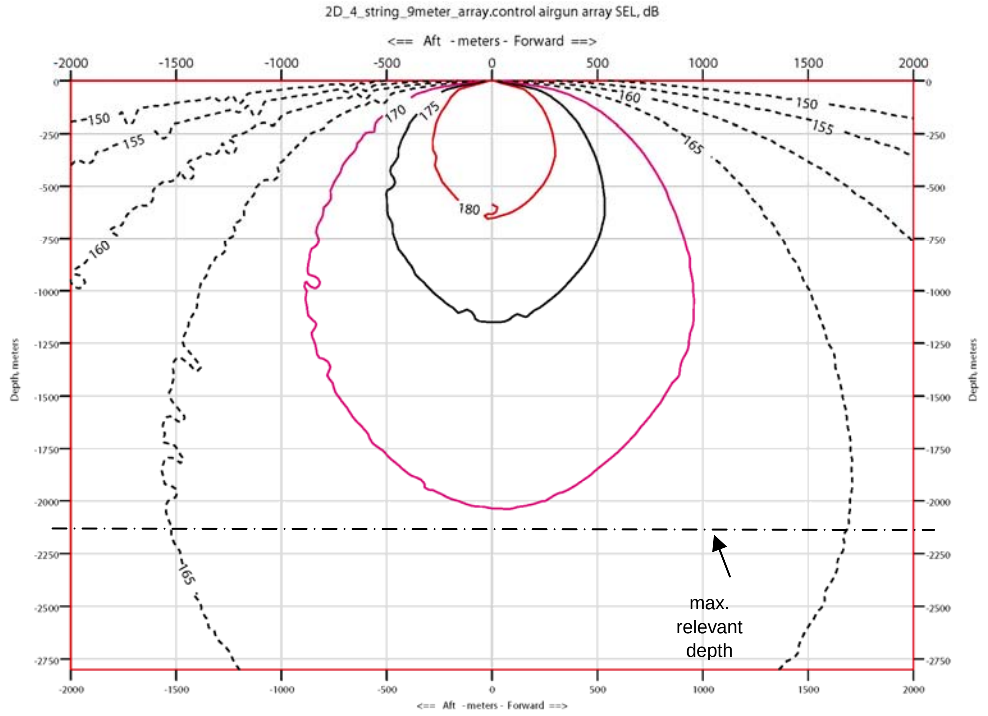

FIGURE 4. Modeled received sound levels (SELs) from the 36-airgun array operating in deep water at a ***9-m*** tow depth, planned for use during the ELSC survey, 14 January–21 February 2009. Received rms levels (SPLs) are expected to be ~10 dB higher. Maximum relevant depth is applicable to marine mammals.

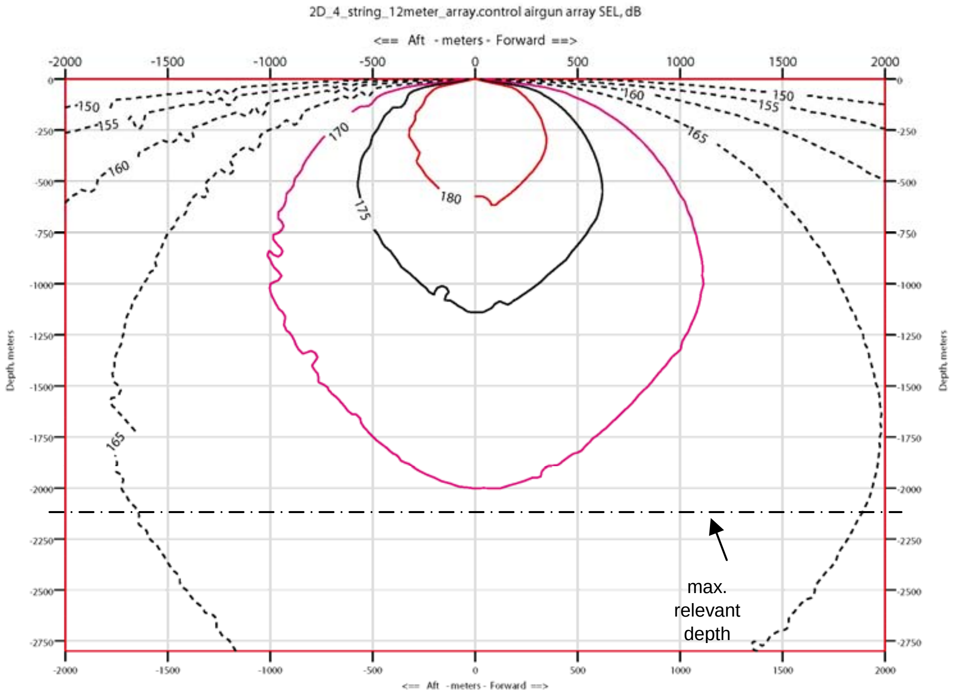

FIGURE 5. Modeled received sound levels (SELs) from the 36-airgun array operating in deep water at a ***12-m*** tow depth, planned for use during the ELSC survey, 14 January–21 February 2009. Otherwise as above.

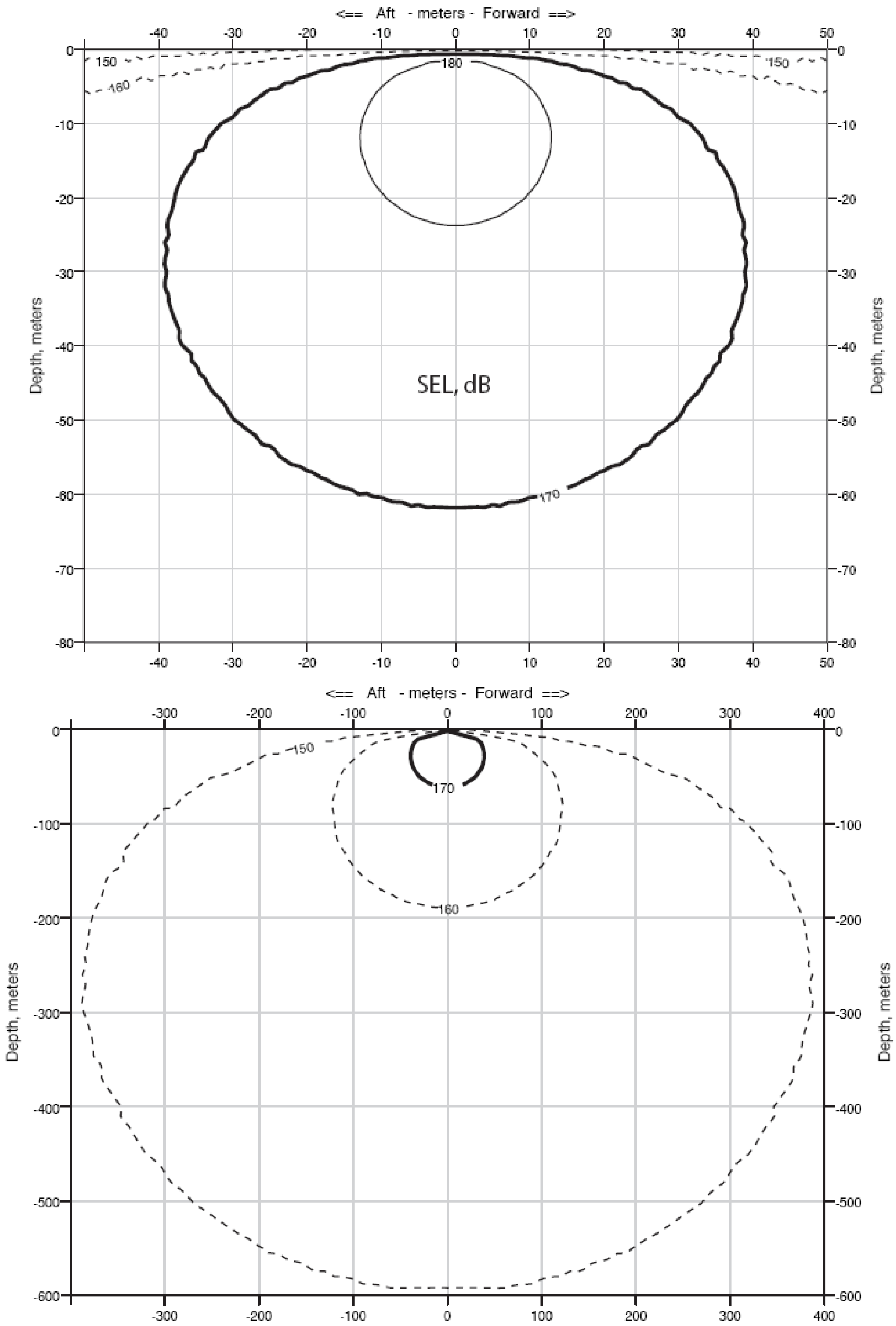

FIGURE 6. Modeled received sound levels (SELs) from a single 40-in^3 airgun operating in deep water, which is planned for use during the ELSC survey, 14 January–21 February 2009. Received rms levels (SPLs) are expected to be ~10 dB higher.

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

Predicted Sound Levels vs. Distance and Depth

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

During the ELSC study, all survey effort will take place in deep (>1000 m) water. The L-DEO model does not allow for bottom interactions, and thus is most directly applicable to deep water and to relatively short ranges. The modeled distances shown in Figures 4–6 for the planned *Langseth* airgun configuration operating in deep water are summarized in Table 1. As very few, if any, mammals are expected to occur below 2000 m, this depth was used as the maximum relevant depth in determining these distances. The tabulated distances are expected to overestimate the actual distances to the corresponding SPLs, given the deep-water results of Tolstoy et al. (2004a,b).

Table 1 shows the distances at which four rms sound levels are expected to be received from the 36-airgun array and a single airgun operating in water >1000 m deep. 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 during most other recent L-DEO seismic projects (e.g., Smultea et al. 2004; Holst et al. 2005b; Holst and Beland 2008; Holst and Smultea 2008). If marine mammals or turtles are detected within or about to enter the appropriate EZ, the airguns will be powered down (or shut down if necessary) immediately.

The conclusion that the model predictions in Table 1 are precautionary, relative to actual 180 and 190-dB (rms) radii, is based on empirical data from the acoustic calibration of different airgun configurations than those used on the *Langseth* (*cf.* Tolstoy et al. 2004a,b); that sound source verification study was done in the northern Gulf of Mexico. L-DEO has recently (late 2007/early 2008) conducted a more extensive acoustic calibration study of the *Langseth*'s 36-airgun (~6600-in^3) array, also in the northern Gulf of Mexico (LGL Ltd. 2006; Holst and Beland 2008). Distances where various sound levels

TABLE 1. Predicted distances to which sound levels ≥190, 180, 170 and 160 dB re 1 μPa$_{rms}$ could be received in deep (>1000 m) water from the 36-airgun array, as well as a single airgun, planned for use during the Eastern Lau Spreading Centre survey, 14 January–21 February 2009 (based on L-DEO modeling). Predicted radii are based on Figures 4–6, assuming that received levels on an RMS basis are, numerically, 10 dB higher than the SEL values shown in Figures 4–6, and that mammals would not typically occur at depths >2000 m.

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

* The tow depth has minimal effect on the maximum near-field output and the shape of the frequency spectrum for the single 40 in^3 airgun; thus, the predicted safety radii are essentially the same at each tow depth. The most precautionary distances (i.e., for the deepest tow depth, 12 m) are shown.

(e.g., 190, 180, 170, and 160 dB re 1 μPa$_{rms}$) were received are being determined for various airgun configurations and water depths. Those results are not yet available. However, the empirical data from the 2007/2008 calibration study will be used to refine the EZs proposed above for use during the cruise, if the data are appropriate and available at the time of the ELSC survey.

Southall et al. (2007) made detailed recommendations for new science-based noise exposure criteria. L-DEO will be prepared to revise its procedures for estimating numbers of mammals "taken", 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.

Description of Operations

The source vessel, the R/V *Marcus G. Langseth*, will deploy an array of 36 airguns as an energy source at a tow depth of 9–12 m. The receiving system for the returning acoustic signals will consist of ~55–64 OBSs. The OBSs record the returning acoustic signals internally for later analysis. A hydrophone streamer up to 6 km in length may also be used. As the airgun array is towed along the survey lines, the hydrophone streamer would receive the returning acoustic signals and transfer the data to the on-board processing system.

The planned seismic survey will consist of ~3650 km of survey lines. All survey effort will take place in deep (>1000 m) water. There will be additional operations associated with equipment testing, start up, line changes, and repeat coverage of any areas where initial data quality is sub-standard. In addition to the operations of the airgun array, a 12-kHz Simrad EM120 MBES and a 3.5-kHz SBP will also be operated from the *Langseth* continuously throughout the ELSC cruise.

OBS Description and Deployment

A total of ~55–64 OBSs will be deployed during the survey and will be spaced ~10–12 km apart (Fig. 2). An initial network of ~55 OBSs will be deployed over the southern part of the study area (south of ~20º15'S). This area will be surveyed first with the 36-airgun array. Some of the OBSs from the initial network will then be retrieved and redeployed over the northern part of the study area so that a second network of ~18 OBSs can be surveyed. All OBSs will be retrieved at the end of the study. Throughout the study, ~16.5 days will be spent deploying and retrieving OBSs.

Two different types of OBSs will be used. The Woods Hole Oceanographic Institution (WHOI) "D2" OBS has a height of ~1 m and a maximum diameter of 50 cm. The anchor is made of hot-rolled steel and weighs 23 kg. The anchor dimensions are 2.5 × 30.5 × 38.1 cm. The other OBS type is the LC4x4 from Scripps Institution of Oceanography. This OBS unit has a volume of ~1 m^3, with an anchor that consists of a large piece of steel grating (~1 m^2). Once the OBS is ready to be retrieved, an acoustic release transponder interrogates the OBS at a frequency of 9–11 kHz, and a response is received at a frequency of 9–13 kHz. The burn wire release assembly is then activated, and the instrument is released from the anchor to float to the surface.

Multibeam Echosounder

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

Sub-bottom Profiler

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

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

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

II. DATES, DURATION, AND REGION OF ACTIVITY

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

The survey will encompass the area 19°40'–21°30'S, 175°30'–176°50'W, within the EEZ of Tonga (Fig. 1). Water depths in the survey area range from 1000 m to 2600 m, and the survey will not approach land closer than 42 km. The project is scheduled to occur 14 January–21 February 2009. The *Langseth* is expected to depart Nuku'alofa, Tonga, on ~14 January 2009 for a one-day transit to the study area in the Lau Basin. Once at the study area, ~19 days of seismic operations will occur. Approximately 16.5 days will be spent deploying and recovering OBSs. Once all of the equipment is recovered at the end of the study, the vessel will start on the two-day transit to Suva, Fiji, for arrival on ~21 February 2009. The exact dates of the activities depend on logistics, weather conditions, and the need to repeat some lines if data quality is substandard.

III. SPECIES AND NUMBERS OF MARINE MAMMALS IN AREA

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

Thirty species of cetacean may occur in the proposed ELSC study area in the SWPO, including 21 odontocete (dolphins and small- and large-toothed whales) species and nine mysticete (baleen whales) (Table 2). Five of those species are listed as ***endangered*** under the ESA: the sperm, humpback, fin, sei, and blue whales. In addition to those six species, the southern bottlenose, pygmy right, Antarctic minke, minke, and Bryde's whales are listed in Appendix I (i.e., threatened with extinction) by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

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

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

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

Sections III and IV are integrated here to minimize repetition.

The marine mammals that occur in the ELSC study area belong to two taxonomic groups: odontocetes (toothed cetaceans, such as dolphins) and mysticetes (baleen whales). Pinnipeds are not expected to occur in the study area. Thus, only cetaceans are the subject of this IHA application. Several of the 30 marine mammal species are common in the area (see below). However, there have been limited surveys for marine mammals in the proposed study area in Lau Basin. What information exists for the area is given in the species accounts below, in part derived from Reeves et al. (1999), who summarized information from the area served by the South Pacific Regional Environment Programme (SPREP). The SPREP region covers a vast area of the Pacific Ocean between the Tropic of Capricorn and the Equator from Papua New Guinea (140°E) to Pitcairn Island (130°W).

TABLE 2. The habitat, occurrence, regional population sizes, and conservation status of marine mammals that could occur in or near the proposed seismic survey area in the Lau Basin, Southwest Pacific Ocean.

Species	Habitat	Occurrence in the South Pacific Ocean	Regional population size	U.S. ESA[1]	IUCN[2]	CITES[3]
Mysticetes						
Humpback whale (*Megaptera novaeangliae*)	Mainly nearshore waters and banks	Rare in Jan–Feb	~6200[4]	EN	VU	I
Pygmy right whale (*Caperea marginata*)	Coastal and oceanic	Common	N.A.	-	N.A.	I
Antarctic minke whale (*Balaenoptera bonaerensis*)	Coastal and oceanic	Rare in Jan–Feb	140,000–155,000[5]	-	LR-cd	I
Minke whale (*Balaenoptera acutorostrata*)	Pelagic and coastal	Rare in Jan–Feb	140,000–155,000[5]	-	LR-nt	I
Bryde's whale (*Balaenoptera edeni*)	Pelagic and coastal	Common	20,000-30,000[6]	-	DD	I
Sei whale (*Balaenoptera borealis*)	Primarily offshore, pelagic	Common	12,000[7]	EN	EN	I
Fin whale (*Balaenoptera physalus*)	Continental slope, mostly pelagic	Uncommon in Jan–Feb	3031[8]	EN	EN	I
Blue whale (*Balaenoptera musculus*)	Pelagic and coastal	Uncommon in Jan–Feb	756[9]	EN	EN	I
Odontocetes						
Sperm whale (*Physeter macrocephalus*)	Usually pelagic and deep seas	Common	22,700[10]	EN	VU	I
Pygmy sperm whale (*Kogia breviceps*)	Deep waters off the shelf	Common	N.A.	-	N.A.	II
Dwarf sperm whale (*Kogia sima*)	Deep waters off the shelf	Uncommon?	11,200[10]	-	N.A.	II
Cuvier's beaked whale (*Ziphius cavirostris*)	Pelagic	Common	20,000[10]	-	DD	II
Southern bottlenose whale (*Hyperoodon planifrons*)	Pelagic	Rare	N.A.	-	LR-cd	I
Longman's beaked whale (*Indopacetus pacificus*)	Pelagic	Uncommon	NA	-	DD	II
Blainville's beaked whale (*Mesoplodon densirostris*)	Pelagic	Common	25,300[10*]	-	DD	II
Ginkgo-toothed beaked whale (*Mesoplodon ginkgodens*)	Pelagic	Rare	25,300[10*]	-	DD	II
Rough-toothed dolphin (*Steno bredanensis*)	Deep water	Uncommon	145,900[10]	-	DD	II
Bottlenose dolphin (*Tursiops truncatus*)	Coastal and oceanic, shelf break	Common	243,500[10]	-	DD	II
Pantropical spotted dolphin (*Stenella attenuata*)	Coastal and pelagic	Uncommon	1,298,400[10]	-	LR-cd	II
Spinner dolphin (*Stenella longirostris*)	Coastal and pelagic	Rare south of 15ºS	1,019,300[10]	-	LR-cd	II
Striped dolphin (*Stenella coeruleoalba*)	Off continental shelf	Rare	1,918,000[10]	-	LR-cd	II
Fraser's dolphin (*Lagenodelphis hosei*)	Waters >1000 m	Rare south of 30°S	289,300[10]	-	DD	II
Short-beaked common dolphin (*Delphinus delphis*)	Shelf and pelagic, seamounts	Common	2,210,900[10]	-	N.A.	II
Risso's dolphin (*Grampus griseus*)	Waters >1000 m, seamounts	Common	175,800[10]	-	DD	II
Melon-headed whale (*Peponocephala electra*)	Oceanic	Uncommon south of 20ºS	45,400[10]	-	N.A.	II

Species	Habitat	Occurrence in the South Pacific Ocean	Regional population size	U.S. ESA[1]	IUCN[2]	CITES[3]
Pygmy killer whale (*Feresa attenuata*)	Deep, pantropical waters	Uncommon	38,900[10]	-	DD	II
False killer whale (*Pseudorca crassidens*)	Pelagic	Uncommon	39,800[10]	-	N.A.	II
Killer whale (*Orcinus orca*)	Widely distributed	Common	8,500[10]	-	LR-cd	II
Short-finned pilot whale (*Globicephala macrorhynchus*)	Mostly pelagic, high-relief topography	Common north of 40°S	160,200[10†]	-	LR-cd	II

N.A. - Data not available or species status was not assessed.
[1] EN = Endangered, - = Not listed
[2] EN = Endangered; VU = Vulnerable; LR = Lower Risk (-cd = Conservation Dependent; -nt = Near Threatened); DD = Data Deficient (IUCN 2007).
[3] UNEP-WCMC 2008.
[4] Humpback Group E, 2004 (Johnston and Butterworth 2005).
[5] Antarctic Area V, 1991/1992-2003/2004 (Branch 2006).
[6] Western South Pacific (IWC 1981 *in* Reeves et al. 1999).
[7] Antarctic Area V, 1973 (Horwood 1987:295).
[8] Antarctic Area V, 2003 (Murase et al. 2005).
[9] Antartctic Area V, 2001/2002-2003/2004 (Branch 2007)
[10] Eastern Tropical Pacific (Wade and Gerrodette 1993).
* Estimate is for all *Mesoplodon* species combined.
† Estimate includes long- and short-finned pilot whales.

The survey area occurs in deep-water habitat (>1000 m) but is close to oceanic island habitats, so both coastal and oceanic species might be encountered. Abundance and density estimates of cetaceans noted below are provided for reference only, and are not necessarily the same as those that likely occur in the survey area.

Mysticetes

Pygmy Right Whale

The pygmy right whale is the smallest of the baleen whales, with a maximum length of only 6.5 m (Kemper 2002a). Its distribution is circumpolar in the Southern Hemisphere and is believed to extend from 30°S to 55°S, where water temperatures are ~5–20°C (Kemper 2002a). Little is known regarding this species, as it has rarely been seen at sea, and has a short dive time of ~4 min (Kemper 2002a). Pygmy right whales have been seen in oceanic and coastal environments (Kemper 2002a). Most animals are seen in groups of one or two, but one group of 80 has been seen in oceanic waters (Kemper 2002a). They appear to be non-migratory, although there may be some movement inshore in spring and summer (Kemper 2002b). This species may occasionally occur in the survey area (Reeves et al. 1999), but is not listed by SPREP (2007) as occurring within the SPREP region.

Humpback Whale

The humpback whale is found throughout all of the oceans of the world (Clapham 2002). The species is listed as ***Endangered*** under the ESA, ***Vulnerable*** on the 2007 IUCN Red List of Threatened Species (IUCN 2007), and it is listed in CITES Appendix I (UNEP-WCMC 2008) (Table 2). The worldwide population of humpback whales is divided into northern and southern ocean populations, but genetic analyses suggest some gene flow (either past or present) between the North and South Pacific oceans (e.g., Baker et al. 1993; Caballero et al. 2001). Although considered to be mainly a coastal species, humpback whales often traverse deep pelagic areas while migrating. Most migratory paths for southern humpback whales are unknown (Perry et al. 1999a). Humpback whales spend spring through fall on mid- or high-latitude feeding grounds, and winter on low-latitude breeding grounds, with limited interchange between regions (Clapham 2002; Baker et al. 1998; Garrigue et al. 2002). 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).

The Southern Hemisphere population that can be found south of 60°S in the austral summer feeding season is on the order of 42,000 individuals (IWC 2007a). Humpback whale populations in the Southwest Pacific were severely depleted by commercial whaling (see Robbins et al. 2008). Whereas some breeding stocks, including those off western and eastern Australia, appear to have recovered to numbers in the thousands, the humpback whales that winter off New Caledonia likely number only in the few hundreds (Baker et al. 1998; Noad et al. 2006). Some stocks that were formerly found around New Zealand and Fiji were extirpated through whaling activities and few humpbacks remain from those stocks (Gibbs et al. 2006 *in* Olavarría et al. 2007; Constantine et al. 2006). In Tonga, humpback whales were hunted until 1979 (Reeves 2002), but the population is now making some recovery (Robbins et al. 2008). Only 200–400 whales were estimated to occur off Tonga in 1979–1980 (Keller 1982 *in* Reeves et al. 1999), but based on data from 1991–2000, the population that winters around Tonga is estimated at 730–990 (IWC 2006).

Humpback whales are often sighted singly or in groups of two or three; however, while on their breeding and feeding ranges, they may occur in groups of up to 15 (Leatherwood and Reeves 1983; Donoghue 1996). Mean observed group size around the Cook Islands was 1.6 (Hauser and Clapham 2006). Humpback whales can be seen in Tongan waters from June to November, with a peak in August and September (Reeves et al. 1999). Tonga is considered an important breeding and calving ground, based on the presence of singing males, cow/calf pairs, and surface active groups (Donoghue 1996; Erikson et al. 2005). Humpbacks have been recorded from January to October around other nearby islands, including Fiji, Samoa, and Niue (Reeves et al. 1999). Peak numbers in American Samoa occur in September–October (Craig 1995 *in* Reeves et al. 1999).

Genetic evidence suggests several discrete breeding grounds in the South Pacific Ocean, including distinction between the Cook Islands, French Polynesia, Tonga, and New Caledonia (Olavarría et al. 2003, 2007; Garrigue et al. 2006a). However, photo-identification work suggests some movement between these breeding grounds, but at a relatively low level of interchange (Garrigue et al. 2002, 2006b; Hauser and Clapham 2006). Humpback whales that winter off East Australia and New Caledonia apparently belong to the Antarctic Area V stock, whereas humpback whales that winter off Tonga appear to be connected with Areas I, V, or VI (Garrigue and Gill 1994; Garrigue et al. 2002; Olavarría et al. 2003; Steel et al. 2008). However, such distinctions may be difficult to make since there is some evidence of stocks mixing on the summer feeding grounds between Antarctic areas IV (70º–130ºE), V (130ºE–170ºW), and VI (170º–120º W) (Rock et al. 2006). Albertson-Gibb et al. (2008) noted that 78.9% of animals in the Antarctic Area VI originate from Tonga. Tonga is currently identified as a sub-stock of breeding stock E, distinct from the sub-stock in New Caledonia; no feeding ground is officially recognized for humpback whales over-wintering in Tonga (Garrigue et al. 2006a; IWC 2006) .

The available evidence suggests that humpback whales could be seasonally common in waters of the survey area. However, as the survey is currently scheduled to occur during January–February, they likely would not be present in high numbers in the area at that time, it at all, because they would be on higher-latitude summer feeding grounds.

Antarctic Minke Whale

The minke whale has a cosmopolitan distribution that spans ice-free latitudes (Stewart and Leatherwood 1985). The species of minke whale in the Southern Hemisphere, the Antarctic minke whale, is found between 55°S and the ice edge during the austral summer, between 55°S and the ice edge during the austral summer, and between 10°S and 30°S, 170°E and 100°W in the austral winter (Perrin and Brownell 2002). A smaller form (unnamed subspecies) of the common minke whale, known as the dwarf minke whale, occurs in the Southern Hemisphere where its distribution overlaps with that of the Antarctic minke whale (Perrin and Brownell 2002). Although not well known, the range of the dwarf minke whale extends as far north as 11°S off Australia, where it can be found year-round, and as far south as 65°S (Reeves et al. 2002). Based on data from 1992–1993 and 2003–2004, the most recent minimum estimate of minke whale abundance from 60ºS to the Antarctic ice edge during the austral summer was 338,000, and estimated abundance in Antarctic Area V, south of the study area, was 140,000–155,000 (Branch 2006).

The minke whale is relatively solitary, usually seen individually or in groups of two or three, but can occur in large aggregations of up to 100 at high latitudes where food resources are concentrated (Perrin and Brownell 2002). Little is known about the diving behavior of minke whales, but they are not known to make prolonged deep dives (Leatherwood and Reeves 1983).

Kasamatsu et al. (1990) used data from Japanese sightings surveys in October–December 1976–1987 to suggest a breeding area for minke whales between 10°S and 20°S and from 150°W to 170°W, i.e., just east to northeast of the proposed study area. Minke whale abundance there was highest in October, at the end of the estimated peak of the Southern Hemisphere breeding season (August–October). Within the study area, abundance was fairly consistent during October and November, at 0.003/n.mi. north of 20ºS and 0.001/n.mi. south of 20ºS (Kasamatsu et al. 1990). However, in December, the abundance of minke whales in the southern portion of the study area (south of 20ºS) increased to 0.002/n.mi., but there was no comparable effort during this month in the northern portion of the study area (north of 20ºS) (Kasamatsu et al. 1990). A possible Antarctic minke whale was seen in the waters of Tonga in August/September of 2002 (SPWRC 2002), and SPREP (2007) confirms the presence of minke whales in Tonga.

Kasamatsu et al. (1990) suggested that younger animals tend to migrate early and arrive in Antarctic waters in November, whereas mature minke whales, consisting mainly of pregnant females, migrate south beginning in November, and arrive in the Antarctic by January. Minke whales then leave the Antarctic for their northward migration by February and begin arriving in waters between 30°S and 40°S in March. Thus, minke whales likely would not be present in the survey area at the scheduled time of the proposed seismic survey (January–February), because most would still be feeding farther south at that time, or just starting their migration northward from Antarctic waters.

Bryde's Whale

Bryde's whale is found in tropical and subtropical waters throughout the world between 40ºN and 40ºS, generally in waters warmer than 20ºC, but at minimum 15ºC (Reeves et al. 1999; Kato 2002; Kanda et al. 2007). Populations in the western North Pacific, western South Pacific, eastern South Pacific, and eastern Indian Ocean currently show low levels of genetic interchange (Kanda et al. 2007). The western South Pacific stock (west of 120ºW) has been estimated at 52,700 (Ohsumi 1981 *in* Kanda et al. 2007). However, using the same data, the IWC arrived at an estimate of 16,500 for the western South Pacific population (IWC 1981 *in* Reeves et al. 1999).

Some populations show a general pattern of movement toward the equator in winter and toward higher latitudes in summer, though the locations of actual winter breeding grounds are unknown (Reeves et al. 1999; Kato 2002; Kanda et al. 2007). Bryde's whales are both pelagic and coastal (Reeves et al. 1999), and occur singly or in groups of up to five. Wade and Gerrodette (1993) reported a mean group size of 1.7 for the Eastern Tropical Pacific (ETP). The durations of Bryde's whale dives are 1–20 min (Cummings 1985).

Bryde's whale densities are thought to be relatively high in the SPREP region (see Fig. 3 *in* Kato 2002), and it is likely the most abundant mysticete in the area (Reeves et al. 1999). Although no sightings have been recorded for Tonga, confirmed sightings of "Bryde's-like" whales exist for Samoa, Fiji, and New Caledonia (SPREP 2007).

Sei Whale

The sei whale has a cosmopolitan distribution, with a marked preference for temperate oceanic waters (Gambell 1985a). It is listed as ***Endangered*** under the U.S. ESA and on the 2007 IUCN Red List of Threatened Species (IUCN 2007), and it is listed in CITES Appendix I (UNEP-WCMC 2008) (Table 2). Sei whale populations were depleted by whaling, and their current status is generally uncertain (Horwood 1987). The global population is thought to be ~80,000 (Horwood 2002).

The sei whale is a mainly pelagic species and usually occurs in small groups of up to six. Sei whales generally do not dive deeply, and dive durations are 15 min or longer (Gambell 1985a). Sei whales migrate from temperate zones occupied in winter to higher latitudes in the summer, where most feeding takes place (Gambell 1985a). In the Southern Hemisphere, they migrate into and out of the Antarctic somewhat later than do blue and fin whales, and they do not migrate as far south. Their main summer concentrations appear to be between 40°S and 50°S (Gambell 1985a). They generally are not found north of 30ºS in the southern hemisphere, but can occasionally visit the southern portion of the SPREP region, which includes the study area, in the winter (Reeves et al. 1999). There have been no sightings in Tonga, but confirmed sighting records exist for Papua New Guinea and New Caledonia, with unconfirmed sightings in the Cook Islands (SPREP 2007). Sei whales likely would occur south of the seismic survey area, especially at the time that the survey is scheduled (January–February), because most sei whales feed at higher latitudes at that time.

Fin Whale

The fin whale is widely distributed in all the world's oceans (Gambell 1985b), but typically occurs in temperate and polar regions from 20° to 70° north and south of the equator (Perry et al. 1999b). It is listed as ***Endangered*** under the U.S. ESA and on the 2007 IUCN Red List of Threatened Species (IUCN 2007), and it is listed in CITES Appendix I (UNEP-WCMC 2008) (Table 2). The fin whale is sometimes observed alone or in pairs, but on feeding grounds, groups of up to 20 are more common (Gambell 1985b). 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).

Northern and southern fin whale populations are distinct, and are sometimes recognized as different subspecies (Aguilar 2002). In the Southern Hemisphere, the peak breeding season is April–August (Laws 1961). Whales from the Southern Hemisphere usually are distributed south of 50ºS in the austral summer, and in winter some migrate northward to breed (Gambell 1985b). There have been few sightings of fin whales in tropical waters, which may be related to the low level of survey effort at low latitudes (Reeves et al. 1999). The lack of records of large aggregations during the winter months suggests that they are more dispersed throughout their range during this time (Reeves et al. 1999). No sighting records exist for Tonga (SPREP 2007). They tend to enter and leave the Antarctic after the blue whales but before the sei whales (Gambell 1985b). Fin whales encountered in the seismic survey area likely would be from the New Zealand stock, which summers from 170ºE to 145ºW and winters in the Fiji Sea and adjacent waters (Gambell 1985b).

Fin whales likely would be uncommon in the survey area, especially during the time of the year that the survey is scheduled (January–February). Most fin whales would be south of the area on their summer feeding grounds, although some may have begun their migration from the Antarctic to wintering grounds in the Fiji Sea and adjacent waters.

Blue Whale

The blue whale is widely distributed throughout the world's oceans, occurring in pelagic, continental shelf, and inshore waters (Leatherwood and Reeves 1983). It is listed as ***Endangered*** under the U.S. ESA and on the 2007 IUCN Red List of Threatened Species (IUCN 2007), and it is listed in CITES Appendix I (UNEP-WCMC 2008) (Table 2). Three subspecies of blue whale are generally recognized. *B. musculus musculus* is found in the Northern Hemisphere; *B. m. intermedia* (the true blue whale) is an Antarctic species; and *B. m. brevicauda* (the pygmy blue whale) inhabits the sub-Antarctic zone of the southern Indian Ocean and the SWPO (Perry et al. 1999a; Sears 2002). A fourth subspecies has been tentatively recognized; *B. m. indica* occurs in the northern Indian Ocean (Jefferson et al. 2008). All blue whale populations have been exploited commercially, and many have been severely depleted as a result. The Southern Hemisphere population, once the most numerous population, was estimated to contain 400–1400 individuals during the years 1980–2000 (IWC 2007a). Current population estimates range from 710 to 1255 (Sears 2002).

Blue whales usually occur alone or in small groups (Leatherwood and Reeves 1983; Palacios 1999). Wade and Gerrodette (1993) reported a mean group size of 1.5 for the ETP. 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).

Generally, blue whales are seasonal migrants between high latitudes in the summer, where they feed, and low latitudes in the winter, where they mate and give birth (Lockyer and Brown 1981). During the austral summer, true blue whales are located south of the Antarctic Convergence, whereas pygmy blue whales can be found north of the Antarctic Convergence (Perry et al. 1999a). Blue whales tend to enter and leave the Antarctic before the fin whales and the sei whales (Gambell 1985b). Little information is available on blue whale wintering areas (Perry et al. 1999a).

It is likely that the pygmy blue whale occurs more regularly in the SPREP region than the true blue whale (see Kato et al. 1995 *in* Reeves et al. 1999). There have been few confirmed sightings of blue whales outside of the Solomon Islands (Reeves et al. 1999). One sighting was made near the equator at 170ºE (Reeves et al. 1999), and confirmed sightings also exist for the Cook, Marshall, and Solomon islands, as well as New Caledonia (SPREP 2007). Unconfirmed sightings have been made in Fiji and Kiribati, but no sighting records exist for Tonga (SPREP 2007).

Blue whales could be encountered during the proposed survey, but are expected to be uncommon in the area, especially during the time of the year that the survey is scheduled (January–February), as they would be far south of the area on their summer feeding grounds.

Odontocetes

Sperm Whale

Sperm whales are the largest of the toothed whales, with an extensive worldwide distribution (Rice 1989). The species is listed as ***Endangered*** under the U.S. ESA, but on a worldwide basis it is abundant and not biologically endangered. It is listed as ***Vulnerable*** on the 2007 IUCN Red List of Threatened Species (IUCN 2007), and it is listed in CITES Appendix I (UNEP-WCMC 2008) (Table 2).

Sperm whale distribution is linked to social structure—mixed groups of adult females and juvenile animals of both sexes generally occur in tropical and subtropical waters, whereas adult males are commonly found alone or in same-sex aggregations, often occurring in higher latitudes outside the breeding season (Best 1979; Watkins and Moore 1982; Arnbom and Whitehead 1989; Whitehead and Waters 1990). In the South Pacific, males range into the Antarctic (65–70°S) in the summer, whereas females are rarely seen south of 40°S.

Mature male sperm whales migrate to warmer waters to breed when they are in their late twenties (Best 1979). They spend periods of at least months on the breeding grounds, moving between mixed groups of 20–30 on average (Whitehead 1993, 2003). Wade and Gerrodette (1993) noted a mean group size of 7.9 for the ETP. In the Southern Hemisphere, mating occurs from July to March, with a peak from September to December, and most calves are born between November and March (Rice 1989).

Sperm whales generally are distributed over large areas that have high secondary productivity and steep underwater topography, in waters at least 1000 m deep (Jaquet and Whitehead 1996; Whitehead 2002a). They are often found far from shore, but can be found closer to oceanic islands that rise steeply from deep ocean waters (Whitehead 2002a). 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). During a foraging dive, sperm whales typically travel ~3 km horizontally and 0.5 km vertically (Whitehead 2003). Whales in the Galápagos Islands typically dove for ~40 min and then spent 10 min at the surface (Papastavrou et al. 1989).

There currently is no valid estimate for the size of any sperm whale population (Whitehead 2002a). Best estimates probably are those of Whitehead (2002b), who provided a sperm whale population size estimate of 12,069 for the Antarctic (south of 60°S) and a corresponding density estimate of 0.65/1000 km^2. The abundance of sperm whales in most of the remainder of the South Pacific Ocean is unknown. Sperm whale density in the proposed seismic survey area likely is substantially greater than that observed in the Antarctic, because female sperm whales generally do not occur south of 40°S, and the density of male sperm whales between 50°S and 70°S is probably <¼ of that between 30°S and 50°S (Gaskin 1973).

Sperm whales are the most common large cetacean (except perhaps for Bryde's whales) in the SPREP region (Reeves et al. 1999), and the most widespread cetacean species in the area (SPREP 2007). Sightings have been made throughout the SPREP region, including the waters of Tonga, Fiji, American Samoa, Samoa, and Niue (SPREP 2007). In 1979, 30 sperm whales were sighted off Tonga’s Tongatapu group, and both male and female sperm whales were detected acoustically in the vicinity of Tonga between 20 October and 7 November 1992 (see Reeves et al. 1999). Jaquet and Whitehead (1996) noted that high densities of sperm whales occurred along the Tonga archipelago in 1992/1993. In October–November 1977, Japanese whalers recorded sperm whales south of 21ºS between Fiji and Niue/Rarotonga (Reeves et al. 1999). Small groups of sperm whales were hunted off the Samoan islands in the late 1820s to late 1840s; they were not recorded in February–March (Reeves et al. 1999).

Mixed groups of sperm whales and some solitary males likely occur in the survey area. Young calves could also be present at the time of the year (January–February) during which the survey is scheduled.

Pygmy and Dwarf Sperm Whales

Pygmy sperm whales (*Kogia breviceps*) and dwarf sperm whales (*K. sima*) are distributed widely throughout tropical and temperate seas, but their precise distributions are unknown as most information on these species comes from strandings (McAlpine 2002). They are difficult to sight at sea, perhaps because of their avoidance reactions to ships and behavior changes in relation to survey aircraft (Würsig et al. 1998). The two species are difficult to distinguish from one another when sighted (McAlpine 2002). During sighting surveys and, hence, in population and density estimates, the two species are most often categorized together as *Kogia* spp. (Waring et al. 2008).

Barros et al. (1998) suggested that dwarf sperm whales could be more pelagic and dive deeper than pygmy sperm whales. Also, the dwarf sperm whale could prefer warmer waters than the pygmy sperm whale (McAlpine 2002). Pygmy sperm whales feed mainly on various species of squid in the deep zones of the continental shelf and slope (McAlpine et al. 1997). Pygmy sperm whales occur in small groups of up to six, and dwarf sperm whales can form groups of up to 10 (Caldwell and Caldwell 1989). Wade and Gerrodette (1993) noted a mean group size of 1.7 for the dwarf sperm whale in the ETP.

Although there are few useful estimates of abundance for pygmy or dwarf sperm whales anywhere in their range, they are thought to be fairly common in some areas. In the SPREP region, confirmed sightings have been recorded for Niue, New Caledonia, French Polynesia, Palau, Guam, and the Pitcairn Islands (SPREP 2007). Recent sighting data also confirm their presence in Tuvalu (SPWRC 2008). Unconfirmed sighting records exist for American Samoa and Fiji, but no sightings have been made in Tonga (SPREP 2007). There are stranding records for both *Kogia* species from New Caledonia (Reeves et al. 1999).

Cuvier's Beaked Whale

Cuvier's beaked whale is probably the most widespread of the beaked whales, although it is not found in polar waters (Heyning 1989). It is rarely observed at sea and is mostly known from strandings. It strands more commonly than any other beaked whale (Heyning 1989). Its inconspicuous blows, deep-diving behavior, and tendency to avoid vessels all help to explain the infrequent sightings (Barlow and Gisner 2006). Adult males of this species usually travel alone, but these whales can be seen in groups of up to 15 individuals, with a mean group size of 2.3 (MacLeod and D'Amico 2006). Wade and Gerrodette (1993) reported a mean group size of 2.2 for the ETP.

Cuvier's beaked whale is an offshore, deep-diving species that feeds on fish and squid (Heyning 2002). Its dives generally last 30–60 min, but dives of 85 min have been recorded (Tyack et al. 2006). Maximum dive depths have been reported as 1450 m (Baird et al. 2006) and 1888 m (Tyack et al. 2006). Reeves et al. (1999) reported that Cuvier's beaked whale "probably occurs in deep waters throughout much of the SPREP region". Recent sighting data confirm the presence of Cuvier's beaked whale in French Polynesia and the Cook Islands (SPWRC 2004; SPREP 2007). Sightings have also been reported for American Samoa, the Cook Islands, Niue, New Caledonia, French Polynesia, Palau, and the Pitcairn Islands (SPREP 2007). Two groups of two were sighted during >4600 km of inshore survey effort and >550 km of offshore survey effort in the Society Islands during three years of fall and spring shipboard surveys (Gannier 2000). Those sightings occurred at depths 1100 m and 2100 m. No Cuvier's beaked whales were sighted during >1000 km of inshore survey effort and >500 km of offshore survey effort during November–January 1999 in the Marquesas Islands (Gannier 2002a).

Southern Bottlenose Whale

The southern bottlenose whale generally can be found throughout the Southern Hemisphere from 30°S to the ice edge, and there are no known areas of concentration (Gowans 2002). It is apparently migratory, found in Antarctic waters during the summer (Jefferson et al. 1993). The southern bottlenose whale is primarily a deep-water animal (Mead 1989a). Its main prey is deep-water oceanic squid from Antarctic, sub-Antarctic, and more temperate areas (Clarke and Goodall 1994; Slip et al. 1995).

Southern bottlenose whales can be found in groups of 1–20 (Gowans 2002). Mean group sizes in the Antarctic (south of 60°S) were estimated as 1.77 and 1.89 for two different sets of surveys (Branch and Butterworth 2001). The southern bottlenose whale is listed by CITES as an Appendix I species (Table 2).

Possible sightings have been made in the SPREP region and the North Pacific (Reeves et al. 1999). A sighting of 25 bottlenose whales was made northeast of the Phoenix Islands in 1966 (Reeves et al. 1999). Bottlenose whales have also been seen in the Philippines and the ETP (Wade and Gerrodette 1993; Reeves et al. 1999). It is possible that some sightings in these areas were of Longman’s beaked whales. SPREP (2007) reported on confirmed sightings of southern bottlenose whales in Kiribati.

Longman’s Beaked Whale

Until very recently, Longman's beaked whale was thought to be extremely rare, and 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). It seems likely that it is, in fact, the cetacean that has been seen in Indo-Pacific waters and called the “tropical bottlenose whale”. Some authorities place the species in the genus *Mesoplodon*, but there now seems to be sufficient information to afford it status as a separate genus (Dalebout et al. 2003).

Pitman et al. (1999) suggested that several sightings of bottlenose whales in the tropical Pacific were misidentifications (e.g., Wade and Gerrodette 1993) and were, in fact, sightings of Longman’s beaked whale. Sightings of Longman’s beaked whale have occurred at many locations in tropical waters of the Indo-Pacific region (Jefferson et al. 2008). They have been sighted in waters with temperatures 21–31ºC, and have been seen in the tropics every month of the year except June, indicating year-round residency (Pitman et al. 1999; Jefferson et al. 2008). Longman’s beaked whales have been seen alone, but more commonly in groups of at least ten and up to 100, with an average group size of 15–20 (Reeves et al. 2002; Jefferson et al. 2008). Pitman et al. (1999) reported a mean group size of 18.5 in the tropics. Dives are thought to last 18–33 min (Reeves et al. 2002; Jefferson et al. 2008).

Although widespread throughout the tropical Pacific, the species must still be considered rare because of a scarcity of sightings despite a great deal of survey effort (Pitman et al. 1999). No population estimates exist.

Mesoplodont Beaked Whales

Two species of mesoplodont whales likely occur in deep waters in the study area. They are Blainville’s and the gingko-toothed beaked whales. No population estimates exist for either of these species in the South Pacific. Mesoplodont beaked whales that could occur but would be considered extralimital include Gray's and Andrew's beaked whales. These extralimital species will not be discussed further.

Almost everything that is known regarding most mesoplodont species has come from stranded animals (Pitman 2002). The different mesoplodont species are difficult to distinguish in the field, and are most often categorized during sighting surveys, and therefore in density and population estimates, as *Mesoplodon* spp. They are all thought to be deep-water animals, only rarely seen over the continental shelf. Typical group sizes range from one to six (Pitman 2002). Because of the scarcity of sightings, most are thought to be rare.

Blainville's beaked whale.—This species is found in tropical and temperate waters of all oceans (Jefferson et al. 2008). Blainville's beaked whale has the widest distribution throughout the world of all *Mesoplodon* species (Mead 1989b). There is no evidence that Blainville's beaked whales undergo seasonal migrations. Blainville's beaked whales are most often found in singles or pairs, but also in groups of 3–7 (Jefferson et al. 2008).

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

In the SPREP region, there are sighting records for the Cook Islands and French Polynesia (SPWRC 2004; SPREP 2007) and for Fiji and New Caledonia (SPREP 2007). Unconfirmed sightings have been reported for Samoa, Kiribati, and Palau, but there are no sighting records for Tonga (SPREP 2007).

Ginkgo-toothed beaked whale.—This species is only known from stranding records (Mead 1989b; Jeffer-son et al. 2008). In the South Pacific Ocean, it has stranded in New South Wales, Australia, and the North Island and Chatham Islands, New Zealand (Mead 1989b; Baker and van Helden 1999). The ginkgo-toothed whale is hypothesized to occupy tropical and warm temperate waters of the Indian and Pacific oceans (Pitman 2002). Although Reeves et al. (1999) reported that the ginkgo-toothed whale likely occurs in the SPREP region, SPREP (2007) did not include this species in the list of marine mammals occurring there.

Rough-toothed Dolphin

The rough-toothed dolphin is widely distributed around the world, but mainly occurs in tropical and warm temperate waters (Miyazaki and Perrin 1994), including the SPREP region (Reeves et al. 1999; SPREP 2007). Confirmed sightings in the SPREP region are known for Samoa, American Samoa, Solomon Islands, French Polynesia, Kiribati, New Caledonia, and the Northern Marianas Islands, with unconfirmed sightings in Fiji; no sighting have been made in Tonga (SPREP 2007).

Rough-toothed dolphins are deep divers and can dive for up to 15 min (Reeves et al. 2002). They usually form groups of 10–20 (Reeves et al. 2002), but aggregations of hundreds have been seen (Leatherwood and Reeves 1983). Wade and Gerrodette (1993) reported a mean group size of 14.7 for the ETP. Group sizes off the Society Islands were 1–40, and off the Marquesas, the average group size was 17.7 (Gannier 2002a). The rough-toothed dolphin has been seen in mixed-species associations with melon-headed whales and Fraser's dolphins off the Society Islands (Gannier 2000).

Off the Society Islands, it has been seen in waters ranging from <100 m to >3000 m deep (Gannier 2000). Off the Marquesas Islands, it was seen in coastal waters, over the continental slope, and in offshore waters (Gannier 2002a). Rough-toothed dolphins were sighted 30 times during >4600 km of inshore survey effort and twice during >550 km of offshore survey effort in the Society Islands during three years of fall and spring shipboard surveys (Gannier 2000). They were sighted four times during >1000 km of inshore survey effort and >500 km of offshore survey effort during November–January 1999 in the Marquesas Islands (Gannier 2002a).

Bottlenose Dolphin

The bottlenose dolphin is distributed worldwide. There are two distinct bottlenose dolphin types: a shallow water type, mainly found in coastal waters, and a deep water type, mainly found in oceanic waters (Duffield et al. 1983; Hoelzel et al. 1998; Walker et al. 1999). As well as inhabiting different areas, these ecotypes differ in their diving abilities (Klatsky 2004) and prey types (Mead and Potter 1995). Bottlenose dolphins are known to occur throughout the SPREP region, including Tonga, Samoa, American Samoa, Fiji, Tuvatu, Vanuatu, New Caledonia, French Polynesia, Papua New Guinea, Solomon Islands, Micronesia, Kiribati, and the Marshall Islands (SPREP 2007). Possible sightings also exist for the Cook Islands (SPWRC 2004; SPREP 2007).

Although often seen in coastal areas, bottlenose dolphins have been reported to regularly dive to depths >450 m for periods of >5 min (Klatsky 2004), and even down to depths of 600–700 m for up to 12 min (Klatsky et al. 2005). Off the Marquesas Islands, the species was most often sighted in coastal waters and occasionally close to the shelf break (Gannier 2002a). Mean group size in the ETP has been estimated at 24 (Smith and Whitehead 1999) and 22.7 (Wade and Gerrodette 1993). The average group size seen off the Marquesas Islands was 8.2 (Gannier 2002a).

Off the Marquesas Islands, the species was most often sighted in coastal waters and occasionally close to the shelf break (Gannier 2002a). Mean group size in the ETP has been estimated at 24 (Smith and Whitehead 1999) and 22.7 (Wade and Gerrodette 1993). The average group size seen off the Marquesas Islands was 8.2 (Gannier 2002a).

Bottlenose dolphins were sighted only twice during >4600 km of inshore survey effort and >550 km of offshore survey effort in the Society Islands during three years of fall and spring shipboard surveys (Gannier 2000). In contrast, they were sighted 17 times during >1000 km of inshore survey effort and >500 km of offshore survey effort during November–January 1999 in the Marquesas Islands, off almost every island (Gannier 2002a). Gannier (2002a) noted that bottlenose dolphins accounted for >17% of the delphinid sightings off the Galápagos Islands, whereas they made up ~6% of delphinid sightings off the Marquesas Islands, only 1% of sightings in the southwestern ETP, and a mere 0.2% of delphinid sightings in the Society Islands. Preliminary investigation of the species off Rangiroa (Tuamotu Islands, French Polynesia) suggests a local population of 20–30 off that island (Brasseur et al. 2002).

Pantropical Spotted Dolphin

The pantropical spotted dolphin can be found throughout tropical and some subtropical oceans of the world (Perrin and Hohn 1994). The southernmost limit of its range is ~40°S (Perrin 2002a). In the ETP, this dolphin is associated with warm (>25ºC) tropical surface water (Au and Perryman 1985; Reilly 1990; Reilly and Fiedler 1994; Reeves et al. 1999). There are two forms of pantropical spotted dolphin, coastal and offshore forms, although the coastal form occurs mainly in the ETP from Baha California to South America (Jefferson et al. 2008). The offshore form inhabits tropical, equatorial, and southern subtropical water masses (Perrin 2002a). They are found primarily in deeper waters, and rarely over the continental shelf or continental shelf edge (Davis et al. 1998). Pantropical spotted dolphins are extremely gregarious, forming groups of hundreds or even thousands. Wade and Gerrodette (1993) reported a mean group size of 149.4 for the western/southern stock in the ETP. Pantropical spotted and spinner dolphins are commonly seen together in mixed-species groups, e.g., in the ETP (Au and Perryman 1985), off Hawaii (Psarakos et al. 2003), and off the Marquesas Archipelago (Gannier 2002a).

Within the SPREP region, confirmed sightings are known for Tonga, Cook Islands, Fiji, American Samoa, Vanuata, Papua New Guinea, Solomon Islands, French Polynesia, Kiribati, Marshall Islands, and New Caledonia (SPREP 2007), and a recent sighting was made in Tuvalu (SPWRC 2008). Pantropical spotted dolphins were not seen during >4600 km of inshore survey effort and >550 km of offshore survey effort in the Society Islands during three years of fall and spring shipboard surveys (Gannier 2000). In contrast, they were the most commonly-sighted cetacean species off the Marquesas Islands, with 37 sightings during >1000 km of inshore survey effort and >500 km of offshore survey effort during November–January 1999 (Gannier 2002a). Off the Marquesas Islands, they were sighted more frequently in coastal and inshore waters, but were also seen in the deep ocean (Gannier 2002a). The mean group size was 17.6 off the Marquesas Islands (Gannier 2002a). Gannier (2002a) noted that pantropical spotted dolphins accounted for more than one quarter of the delphinid sightings off the Marquesas Islands and in the southwestern ETP, whereas they made up only 2% of delphinid sightings off the Society Islands and <1% of delphinid sightings off the Galápagos Islands.

Spinner Dolphin

The spinner dolphin is distributed in oceanic and coastal tropical waters, although its range is mostly oceanic in the ETP (Jefferson et al. 2008). In the ETP, it is associated with warm, tropical surface water, similar in distribution to the Pantropical spotted dolphin (Au and Perryman 1985; Reilly 1990; Reilly and Fiedler 1994; Reeves et al. 1999). In the South Pacific Ocean, it rarely occurs south of northern Australia (Evans 1987:113; see also Fig. 1 *in* Perrin and Gilpatrick 1994). Reeves et al. (1999) consider this species to be the dolphin most commonly sighted around oceanic islands in the SPREP region. Sightings are known for many areas within the SPREP region, including Tonga, Niue, Fiji, the Cook Islands, American Samoa, and Samoa (see SPREP 2007).

Spinner dolphins are extremely gregarious, and usually form large schools in the open sea and small ones in coastal waters (Perrin and Gilpatrick 1994). A mean group size of 33.5 was reported for the Society Islands (Gannier 2000), and a mean group size of 7.6 was reported off the Marquesas (Gannier 2002a). Group sizes of resting spinner dolphins in Baie des Pêcheurs, Tahiti, ranged from 15–30 to 100–150 (Gannier 2002b). Wade and Gerrodette (1993) reported a mean group size of 134.1 in the ETP. Spinner dolphins and pantropical spotted dolphins are commonly seen together in mixed-species groups, e.g., in the ETP (Au and Perryman 1985), off Hawaii (Psarakos et al. 2003), and off the Marquesas Archipelago (Gannier 2002a).

Spinner dolphins are seen year-round off the Society Islands in water depths 50–1000 m (Gannier 2000). Off the Marquesas Islands, they were most often observed in coastal or inshore waters, but were also seen offshore (Gannier 2002a). Spinner dolphins can be found resting in shallow sheltered sites in the Society Islands. They were seen resting in Baie des Pêcheurs, Tahiti West, with a higher occurrence from May to October than from February to April (Gannier 2002b).

Spinner dolphins were the most frequently seen cetacean species during >4600 km of inshore survey effort and >550 km of offshore survey effort in the Society Islands (Gannier 2000). The species was sighted 43 times during three years of fall and spring shipboard surveys. Off the Marquesas Archipelago, they were the second-most frequently-seen cetacean species, with 23 sightings during >1000 km of inshore survey effort and >500 km of offshore survey effort during November–January 1999 (Gannier 2002a). Gannier (2002a) noted that spinner dolphins accounted for more than half of the delphinid sightings off the Society Islands, whereas they made up <10% of delphinid sightings off the Marquesas Islands and in the southwestern ETP, and only 1% of delphinid sightings off the Galápagos Islands.

Striped Dolphin

The striped dolphin has a cosmopolitan distribution in tropical to warm temperate waters (Perrin et al. 1994a), and it generally seen below 43ºN (Archer 2002). It is typically found in waters outside the continental shelf and is often associated with convergence zones and areas of upwelling (Archer 2002). Striped dolphins are fairly gregarious (groups of 20 or more are common) and active at the surface (Whitehead et al. 1998). Wade and Gerrodette (1993) reported a mean group size of 60.9 in the ETP, and Smith and Whitehead (1999) reported a mean group size of 50 in the Galápagos Islands.

The distribution mapped by Perrin et al. (1994a) indicates that striped dolphins occur throughout the SPREP region (Reeves et al. 1999). In fact, there have been confirmed sightings of striped dolphins in Palau, Samoa, the Solomon Islands, Micronesia, and the Marshall Islands (SPREP 2007). There are no confirmed sightings for Tonga, but unconfirmed sighting records exist for Fiji (SPREP 2007). This species was not sighted during three years of fall and spring shipboard surveys off the Society Islands (Gannier 2000) or during November–January 1999 sighting surveys in the Marquesas Islands (Gannier 2002a).

Fraser’s Dolphin

Fraser’s dolphin is a tropical species found between 30°N and 30°S (Dolar 2002). It only occurs rarely in temperate regions, and then only in relation to temporary oceanographic anomalies such as El Niño events (Perrin et al. 1994b). The species typically occurs in deep, oceanic waters. In the ETP, most sightings were 45–100 km from shore in waters 1500–2500 m deep (Dolar 2002). Off Huahine and Tahiti (Society Islands), it was observed in waters 500–1500 m deep (Gannier 2000).

Fraser’s dolphins travel in groups ranging from just a few animals to 100 or even 1000 (Perrin et al. 1994b). Wade and Gerrodette (1993) reported a mean group size of 394.9 for the ETP. Gannier (2000) reported school sizes ranging from 25 to 30 off the Society Islands. Fraser’s dolphins were observed in association with melon-headed whales and rough-toothed dolphins in that study.

In the SPREP region, Fraser’s dolphins are known to occur in the Cook Islands, Micronesia, French Polynesia, Kiribati, Nauru, Papua New Guinea, Samoa, and the Solomon Islands (SPREP 2007). Fraser’s dolphins were sighted four times during >4600 km of inshore survey effort and >550 km of offshore survey effort in the Society Islands during three years of fall and spring shipboard surveys, but were not sighted in the Marquesas Islands during >1000 km of inshore survey effort and >500 km of offshore survey effort during November–January 1999 (Gannier 2002a). Gannier (2002a) noted that Fraser’s dolphins accounted for almost one third of the delphinid sightings in the southwestern ETP, whereas they made up <10% of delphinid sightings off the Society Islands, <4% of sightings off the Galápagos Islands, and were not seen at all off the Marquesas Archipelago. Reeves et al. (1999) reported a historic sighting (from the 1930s) of Fraser’s dolphin off the Fiji Islands, but this sighting appears to be unconfirmed (see SPREP 2007).

Short-beaked Common Dolphin

The common dolphin is found in tropical and warm temperate oceans around the world (Perrin 2002b). It ranges as far south as 40°S in the Pacific Ocean, is common in coastal waters 200–300 m deep, and is also associated with prominent underwater topography, such as seamounts (Evans 1994). Off northern New Zealand, it is generally seen at a mean distance <10 km from shore in the summer, and move further offshore in winter (Neumann 2001). Common dolphins often travel in fairly large groups; schools of hundreds or even thousands are common. Smith and Whitehead (1999) noted that common dolphins were frequently seen in waters near the Galápagos Islands, with a mean group size of 125. Wade and Gerrodette reported a mean group size of 472.8 in the southern portion of the ETP.

There are two species of common dolphins: the short-beaked common dolphin (*D. delphis*) and the long-beaked common dolphin (*D. capensis*). In the SPREP region, short-beaked common dolphins are known to occur in the waters of New Caledonia, but there have been no confirmed sightings of long-beaked common dolphins in the SPREP area (Reeves et al. 1999). Confirmed sightings of common dolphins in the SPREP region also exist for the Cook and Marshall islands, whereas unconfirmed sightings have been recorded for Fiji, Solomon Islands, and the Northern Mariana Islands (SPREP 2007). The species was not sighted during three years of fall and spring shipboard surveys off the Society Islands (Gannier 2000) or during November–January 1999 sighting surveys in the Marquesas Islands (Gannier 2002a). Similarly, no sighting records exist for the EEZ of Tonga, although 40 common dolphins were sighted southwest of Tonga (25º27’S, 177 º42’W) in November 1992 (see Reeves et al.1999).

Risso’s Dolphin

Risso’s dolphin is primarily a tropical and mid-temperate species distributed worldwide. It occurs between 60ºN and 60ºS, where surface water temperatures are at least 10ºC (Kruse et al. 1999). In the northern Gulf of Mexico, Risso’s dolphin usually occurs over steeper sections of the upper continental slope (Baumgartner 1997) in waters 150–2000 m deep (Davis et al. 1998). In Monterey Bay, California, it is most numerous where there is steep bottom topography (Kruse et al. 1999). Risso’s dolphins occur individually or in small to moderate-sized groups, normally ranging from 2 to <250. The majority of groups consist of <50 (Kruse et al. 1999). Wade and Gerrodette (1993) reported a mean group size of 11.8 in the ETP.

Risso’s dolphin occurs throughout the SPREP region (Reeves et al. 1999; SPREP 2007), and its presence has been confirmed in Tonga (SPREP 2007). Off Moorea, it was sighted in groups of 10–20 in January–February 1994 (Reeves et al. 1999). Gannier (2000) reported a single sighting of Risso’s dolphin in the Society Islands (~6 km south of Tahiti) during three years of fall and spring shipboard surveys. Risso’s dolphin was also sighted only once in the Marquesas Islands during >1000 km of inshore survey effort and >500 km of offshore survey effort during November–January 1999 (Gannier 2002a). Gannier (2002a) noted that Risso’s dolphins accounted for a mere 0.1% of delphinid sightings off the Marquesas and Society Islands, whereas they made up >4% of delphinid sightings off Galápagos Islands and 3.4% of delphinid sightings in the southwestern ETP. Risso’s dolphins off the Marquesas Islands were sighted in water 800 m deep (Gannier 2002a).

Melon-headed Whale

The melon-headed whale is a pantropical and pelagic species that occurs mainly between 20ºN and 20ºS in offshore waters (Perryman et al. 1994). Melon head whales are known to occur throughout the SPREP region, with confirmed sightings in Tonga (SPREP 2007). Sightings off the Society Islands, French Polynesia, occurred in water depths 500–1500 m. Off the Marquesas Islands, on the other hand, melon-headed whales were commonly observed in coastal waters with depths as shallow as 300 m (Gannier 2002a).

Melon-headed whales tend to occur in groups of 100–500, but have also been seen in groups of up to 2000 (Jefferson et al. 2008). Wade and Gerrodette (1993) reported a mean group size of 199 for the ETP. Gannier (2000) reported group sizes ranging from 50 to 120 off the Society Islands. The average group size seen off the Marquesas Islands was 85 (Gannier 2002a). Melon-headed whales accounted for greater than half the delphinid sightings off the Marquesas Islands, whereas they made up <16% of delphinid sightings off the Society Islands (Gannier 2002a). Melon-head whales are commonly seen in mixed groups with other cetaceans (Jefferson and Barros 1997). Off the Society Islands of Huahine and Tahiti, they were sighted in association with Fraser's dolphins and rough-toothed dolphins (Gannier 2000). In January–February 1994, large groups (200–300) of melon-headed whales were sighted off Moorea (French Polynesia), often with Fraser's dolphins (Reeves et al. 1999).

Pygmy Killer Whale

The pygmy killer whale is distributed throughout tropical and subtropical oceans worldwide (Ross and Leatherwood 1994; Donahue and Perryman 2002). Little is known about the species in most of its range, but it is sighted frequently in the ETP, off Hawaii, and off Japan (Donahue and Perryman 2002). In warmer water, it is usually seen close to the coast (Wade and Gerrodette 1993), but it is also found in deep waters. In the Marquesas, it was sighted in water 100 m deep (Gannier 2002a). Pygmy killer whales tend to travel in groups of 15–50, although herds of a few hundred have been sighted (Ross and Leatherwood 1994). Wade and Gerrodette (1993) reported a mean group size of 27.9 in the ETP.

Recent sighting evidence confirms the presence of pygmy killer whales in Tonga, New Caledonia, and French Polynesia (SPWRC 2004; SPREP 2007). Gannier (2002a) reported one sighting of three pygmy killer whales in water 100 m deep during surveys in November–January 1999 in the Marquesas Islands. No sightings were made surveys in the Society Islands during three years of fall and spring shipboard surveys (Gannier 2000).

False Killer Whale

The false killer whale is found in all tropical and warmer temperate oceans, especially in deep, offshore waters (Odell and McClune 1999). It is also known to occur in nearshore areas (e.g., Stacey and Baird 1991). In the ETP, it is usually seen far offshore (Wade and Gerrodette 1993). False killer whales travel in pods of 20–100 (Baird 2002), although groups of several hundred are sometimes observed. Wade and Gerrodette (1993) reported a mean group size of 11.4 in the ETP.

False killer whales are thought to occur year-round in the SPREP region (Reeves et al. 1999). Recent sighting evidence confirms their presence in Tonga, American Samoa, Samoa, Fiji, New Caledonia, Niue, Solomon Islands, Papua New Guinea, and French Polynesia (SPWRC 2004; SPREP 2007). A group of 15 false killer whales was seen in the northern Tonga archipelago in October 1992 (Reeves et al. 1999). Gannier (2002a) reported a sighting of a group of three adults and one calf in water ~2000 m deep off the Marquesas Islands during November–January 1999. False killer whales were not sighted during >4600 km of inshore survey effort or during >550 km of offshore survey effort in the Society Islands during three years of fall and spring shipboard surveys (Gannier 2000).

Killer Whale

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

Killer whales occur at least seasonally in many areas within the SPREP region (Reeves et al. 1999). Confirmed sightings exist for areas near the proposed study area, including Tonga, Cook Islands, American Samoa, Samoa, and Niue (SPREP 2007). Unconfirmed sightings exist for Fiji (Reeves et al. 1999; SPREP 2007). Although killer whales are also known to occur in French Polynesia, they were not sighted during >4600 km of inshore survey effort or during >550 km of offshore survey effort in the Society Islands during three years of fall and spring shipboard surveys (Gannier 2000). However, they were sighted only once during >1000 km of inshore survey effort and >500 km of offshore survey effort during November–January 1999 in the Marquesas Islands (Gannier 2002a). Japanese vessels observed a concentration of killer whales in November between the Phoenix and Tongan islands, in October near Samoa, and in March west of Samoa (Reeves et al. 1999).

Short-finned Pilot Whales

The short-finned pilot whale is found in tropical and warm temperate waters (Olson and Reilly 2002); it is seen as far south as ~40ºS, but is more common north of ~35ºS (Olson and Reilly 2002). Pilot whales occur on the shelf break, over the slope, and in areas with prominent topographic features, and are usually seen in groups of 20–90 (Olson and Reilly 2002). Wade and Gerrodette (1993) reported a mean group size of 18.3 in the ETP. Long-finned pilot whales outfitted with time-depth recorders dove to depths up to 828 m, although most of their time was spent above depths of 7 m (Heide-Jørgensen et al. 2002). The species' maximum recorded dive depth is 971 m (Baird pers. comm. *in* DoN 2005).

Short-finned pilot whales are thought to be widespread and common throughout the SPREP region (Reeves et al. 1999). Confirmed sightings exist for most islands in the SPREP area, including Tonga (SPREP 2007). Two large groups of 50–100 were sighted off Moorea, French Polynesia, in January–February 1994 (Reeves et al. 1999). Short-finned pilot whales were sighted five times during >4600 km of inshore survey effort but not during >550 km of offshore survey effort in the Society Islands during three years of fall and spring shipboard surveys (Gannier 2000). They were sighted once during >1000 km of inshore survey effort and >500 km of offshore survey effort during November–January 1999 in the Marquesas Islands (Gannier 2002a). Gannier (2002a) reported that short-finned pilot whales accounted for >5% of the delphinid sightings off the Society Islands, whereas they made up <2% of delphinid sightings off the Marquesas Islands.

Short-finned pilot whales sighted off the Marquesas were in water ~700 m deep (Gannier 2002a). Sightings of the species off Huahine, Tahiti, and Moorea (Society Islands) occurred in waters with depths ranging from 300 to 1400 m (Gannier 2000). In the Society Archipelago, sightings occurred between 0.5 and 7 km offshore (Gannier 2000). Group sizes off the Society Islands ranged from 10 to 35, and one group of 32 was seen off the Marquesas Archipelago (Gannier 2002a).

Pinnipeds

There are no pinnipeds that have primary habitat within the SPREP region (Reeves et al. 1999). Two species of pinnipeds could occur in the proposed seismic survey area as extralimital sightings: the New Zealand fur seal (*Arctocephalus forsteri*) and the leopard seal (*Hydrurga leptonyx*) (Reeves et al.

1999; Rogers 2002). Because of the rare occurrence of these species in the area, they will not be discussed further.

V. TYPE OF INCIDENTAL TAKE AUTHORIZATION REQUESTED

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

L-DEO requests an IHA pursuant to Section 101 (a) (5) (D) of the Marine Mammal Protection Act (MMPA) for incidental take by harassment during its planned seismic survey in the Lau Basin of the SWPO during January–February 2009.

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

VI. NUMBERS OF MARINE MAMMALS THAT COULD BE TAKEN

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

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

VII. ANTICIPATED IMPACT ON SPECIES OR STOCKS

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

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

- First we summarize the potential impacts on marine mammals of airgun operations, as called for in § VII. A more comprehensive review of the relevant background information appears in Appendix B of the EA.
- Then we discuss the potential impacts of operations by the echosounders.
- Finally, we estimate the numbers of marine mammals that could be affected by the proposed activity in the SWPO during January–February 2009. This section includes a description of the rationale for the estimates of the potential numbers of harassment "takes" during the planned survey, as called for in § VI.

Summary of Potential Effects of Airgun Sounds

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

Tolerance

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

Masking

Masking effects of pulsed sounds (even from large arrays of airguns) on marine mammal calls and other natural sounds are expected to be limited, although there are very few specific data on this. Because of the intermittent nature and low duty cycle of seismic pulses, animals can emit and receive sounds in the relatively quiet intervals between pulses. However, in 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. 1999; Nieukirk et al. 2004; Smultea et al. 2004; Holst et al. 2005a,b, 2006). In the northeast Pacific Ocean, blue whale calls have been recorded during a seismic survey off Oregon (McDonald et al. 1995). Among odontocetes, there has been one report that sperm whales ceased calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994), but more recent studies found that they continued calling in the presence of seismic pulses (Madsen et al. 2002; Tyack et al. 2003; Smultea et al. 2004; Holst et al. 2006; Jochens et al. 2006). Dolphins and porpoises commonly are heard calling while airguns are operating (e.g., Gordon et al. 2004; Smultea et al. 2004; Holst et al. 2005a,b; Potter et al. 2007). The sounds important to small odontocetes are predominantly at much higher frequencies than are the dominant components of airgun sounds, thus limiting the potential for masking. In general, masking effects of seismic pulses are expected to be minor, given the normally intermittent nature of seismic pulses. Masking effects on marine mammals are discussed further in Appendix B (4).

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). 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. Given the many uncertainties in predicting the quantity and types of impacts of noise on marine mammals, it is common practice to estimate how many mammals would be present within a particular distance of industrial activities and exposed to a particular level of industrial sound. In most cases, this approach likely overestimates the numbers of marine mammals that would be affected in some biologically-important manner.

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

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

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

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

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

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

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

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

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

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

Data on short-term reactions by cetaceans to impulsive noises are not necessarily indicative of long-term or biologically significant effects. It is not known whether impulsive sounds affect reproductive rate or distribution and habitat use in subsequent days or years. However, gray whales have continued to migrate annually along the west coast of North America with substantial increases in the population over recent years, despite intermittent seismic exploration (and much ship traffic) in that area for decades (Appendix A *in* Malme et al. 1984; Richardson et al. 1995; Angliss and Outlaw 2008). The western Pacific gray whale population did not seem affected by a seismic survey in its feeding ground during a previous year (Johnson et al. 2007). Similarly, bowhead whales have continued to travel to the eastern Beaufort Sea each summer, and their numbers have increased notably, despite seismic exploration in their summer and autumn range for many years (Richardson et al. 1987; Angliss and Outlaw 2008).

Toothed Whales.—Little systematic information is available about reactions of toothed whales to noise pulses. Few studies similar to the more extensive baleen whale/seismic pulse work summarized above and (in more detail) in Appendix B of the EA have been reported for toothed whales. However, there are recent systematic studies on sperm whales (Jochens et al. 2006; Miller et al. 2006), and 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; Weir 2008).

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

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

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

Most studies of sperm whales exposed to airgun sounds indicate that the sperm whale shows considerable tolerance of airgun pulses (e.g., Stone 2003; Moulton et al. 2005, 2006a; Stone and Tasker 2006; Weir 2008). In most cases the whales do not show strong avoidance, and they continue to call (see Appendix B in the EA for review). However, controlled exposure experiments in the Gulf of Mexico indicate that foraging behavior was altered upon exposure to airgun sound (Jochens et al. 2006).

There are almost no specific data on the behavioral reactions of beaked whales to seismic surveys. However, northern bottlenose whales continued to produce high-frequency clicks when exposed to sound pulses from distant seismic surveys (Laurinolli and Cochrane 2005; Simard et al. 2005). Most beaked whales tend to avoid approaching vessels of other types (e.g., Würsig et al. 1998). They may also dive for an extended period when approached by a vessel (e.g., Kasuya 1986). Thus, it is likely that beaked whales would also show strong avoidance of an approaching seismic vessel, although this has not been documented explicitly.

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

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

Pinnipeds.—Pinnipeds are not likely to show a strong avoidance reaction to the airgun array. Visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds, and only slight (if any) changes in behavior—see Appendix B (5). In the Beaufort Sea, some ringed seals avoided an area of 100 m to (at most) a few hundred meters around seismic vessels, but many seals remained within 100–200 m of the trackline as the operating airgun array passed by (e.g., Harris et al. 2001; Moulton and Lawson 2002; Miller et al. 2005). Ringed seal sightings averaged somewhat farther away from the seismic vessel when the airguns were operating than when they were not, but the difference was small (Moulton and Lawson 2002). Similarly, in Puget Sound, sighting distances for harbor seals and California sea lions tended to be larger when airguns were operating (Calambokidis and Osmek 1998). Previous telemetry work suggests that avoidance and other behavioral reactions may be stronger than evident to date from visual studies (Thompson et al. 1998). Even if reactions of any pinnipeds that might be encountered in the present study area are as strong as those evident in the telemetry study, reactions are expected to be confined to relatively small distances and durations, with no long-term effects on pinniped individuals or populations. As for delphinids, a ≥170 dB disturbance criterion is considered appropriate for pinnipeds, which tend to be less responsive than many cetaceans.

Hearing Impairment and Other Physical Effects

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds, 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 B 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).

NMFS is developing new noise exposure criteria for marine mammals that account for the now-available scientific data on TTS, the expected offset between the TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors. Preliminary information about this process, and about the possible structure of the new criteria, was given by Wieting (2004) and NMFS (2005). Detailed recommendations for new science-based noise exposure criteria for marine mammals, frequency-weighting procedures, and related matters were published recently (Southall et al. 2007).

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

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

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

For toothed whales exposed to single short pulses, the TTS threshold appears to be, to a first approximation, a function of the energy content of the pulse (Finneran et al. 2002, 2005). Given the available data, the received energy level of a single seismic pulse (with no frequency weighting) might need to be ~186 dB re 1 $\mu Pa^2 \cdot s$ (i.e., 186 dB SEL or ~196–201 dB re 1 μPa_{rms}) in order to produce brief, mild TTS[1]. Exposure to several strong seismic pulses that each have received levels near 190 dB re 1 μPa_{rms} might result in cumulative exposure of ~186 dB SEL and thus slight TTS in a small odontocete, assuming the TTS threshold is (to a first approximation) a function of the total received pulse energy. The distances from the *Langseth*'s airguns at which the received energy level (per pulse, flat-weighted) would be expected to be ≥190 dB re 1 μPa_{rms} are estimated in Table 1. Levels ≥190 dB re 1 μPa_{rms} are expected to be restricted to radii no more than 380 m (Table 1). For an odontocete closer to the surface, the maximum radius with ≥190 dB re 1 μPa_{rms} would be smaller.

The above TTS information for odontocetes is derived from studies on the bottlenose dolphin and beluga. There is no published TTS information for other types of cetaceans. However, preliminary evidence from a harbor porpoise exposed to airgun sound suggests that its TTS threshold may have been lower (Lucke et al. 2007).

For baleen whales, there are no data, direct or indirect, on levels or properties of sound that are required to induce TTS. The frequencies to which baleen whales are most sensitive are assumed to be

---

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

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

In pinnipeds, TTS thresholds associated with exposure to brief pulses (single or multiple) of underwater sound have not been measured. Initial evidence from more prolonged (non-pulse) exposures suggested that some pinnipeds (harbor seals in particular) incur TTS at somewhat lower received levels than do small odontocetes exposed for similar durations (Kastak et al. 1999, 2005; Ketten et al. 2001). The TTS threshold for pulsed sounds has been indirectly estimated as being an SEL of ~171 dB re 1 $\mu Pa^2 \cdot s$ (Southall et al. 2007), which would be equivalent to a single pulse with received level ~181–186 dB re 1 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.— 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 has an impaired ability to hear sounds in specific frequency ranges (Kryter 1985).

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

Relationships between TTS and PTS thresholds have not been studied in marine mammals, but are assumed to be similar to those in humans and other terrestrial mammals. PTS might occur at a received sound level at least several decibels above that inducing mild TTS if the animal were exposed to strong sound pulses with rapid rise time—see Appendix B (6). Based on data from terrestrial mammals, a precautionary assumption is that the PTS threshold for impulse sounds (such as airgun pulses as received close to the source) is at least 6 dB higher than the TTS threshold on a peak-pressure basis, and probably

>6 dB (Southall et al. 2007). On an SEL basis, Southall et al. (2007:441-4) estimated that received levels would need to exceed the TTS threshold by at least 15 dB for there to be risk of PTS. Thus, for cetaceans they estimate that the PTS threshold might be an M-weighted SEL (for the sequence of received pulses) of ~198 dB re 1 $\mu Pa^2 \cdot s$ (15 dB higher than the TTS threshold for an impulse), where the SEL value is cumulated over the sequence of pulses. Additional assumptions had to be made to derive a corresponding estimate for pinnipeds, as the only available data on TTS-thresholds in pinnipeds pertain to non-impulse sound. Southall et al. (2007) estimate that the PTS threshold could be a cumulative M_{pw}-weighted SEL of ~186 dB re 1 $\mu Pa^2 \cdot s$ in the harbor seal exposed to impulse sound. The PTS threshold for the California sea lion and northern elephant seal 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. A peak pressure of 230 dB re 1 μPa (3.2 bar·m, 0-pk) would only be found within a few meters of the largest (360-in^3) airguns in the planned airgun array (Caldwell and Dragoset 2000). A peak pressure of 218 dB re 1 μPa could be received somewhat farther away; to estimate that specific distance, one would need to apply a model that accurately calculates peak pressures in the near-field around an array of airguns.

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

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

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

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

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 Multibeam Echosounder Signals

The Simrad EM120 12-kHz MBES will be operated from the source vessel during the planned study. Information about this equipment was provided in § I. Sounds from the MBES are very short pulses, occurring for 2–15 ms once every 5–20 s, depending on water depth. Most of the energy in the sound pulses emitted by this MBES is at frequencies near 12 kHz, and the maximum source level is 242 dB re 1 $\mu Pa_{rms} \cdot m$ (rms). The beam is narrow (1º) in fore-aft extent and wide (150º) in the cross-track extent. Each ping consists of nine successive fan-shaped transmissions (segments) at different cross-track angles. Any given mammal at depth near the trackline would be in the main beam for only one or two of the nine segments. Also, marine mammals that encounter the Simrad EM120 are unlikely to be subjected to repeated pulses because of the narrow fore–aft width of the beam and will receive only limited amounts of pulse energy because of the short pulses. Animals close to the ship (where the beam is narrowest) are especially unlikely to be ensonified for more than one 2–15 ms pulse (or two pulses if in the overlap area). Similarly, Kremser et al. (2005) noted that the probability of a cetacean swimming through the area of exposure when an MBES emits a pulse is small. The animal would have to pass the transducer at close range and be swimming at speeds similar to the vessel in order to receive the multiple pulses that might result in sufficient exposure to cause TTS.

Navy sonars that have been linked to avoidance reactions and stranding of cetaceans (1) generally have a longer pulse duration than the Simrad EM120, and (2) are often directed close to horizontally vs. more downward for the MBES. The area of possible influence of the MBES is much smaller—a narrow band below the source vessel. The duration of exposure for a given marine mammal can be much longer for a naval sonar. During L-DEO's operations, the individual pulses will be very short, and a given mammal would not receive many of the downward-directed pulses as the vessel passes by. Possible effects of an MBES on marine mammals are outlined below.

Masking

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

Behavioral Responses

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

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

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

Hearing Impairment and Other Physical Effects

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

Given the maximum source level of 242 dB re 1 μPa·m_{rms} (see § I), the received level for an animal within the MBES beam 100 m below the ship would be ~202 dB re 1 μPa_{rms}, assuming 40 dB of spreading loss over 100 m (circular spreading). Given the narrow beam, only one pulse is likely to be received by a given animal as the ship passes overhead. The received energy level from a single pulse of duration 15 ms would be about 184 dB re 1 $\mu Pa^2 \cdot s$, 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 EM120. That animal might incur some TTS (which would be fully recoverable), but the exposure would still be below the anticipated PTS threshold for cetaceans. As noted by Burkhardt et al. (2007, 2008), cetaceans are very unlikely to incur PTS from operation of scientific sonars on a ship that is underway

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

Possible Effects of the Sub-bottom Profiler Signals

An SBP may be operated from the source vessel at times during the planned study. Details about this equipment were provided in § I. Sounds from the sub-bottom profiler are very short pulses, occurring for 1–4 ms once every second. Most of the energy in the sound pulses emitted by the SBP is at 3.5 kHz, and the beam is directed downward. The sub-bottom profiler on the *Langseth* has a maximum source level of 204 dB re 1 µPa·m (see § I). Kremser et al. (2005) noted that the probability of a cetacean swimming through the area of exposure when a bottom profiler emits a pulse is small—even for an SBP more powerful than that on the *Langseth*—if the animal was in the area, it would have to pass the transducer at close range and in order to be subjected to sound levels that could cause TTS.

Masking

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

Behavioral Responses

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

Hearing Impairment and Other Physical Effects

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

Possible Effects of the Acoustic Release Signals

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

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

All anticipated takes would be "takes by harassment", involving temporary changes in behavior. The mitigation measures to be applied will minimize the possibility of injurious takes. (However, as noted earlier, there is no specific information demonstrating that injurious "takes" would occur even in the absence of the planned mitigation measures.) In the sections below, we describe methods to estimate the number of potential exposures to various received sound levels and present estimates of the numbers of marine mammals that could be affected during the proposed ELSC seismic program. The estimates are based on a consideration of the number of marine mammals that could be disturbed appreciably by operations with the 36-airgun array to be used during ~3650 km of seismic surveys (plus an additional 25% contingency) in the Lau Basin. The sources of distributional and numerical data used in deriving the estimates are described in the next subsection.

The following estimates are based on a consideration of the number of marine mammals that could be disturbed appreciably by operations with the 36-airgun array to be during ~3650 km of seismic surveys (plus an additional 25% contingency) in the Lau Basin. It is assumed that, during simultaneous operations of the airgun array and the other sources, any marine mammals close enough to be affected by the MBES and SBP would already be affected by the airguns. However, whether or not the airguns are operating simultaneously with the other sources, marine mammals are expected to exhibit no more than short-term and inconsequential responses to the MBES and SBP given their characteristics (e.g., narrow downward-directed beam) and other considerations described in § I. Such reactions are not considered to constitute "taking" (NMFS 2001). Therefore, no additional allowance is included for animals that might be affected by sound sources other than airguns.

Basis for Estimating "Take by Harassment"

Few systematic aircraft- or ship-based surveys have been conducted for marine mammals in offshore waters of the South Pacific Ocean, and the species of marine mammals that occur there are not well known. The density estimates used in this assessment are from one of Longhurst's (2007) biogeographic provinces north of the survey area that is oceanographically similar to the province in which the seismic activities will take place. Some of the surveys conducted by Ferguson and Barlow (2001) in the ETP during 1986–1996 are in Longhurst's (2007) North Pacific Tropical Gyre Province, which is similar to the SPSG, in which the proposed seismic survey will occur. The similarities are (1) they are both low-nitrate, low-chlorophyll regions of the oceans with numerous coral reefs, and (2) upwelled nutrients by islands are used by corals and do not increase pelagic productivity. Ferguson and Barlow (2001) calculated cetacean densities in 5º x 5º blocks in the ETP from the coast of North America to as far west as 155ºW. We used the data from Blocks 105, 106, 111, 112, and 124–131, which are bounded by 10ºN, 20ºN, 115ºW, and 155ºW, to compute the species group densities in Table 3.

The species assemblages that occur in the SWPO will be different than those sighted during the surveys in the ETP. However, the overall abundance of species groups with generally similar habitat requirements are expected to be roughly similar. Thus, we used the data from the appropriate part of the ETP to estimate the densities of beaked whales, delphinids, small whales, and mysticetes in the SWPO. Table 3 gives the average and maximum (see further, below) densities for those groups corrected for effort, based on the densities reported in Ferguson and Barlow (2001). Those densities had been corrected, by the original authors, for both detectability bias and availability bias. Detectability bias is associated with diminishing sightability with increasing lateral distance from the track line [$f(0)$]. Availability bias refers to the fact that there is less-than 100% probability of sighting an animal that is present along the survey track line, and it is measured by $g(0)$.

Table 3 also lists the species in each species group that are expected to occur in the offshore SWPO, and their estimated relative abundance within a group on a scale of 1 (rare) to 10 (abundant), based on information from near the proposed seismic survey area and general information on the species' distributions and habitat preferences. The status and relative abundance of each species are described in

Table 3. Densities of cetacean species groups sighted during selected surveys in the ETP during 1986–1996, and estimated densities of species expected to occur in the SPSG Province of Longhurst (2007), during the L-DEO seismic survey in the Lau Basin during January–February 2009. Densities in bold are derived from data in Ferguson and Barlow (2001), as described in the text. Densities are corrected for $f(0)$ and $g(0)$. Species listed as *endangered* or *threatened* under the ESA are in italics.

				Estimated density in Lau Basin (#/1000 km^2)	
Suborder	**Family**	**Species**	**Relative abundance**	**Best Estimate**	**Maximum Estimate**
Mysticeti	Balaenidae	Pygmy right whale	1	0.05	0.16
	Balaenopteridae	*Humpback whale*	*1*	*0.05*	*0.16*
		Minke whale	1	0.05	0.16
		Dwarf minke whale	1	0.05	0.16
		Bryde’s whale	5	0.23	0.79
		Sei whale	*1*	*0.05*	*0.16*
		Fin whale	*1*	*0.05*	*0.16*
		Blue whale	*1*	*0.05*	*0.16*
		All mysticetes		**0.55**	**1.90**
Odontoceti	Physeteridae	*Sperm whale*	*10*	***0.34***	***1.27***
		Pygmy sperm whale	2	5.45	20.15
		Dwarf sperm whale	2	5.45	20.15
		***Kogia* spp.**		**10.90**	**40.31**
	Ziphiidae	Cuvier's beaked whale	5	0.98	2.27
		Southern bottlenose whale	0	0.00	0.00
		Longman's beaked whale	2	0.39	0.91
		Blainville’s beaked whale	5	0.98	2.27
		Ginkgo-toothed beaked whale	2	0.39	0.91
		All Beaked whales		**2.75**	**6.35**
	Delphinidae	Rough-toothed dolphin	5	48.91	94.11
		Bottlenose dolphin	1	9.78	18.82
		Pantropical spotted dolphin	5	48.91	94.11
		Spinner dolphin	10	97.82	188.21
		Striped dolphin	1	9.78	18.82
		Fraser’s dolphin	3	29.35	56.46
		Common dolphin	1	9.78	18.82
		Risso's dolphin	1	9.78	18.82
		All Dolphins		**264.11**	**508.17**
		Melon-headed whale	5	2.48	8.65
		Pygmy killer whale	1	0.50	1.73
		False killer whale	3	1.49	5.19
		Killer whale	2	0.99	3.46
		Short-finned pilot whale	2	0.99	3.46
		All small whales		**6.45**	**22.50**

detail above in §III and IV. No corrected density data were available for any cetacean species in the proposed seismic survey area at the time of year that the seismic survey will be conducted. Therefore, we estimated the density of each species expected to occur in the survey area from the densities for species groups in Table 3 by multiplying their relative abundance divided by the relative abundance for all species in the species group times the density for the species group.

It should be noted that the following estimates of exposures to various sound levels assume that the surveys will be completed; in fact, the planned number of line-kilometers has been increased by 25% to accommodate lines that may need to be repeated, equipment testing, etc. As is typical during offshore ship surveys, inclement weather and equipment malfunctions are likely to cause delays and may limit the number of useful line-kilometers of seismic operations that can be undertaken. Furthermore, any marine mammal sightings within or near the designated exclusion zones will result in the power or shut down of seismic operations as a mitigation measure. Thus, the following estimates of the numbers of marine mammals potentially exposed to 160- or 170-dB 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.

As noted above, 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 are based on average densities from all survey blocks weighted by effort, whereas maximum estimates are based on the highest densities in any one block [based on data from Ferguson and Barlow (2001)]. The estimated numbers of individuals potentially exposed are presented in Table 4 based on the 160-dB re 1 μPa_{rms} criterion for all cetaceans and pinnipeds, 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".

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

Table 4 shows the best and maximum estimated number of exposures and the number of different individuals potentially exposed during the seismic survey if no animals moved away from the survey vessel. The estimates are based on the 160 dB re 1 μPa_{rms} criterion for all cetaceans, and the 170 dB re 1 μPa_{rms} criterion for delphinids. It is assumed that marine mammals exposed to airgun sounds this strong might change their behavior sufficiently to be considered "taken by harassment". The ***Requested Take Authorization***, given in the far right column of Table 4, is based on the maximum estimates rather than the best estimates of the numbers of individuals exposed, because of uncertainties associated with applying density data from one area to another.

***Number of Cetaceans that could be Exposed to ≥160 dB*.—**The number of different individuals that could be exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} on one or more occasions can be estimated by considering the total marine area that would be within the 160-dB radius around the operating airgun array on at least one occasion along with the expected density of animals in the area. The proposed seismic lines run parallel to each other in relatively close proximity; thus, an individual mammal could be exposed numerous times during the survey. The number of possible exposures to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} (including repeated exposures of the same individuals) can be estimated by considering the total marine area that would be within the 160-dB radius around the operating airguns, including areas of overlap. However, it is unlikely that a particular animal

TABLE 4. Estimates of the possible numbers of marine mammal exposures to the different sound levels, and the numbers of different individuals that might be exposed, during L-DEO's proposed seismic survey in the Lau Basin, SWPO, during January–February 2009. Received levels of airgun sounds are expressed in dB re 1 µPa (rms, averaged over pulse duration), consistent with NMFS' practice. Not all marine mammals will change their behavior when exposed to these sound levels, but some may alter their behavior when levels are lower (see text). Delphinids 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.

	# Exposures to sound levels ≥160 dB (≥170 dB, Delphinids)				# Individuals exposed to sound levels ≥160 dB (≥170 dB, Delphinids)					
Species	**Best Estimate**		**Maximum Estimate**		**Best Estimate**		**% Reg'l Pop'n**	**Maximum Estimate**		**Requested Take Authorization**
Mysticetes										
Balaenidae										
Pygmy right whale	3		10		1		NA	3		**3**
Balaenopteridae										
Humpback whale	*3*		*10*		*1*		*0.01*	*3*		**3**
Minke whale	3		10		1		0	3		**3**
Dwarf minke whale	3		10		1		0	3		**3**
Bryde's whale	15		52		4		0.02	14		**14**
Sei whale	*3*		*10*		*1*		*0.01*	*3*		**3**
Fin whale	*3*		*10*		*1*		*0.03*	*3*		**3**
Blue whale	*3*		*10*		*1*		*0.11*	*3*		**3**
Odontocetes										
Physeteridae										
Sperm whale	*22*		*83*		*6*		*0.03*	*22*		**22**
Pygmy sperm whale	358		1324		96		NA	353		**353**
Dwarf sperm whale	358		1324		96		0.85	353		**353**
Ziphiidae										
Cuvier's beaked whale	65		149		17		0.09	40		**40**
Southern bottlenose whale	0		0		0		0	0		**0**
Longman's beaked whale	26		60		7		NA	16		**16**
Blaineville's beaked whale	65		149		17		NA	40		**40**
Ginkgo-toothed beaked whale	26		60		7		NA	16		**16**
Delphinidae										
Rough-toothed dolphin	3214	(1448)	6184	(2786)	857	(726)	0.59	1649	(1397)	**1649**
Bottlenose dolphin	643	(290)	1237	(557)	171	(145)	0.07	330	(279)	**330**
Pantropical spotted dolphin	3214	(1448)	6184	(2786)	857	(726)	0.07	1649	(1397)	**1649**
Spinner dolphin	6428	(2896)	12367	(5571)	1714	(1452)	0.17	3298	(2794)	**3298**
Striped dolphin	643	(290)	1237	(557)	171	(145)	0.01	330	(279)	**330**
Fraser's dolphin	1928	(869)	3710	(1671)	514	(436)	0.18	990	(838)	**990**
Common dolphin	643	(290)	1237	(557)	171	(145)	0.01	330	(279)	**330**
Risso's dolphin	643	(290)	1237	(557)	171	(145)	0.10	330	(279)	**330**
Melon-headed whale	163	(73)	569	(256)	43	(37)	0.10	152	(128)	**152**
Pygmy killer whale	33	(15)	114	(51)	9	(7)	0.02	30	(26)	**30**
False killer whale	98	(44)	341	(154)	26	(22)	0.07	91	(77)	**91**
Killer whale	65	(29)	227	(102)	17	(15)	0.20	61	(51)	**61**
Short-finned pilot whale	65	(29)	227	(102)	17	(15)	0.01	61	(51)	**61**

[1] Best estimate and maximum estimates of density are from Tables 3 and 4.

[2] Regional population size estimates are from Table 2. NA indicates that regional population estimates are not available.

would stay in the area during the entire survey. The best estimates in this section are based on the averages of the densities from the appropriate blocks in the 1986–1996 NMFS surveys (as described above), and maximum estimates are based on the highest density among those blocks.

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

- the expected species density, either "mean" (i.e., best estimate) or "maximum", times
- the anticipated minimum area to be ensonified to that level during airgun operations including overlap (exposures), or
- the anticipated area to be ensonified to that level during airgun operations excluding overlap (individuals).

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

Applying the approach described above, ~17,525 km^2 (including 25% contingency) would be within the 160-dB isopleth on one or more occasions during the survey, whereas 65,710 km^2 is the area ensonified to ≥160 dB when overlap is included. Thus, it is possible that an average individual marine mammal could be exposed up to four times during the survey. Because this approach does not allow for turnover in the mammal populations in the study area during the course of the survey, the actual number of individuals exposed could be underestimated, although the conservative (i.e., probably overestimated) line-kilometer distances used to calculate the area could offset this. Also, the approach assumes that no cetaceans will move away or toward the trackline as the *Langseth* approaches in response to increasing sound levels prior to the time the levels reach 160 dB.

The 'best estimate' of the number of individual cetaceans that could be exposed to seismic sounds with received levels ≥160 dB re 1 µPa$_{rms}$ during the proposed survey is 4996 (Table 4). That total includes 11 baleen whales, four of which are considered ***endangered*** under the ESA: one humpback whale (0.01% of the regional population), one blue whale (0.11%), one sei whale (0.01%), and one fin whale (0.03%) (Table 4).

In addition, six sperm whales (also listed as ***endangered under*** the ESA) or 0.03% of the regional population could be exposed during the survey, as well as 48 beaked whales (Table 4). The spinner dolphin is estimated to be the most common species in the area, with a best estimate of 1714 or 0.17% of the regional population exposed to ≥160 dB re 1 µPa$_{rms}$. However, a more meaningful estimate is the one for sound levels ≥170 dB (see below). The 'Maximum Estimate' column in Table 4 shows an estimated total of 10,173 cetaceans. Again, most of these consist of spinner dolphins. The best estimate of the number of exposures of cetaceans to seismic sounds with received levels ≥160 dB re 1 µPa$_{rms}$ during the survey is 18,734 (Table 4).

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

The area ensonified by levels ≥170 dB was estimated to be 14,848 km^2 (as described above for levels ≥160 dB), and the estimated area, including overlap, is 29,601 km^2. Thus, an average individual delphinid could be exposed to ≥170 dB twice during the survey. The best and maximum estimates of the numbers of individual delphinids that could be exposed to ≥170 dB during the survey are 4017 and 7879, respectively (Table 4). These values are based on the predicted 170-dB radius around the airgun array to be used during the study, and are considered to be more realistic estimates of the number of individual delphinids that could be affected.

Conclusions

The proposed seismic project will involve towing an airgun array that introduces pulsed sounds into the ocean, along with, at times, simultaneous operation of an MBES and a SBP. The survey will employ 36-airgun array similar to the airgun arrays used for typical high-energy seismic surveys, but shot intervals will be long (~400 m or 180 s). The total airgun discharge volume is ~6600 in^3. Routine vessel operations, other than the proposed airgun operations, are conventionally assumed not to affect marine mammals sufficiently to constitute "taking". No "taking" of marine mammals is expected in association with echosounder operations given the considerations discussed in § I, i.e., sounds are beamed downward, the beam is narrow, and the pulses are extremely short.

Cetaceans.—Several species of mysticetes show strong avoidance reactions to seismic vessels at ranges up to 6–8 km and occasionally as far as 20–30 km from the source vessel when medium-large airgun arrays have been used. However, reactions at the longer distances appear to be atypical of most species and situations.

Odontocete reactions to seismic pulses, or at least the reactions of delphinids, 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$_{\text{rms}}$ represent, for all species, <1% of the regional population (Table 4).

Varying estimates of the numbers of marine mammals that might be exposed to strong airgun sounds during the proposed program have been presented, depending on the specific exposure criteria (≥160 or ≥170 dB) and density criterion used (best or maximum). The requested "take authorization" for each species is based on the estimated maximum 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 look outs, ramp ups, and power downs or shut downs when marine mammals are seen within defined ranges, should further reduce short-term reactions, and avoid or minimize any effects on hearing sensitivity. In all cases, the effects are expected to be short-term, with no lasting biological consequence.

Pinnipeds.—No pinnipeds are expected to occur in the survey area.

VIII. ANTICIPATED IMPACT ON SUBSISTENCE

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

There is no legal subsistence hunting for marine mammals in the waters of Tonga, so the proposed activities will not have any impact on the availability of the species or stocks for subsistence users. Historically the people of Tonga hunted humpback whales as recently as the 1970s; 11 whaling operations were active in Tonga in the 1970s (Reeves 2002). A royal ban on Tongan whale hunting has been in effect since 1979 (see Reeves 2002), and marine mammals are also afforded protection under the Tongan Fisheries Management Act of 2002. However, Tonga is not a member of the International Whaling Commission.

IX. ANTICIPATED IMPACT ON HABITAT

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

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

Effects on Fish

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

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

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

Pathological Effects

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

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

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

Some studies have reported, some equivocally, that mortality of fish, fish eggs, or larvae can occur close to seismic sources (Kostyuchenko 1973; Dalen and Knutsen 1986; Booman et al. 1996; Dalen et al. 1996). Some of the reports claimed seismic effects from treatments quite different from actual seismic survey sounds or even reasonable surrogates. Saetre and Ona (1996) applied a ‘worst-case scenario’ mathematical model to investigate the effects of seismic energy on fish eggs and larvae. They concluded that mortality rates caused by exposure to seismic surveys are so low, as compared to natural mortality rates, that the impact of seismic surveying on recruitment to a fish stock must be regarded as insignificant.

Physiological Effects

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

Behavioral Effects

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

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

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

Effects on Invertebrates

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

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

The following sections provide a synopsis of available information on the effects of exposure to seismic survey sound on species of decapod crustaceans and cephalopods, the two taxonomic groups of invertebrates on which most such studies have been conducted. The available information is from studies with variable degrees of scientific soundness and from anecdotal information. A more detailed review of the literature on the effects of seismic survey sound on invertebrates is provided in Appendix E of the EA.

Pathological Effects

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

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

Physiological Effects

Physiological effects refer mainly to biochemical responses by marine invertebrates to acoustic stress. Such stress potentially could affect invertebrate populations by increasing mortality or reducing reproductive success. Any primary and secondary stress responses (i.e., changes in haemolymph levels of enzymes, proteins, etc.) of crustaceans after exposure to seismic survey sounds appear to be temporary (hours to days) in studies done to date (J. Payne, Department of Fisheries and Oceans [DFO] research scientist, St. John's, NL, Canada, pers. comm.). The periods necessary for these biochemical changes to return to normal are variable and depend on numerous aspects of the biology of the species and of the sound stimulus.

Behavioral Effects

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

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

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

The proposed activity is not expected to have any habitat-related effects that could cause significant or long-term consequences for individual marine mammals or their populations, because operations will be limited in duration (~19 days of seismic operations). However, a small minority of the marine mammals that are present near the proposed activity may be temporarily displaced as much as a few kilometers by the planned activity. Concentrations of marine mammals and/or marine mammal prey species are not expected to occur in or near the proposed study area. AT the time of the survey (January–February); the area does not appear to constitute an area of localized or critical feeding, breeding, or migration for cetaceans. However, Tongan waters are used by breeding humpback whales during the austral winters.

Up to 64 OBSs will be deployed during the survey and will be spaced ~10–12 km apart. Two different types of OBSs will be used. The WHOI "D2" OBS has an anchor made of hot-rolled steel with dimensions 2.5 × 30.5 × 38.1 cm. The anchor of the Scripps' LC4x4 OBS consists of a 1-m^2 piece of steel grating. OBS anchors will be left behind upon equipment recovery. Although OBS placement will disrupt a very small area of seafloor habitat and could disturb benthic invertebrates, the impacts are expected to be localized and transitory.

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 within the EEZ of Tonga. To minimize the likelihood that impacts will occur to the species and stocks, airgun operations will be conducted in accordance with all applicable Tongan and U.S. federal regulations, including obtaining permission for incidental harassment or incidental 'take' of marine mammals and other endangered species.

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

Planning Phase

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

Proposed Exclusion Zones

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

Received sound levels have been modeled by L-DEO for the 36-airgun array (Fig. 4 and 5) and for a single 1900LL 40-in^3 airgun (which will be used during power downs; Fig. 6), in relation to distance and direction from the airguns. Based on the modeling for deep water, the distances from the source where sound levels are predicted to be 190, 180, 170, and 160 dB re 1 μPa_{rms} were determined (see Table 1 in § I). The 180- and 190-dB radii vary with tow depth of the airgun array and range up to 1120 m and 340 m, respectively. The 180- and 190-dB levels are shut-down criteria applicable to cetaceans and pinnipeds, respectively, as specified by NMFS (2000); these levels were used to establish the EZs. If the MMO detects marine mammal(s) or turtle(s) within or about to enter the appropriate EZ, the airguns will be powered down (or shut down if necessary) immediately (see below).

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

Mitigation During Operations

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

Power-down Procedures

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

If a marine mammal or turtle is detected outside the EZ but is likely to enter the EZ, and if the vessel's speed and/or course cannot be changed to avoid having the animal enter the EZ, the airguns will be powered down before the animal is within the EZ. Likewise, if a mammal or turtle is already within the EZ when first detected, the airguns will be powered down immediately. During a power down of the airgun array, the 40-in^3 airgun will be operated. If a marine mammal or turtle is detected within or near the smaller EZ around that single airgun (Table 1), it will be shut down (see next subsection).

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

- is visually observed to have left the EZ, or
- has not been seen within the zone for 15 min in the case of small odontocetes or 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., ~6 to 18 min, depending on the sighting distance, vessel speed, and tow depth [based on the length of time it will take the vessel to leave behind the turtle, so that it is outside the exclusion zone; e.g., if a turtle is sighted close to the vessel, the ship speed is 9.3 km/h, and the tow depth is 9 m, it would take the vessel ~6 min to leave the turtle behind].

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

Shut-down Procedures

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

Ramp-up Procedures

A ramp-up procedure will be followed when the airgun array begins operating after a specified period without airgun operations or when a power down has exceeded that period. It is proposed that, for the present cruise, this period would be ~8 min. This period is based on the largest modeled 180-dB radius for the 36-airgun array (see Table 1) in relation to the planned speed of the *Langseth* while shooting (see above). Similar periods (~8–10 min) were used during previous L-DEO surveys.

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

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

XII. PLAN OF COOPERATION

> Where the proposed activity would take place in or near a traditional Arctic subsistence hunting area and/or may affect the availability of a species or stock of marine mammal for Arctic subsistence uses, the applicant must submit either a plan of cooperation or information that identifies what measures have been taken and/or will be taken to minimize any adverse effects on the availability of marine mammals for subsistence uses. A plan must include the following:
>
> (i) A statement that the applicant has notified and provided the affected subsistence community with a draft plan of cooperation;
>
> (ii) A schedule for meeting with the affected subsistence communities to discuss proposed activities and to resolve potential conflicts regarding any aspects of either the operation or the plan of cooperation;
>
> (iii) A description of what measures the applicant has taken and/or will take to ensure that proposed activities will not interfere with subsistence whaling or sealing; and
>
> (iv) What plans the applicant has to continue to meet with the affected communities, both prior to and while conducting activity, to resolve conflicts and to notify the communities of any changes in the operation.

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

XIII. MONITORING AND REPORTING PLAN

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

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

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

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

Vessel-based Visual Monitoring

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

During seismic operations, at least three MMVOs will be based aboard the *Langseth*. MMVOs will be appointed by L-DEO with NMFS concurrence. At least one MMVO, and when practical two MMVOs, will monitor marine mammals and turtles near the seismic vessel during ongoing daytime operations and nighttime start ups of the airguns. Use of two simultaneous observers will increase the proportion of the animals present near the source vessel that are detected. MMVO(s) will be on duty in shifts of duration no longer than 4 h. Other crew will also be instructed to assist in detecting marine mammals and turtles and implementing mitigation requirements (if practical). Before the start of the seismic survey the crew will be given additional instruction regarding how to do so.

The *Langseth* is a suitable platform for marine mammal and turtle observations. When stationed on the observation platform, the eye level will be ~18 m above sea level, and the observer will have a good view around the entire vessel. During daytime, the MMO(s) will scan the area around the vessel systematically with reticle binoculars (e.g., 7×50 Fujinon), Big-eye binoculars (25×150), and with the naked eye. During darkness, night vision devices (NVDs) will be available (ITT F500 Series Generation 3 binocular-image intensifier or equivalent), when required. Laser rangefinding binoculars (Leica LRF 1200 laser rangefinder or equivalent) will be available to assist with distance estimation. Those are useful in training observers to estimate distances visually, but are generally not useful in measuring distances to animals directly; that is done primarily with the reticles in the binoculars.

Passive Acoustic Monitoring

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

The PAM system consists of hardware (i.e., hydrophones) and software. The “wet end” of the system consists of a low-noise, towed hydrophone array that is connected to the vessel by a “hairy” faired cable. The array will be deployed from a winch located on the back deck. A deck cable will connect from the winch to the main computer lab where the acoustic station and signal conditioning and processing system will be located. The lead-in from the hydrophone array is ~400 m long, and the active part of the hydrophone array is ~56 m long. The hydrophone array is typically towed at depths <20 m.

The towed hydrophones will ideally be monitored 24 h per day while at the seismic survey area during airgun operations, and during most periods when the *Langseth* is underway while the airguns are not operating. One MMO will monitor the acoustic detection system at any one time, by listening to the signals from two channels via headphones and/or speakers and watching the real-time spectrographic display for frequency ranges produced by cetaceans. MMOs monitoring the acoustical data will be on shift for 1–6 h at a time. Besides the visual MMOs, an additional MMO with primary responsibility for PAM will also be aboard. All MMOs are expected to rotate through the PAM position, although the most experienced with acoustics will be on PAM duty more frequently.

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

MMVO Data and Documentation

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

They will also provide information needed to order a power down or shut down of the airguns when a marine mammal or sea turtle is within or near the EZ.

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

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

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

All observations and power downs or shut downs will be recorded in a standardized format. Data will be entered into a custom electronic database. The accuracy of the data entry will be verified by computerized data validity checks as the data are entered and by subsequent manual checking of the database. Preliminary reports will be prepared during the field program and summaries forwarded to the operating institution's shore facility and to NSF weekly or more frequently. MMVO observations will provide the following information:

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

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

XIV. COORDINATING RESEARCH TO REDUCE AND EVALUATE INCIDENTAL TAKE

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

L-DEO will coordinate the planned marine mammal monitoring program associated with the ELSC seismic survey in the SWPO (as summarized in § XI and XIII) with other parties that may have interest in the area and/or be conducting marine mammal studies in the same region during the proposed seismic survey. L-DEO and NSF have coordinated, and will continue to coordinate, with applicable Tongan and U.S. agencies (e.g., NMFS), and will comply with their requirements.

XV. LITERATURE CITED

Marine Mammals and Acoustics

Aguilar, A. 2002. Fin whale *Balaenoptera physalus*. p. 435-438 *In:* W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of Marine Mammals. Academic Press, San Diego, CA. 1414 p.

Albertson-Gibb, R., C. Antolik, C. Olavarría, C. Garrigue, N. Hauser, M. Poole, M. Brasseur, D. Steel, and C.S. Baker. 2008. Using mitochondrial DNA and mixed-stock analysis to describe migratory allocation of humpback whales from Antarctic feeding areas to South Pacific breeding grounds. SC/60/SD Abstract presented to the IWC Scientific Committee, May 2008.

Angliss R.P. and R.B. Outlaw. 2008. Alaska marine mammal stock assessments, 2007. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-180. 252 p.

Archer, F.I. 2002. Striped dolphin *Stenella coeruleoalba*. p. 1201-1203 *In:* W.F. Perrin, B. Würsig and J.G.M. Thewissen (eds.), Encyclopedia of Marine Mammals. Academic Press, San Diego, CA. 1414 p.

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.

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. 2002. 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., A.D. Ligon, and S.K. Hooker. 2000. Sub-surface and night-time behavior of humpback whales off Maui, Hawaii: a preliminary report. Report 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., D.L. Webster, D.J. McSweeney, A.D. Ligon, G.S. Schorr, and J. Barlow. 2006. Diving behavior and ecology of Cuvier's (*Ziphius cavirostris*) and Blainville's (*Mesoplodon densirostris*) beaked whales in Hawaii. **Can. J. Zool.** 84(8):1120-1128.

Baker, C.S. and L.M. Herman. 1989. Behavioral responses of summering humpback whales to vessel traffic: Experimental and opportunistic observations. NPS-NR-TRS-89-01. Rep. by Kewalo Basin Mar. Mamm. Lab., Univ. Hawaii, Honolulu, HI, for U.S. Natl. Park Serv., Anchorage, AK. 50 p. NTIS PB90-198409.

Baker, A.N. and A.L. van Helden. 1999. New records of beaked whales, genus *Mesoplodon*, from New Zealand (Cetacea: Ziphiidae). **J. Roy. Soc. New Zealand** 29(3):235-244.

Baker, C.S., L.M. Herman, B.G. Bays, and W.F. Stifel. 1982. The impact of vessel traffic on the behavior of humpback whales in southeast Alaska. Rep. by Kewalo Basin Mar. Mamm. Lab., Honolulu, HI, for U.S. Natl. Mar. Fish. Serv., Seattle, WA. 78 p.

Baker, C.S., L.M. Herman, B.G. Bays, and G.B. Bauer. 1983. The impact of vessel traffic on the behavior of humpback whales in southeast Alaska: 1982 season. Rep. by Kewalo Basin Mar. Mamm. Lab., Honolulu, HI, for U.S. Natl. Mar. Mamm. Lab., Seattle, WA. 30 p. + fig., tables.

Baker, C.S., A. Perry, J.L. Bannister, M.T Weinrich, R.B. Abernethy, J. Calambokidis, J. Lien, R.H. Lambertsen, J. Urbán Ramirez, O. Vasquez, P.J. Clapham, A. Alling, S.J. O'Brien, and S.R. Palumbi. 1993. Abundant mitochondrial DNA variation and world-wide population structure in humpback whales. **Proc. Nat. Acad. Sci. USA** 90:8239-8243.

Baker, C.S., L. Flórez-González, B. Abernethy, H.C. Rosenbaum, R.W. Slade, J. Capella, and J.L. Bannister. 1998. Mitochondrial DNA variation and maternal gene flow among humpback whales of the Southern Hemisphere. **Mar. Mamm. Sci.** 14(4):721-737.

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.

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. Abstract. World Marine Mammal Science Conference, Monaco, 20-24 January.

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.

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

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. 2006. Abundance estimates for Antarctic minke whales from three completed circumpolar sets of surveys, 1978/79 to 2003/04. Paper SC58/IA18 presented to the IWC Scientific Committee, June 2006 (unpublished). 28 p. Available from the IWC Secretariat: secretariat@iwcoffice.org.

Branch, T.A. 2007. Abundance of Antarctic blue whales south of 60 degrees S from three complete circumpolar sets of surveys. **J. Cetac. Res. Manage.** 9(3):253-262.

Branch, T.A. and D.S. Butterworth. 2001. Estimates of abundance south of 60°S for cetacean species sighted frequently on the 1978/79 to 1997/98 IWC/IDCR-SOWER sighting surveys. **J. Cetac. Res. Manage.** 3(3):251-279.

Burkhardt, E., O. Boebel, H. Bornemann, and C. Ruholl. 2007. Risk assessment of scientific sonars. Poster Paper, International Conference, The Effects of Noise on Aquatic Life, 13–17 August 2007, Nyborg, Denmark.

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

Caballero, S., H. Hamilton, C. Jaramillo, J. Capella, L. Flórez-González, C. Olavarria, H. Rosenbaum, F. Guhl, and C.S. Baker. 2001. Genetic characterisation of the Colombian Pacific Coast humpback whale population using RAPD and mitochondrial DNA sequences. **Mem. Queensl. Mus.** 47(2):459-464.

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., T. Chandler, L. Schlender, G.H. Steiger, and A. Douglas. 2003. Research on humpback and blue whales off California, Oregon, and Washington in 2002. Final Report to Southwest Fisheries Science Center, La Jolla, CA. Cascadia Research, 218½ W Fourth Ave., Olympia, WA, 98501. 47 p.

Caldwell, D.K. and M.C. Caldwell. 1989. Pygmy sperm whale Kogia breviceps (de Blainville, 1838): dwarf sperm whale Kogia simus Owen, 1866. p. 235-260 *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.

Caldwell, J. and W. Dragoset. 2000. A brief overview of seismic air-gun arrays. **The Leading Edge** 19(8, Aug.):898-902.

Cawthorn, M.W. 1992. New Zealand Progress report on cetacean research. **Rep. Int. Whal. Comm**. 42:357-360.

Clapham, P.J. 2002. Humpback whale. p. 589-592 *In:* Perrin, W.F., B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals. Academic Press, San Diego, CA. 1414 p.

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. Intern. Whal. Comm. Working Pap. SC/58/E9. 9 p.

Clarke, M. and N. Goodall. 1994. Cephalopods in the diets of three odontocete cetacean species stranded at Tierra del Fuego, *Globicephala melaena* (Traill, 1809), *Hyperoodon planifrons* Flower, 1882 and *Cephalorhynchus commersonii* (Lacepede, 1804). **Antarctic Sci.** 6(2):149-154.

Constantine, R., K. Russel, N. Gibbs, S. Childerhouse, and C.S. Baker. 2006. Photo-identification of humpback whales in New Zealand waters and their migratory connections to breeding grounds of Oceania. IWC Sci. Comm. Rep. SC/A06/HW50. 5 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. Fern ndez, 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. Acevedo-Gutiérrez, B. Tershy, and J. Urbán-Ramírez. 2001. The diving behavior of blue and fin whales: is dive duration shorter than expected based on oxygen stores? **Comp. Biochem. Physiol.** 129A: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.

Cummings, W.C. 1985. Bryde’s whale *Balaenoptera edeni* (Anderson, 1878). p. 137-154 *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.

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.

Dahlheim, M.E. and J.E. Heyning. 1999. Killer whale *Orcinus orca* (Linnaeus, 1758). p. 281-322 *In:* Ridgway, S.H. 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.

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. Jørgensen, and M.V. Jensen. 2002. Satellite tracking of humpback whales in West Greenland. NERI Tech. Rep. No. 411. National Environmental Research Institute, Roskilde, Denmark. 40 p.

Dolar, M.L.L. 2002. Fraser's dolphin *Lagenodelphis hosei*. *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. Dive behavior and foraging of humpback shales in Southeast Alaska. **Can. J. Zool**. 65:354-362.

DoN (U.S. Department of the Navy). 2005. Marine resources assessment for the Southern California Operating Area. Pacific Division, Naval Facilities Engineering Command, Pearl Harbor, Hawaii. Contract N62470-02-D-997, CTO 0025. Prepared by Geo-Marine, Inc., Plano, TX. Final Report. September.

Donahue, M.A. and W.L. Perryman. 2002. Pygmy killer whale. p. 1009-1010 *In:* W.F. Perrin, B. Würsig and J.G.M. Thewissen (eds.), Encyclopedia of Marine Mammals. Academic Press, San Diego, CA. 1414 p.

Donoghue, M.F. 1996. New Zealand, progress report on cetacean research, April 1994 to March 1995. **Rep. Int. Whal. Commn.** 46:265-269.

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.

Duffus, D.A. and P. Dearden. 1993. Recreational use, valuation, and management of killer whales (*Orcinus orca*) on Canada's Pacific coast. **Environ. Conserv**. 20(2):149-156.

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.

Erikson, N., L.A. Miller, J. Tougaard, and D.A. Helweg. 2005. Cultural change in the songs of humpback whales (Megaptera novaeangliae) from Tonga. **Behavior** 142:305-328.

Evans, P.G.H. 1987. The Natural History of Whales and Dolphins. Facts on File Publications, New York. 343 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.

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, SWFSC, NMFS, La Jolla, CA. 61 p.

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:* Perrin, W.F., 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.

Gambell, R. 1985a. Sei whale *Balaenoptera borealis* Lesson, 1828. p. 155-170 *In:* Ridgway, S.H. 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:* Ridgway, S.H 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.

Gannier, A. 2002a. Cetaceans of the Marquesas Islands (French Polynesia): distribution and relative abundance as obtained from a small boat dedicated survey. **Aquat. Mamm.** 28(2):198-210.

Gannier, A. 2002b. Temporal variability of spinner dolphin residency in a bay of Tahiti island (1995-2001). Abstract presented to the 16th Conference of the European Cetacean Society, Liège, Belgium, April 7-12, 2002.

Garrigue, C. and P.C. Gill. 1994. Observations of humpback whales *Megaptera novaeangliae* in New Caledonian waters during 1991–1993. **Biol. Cons.** 70:211-218.

Garrigue, C., A. Aguayo, V.L.U. Amante-Helweg, C.S. Baker, S. Caballero, P. Clapham, R. Constantine, J. Denkinger, M. Donoghue, L. Flórez-González, J. Greaves, N. Hauser, C. Olavarría, C. Pairoa, H. Peckham, and M. Poole. 2002. Movements of humpback whales in Oceania, South Pacific. **J. Cetacean Res. Manage.** 4(3):255-260.

Garrigue, C., C. Olavarria, C.S. Baker, D. Steel, R. Dodemont, R. Constantine, and K. Russel. 2006a. Demographic and genetic isolation of New Caledonia (E2) and Tonga (E3) breeding stocks. IWC Sci. Comm. Rep. SC/A06/HW19. 10 p.

Garrigue, C., C.S. Baker, R. Constantine, M. Poole, N. Hauser, P. Clapham, M. Donoghue, K. Russell, D. Paton, and D. Mattila. 2006b. Interchange of humpback whales in Oceania (South Pacific), 1999 to 2004. IWC Sci. Comm. Rep. SC/A06/HW55. 9 p.

Gaskin, D.E. 1973. Sperm whales in the western South Pacific. **New Zealand J. Mar. Freshw. Res.** 7(1&2):1-20.

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. Available at http://www.nmfs.noaa.gov /pr/acoustics/reports.htm

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.

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.

Gowans, S. 2002. Bottlenose whales *Hyperoodon ampullatus* and *H. planifrons*. p. 128-129 *In:* W.F. Perrin, B. Würsig and J.G.M. Thewissen (eds.), Encyclopedia of Marine Mammals. Academic Press, San Diego, CA. 1414 p.

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. 1999. 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.

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, N. and P. Clapham. 2006. Occurrence and habitat use of humpback whales in the Cook Islands. IWC Sci. Comm. Rep. SC/A06/HW49. 12 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:* Ridgway, S.H. and R.J. Harrison (eds.), Vol. 4: River dolphins and the larger toothed whales. Academic Press, San Diego, CA. 444 p.

Heyning, J.E. 2002. Cuvier's beaked whale *Ziphius cavirostris*. p. 305-307 *In:* W.F. Perrin, B. Würsig and J.G.M. Thewissen (eds.), Encyclopedia of Marine Mammals. Academic Press, San Diego, CA. 1414 p.

Heyning, J.E. and M.E. Dahlheim. 1988. *Orcinus orca.* **Mammal. Spec.** 304:1-9.

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, Feburary–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 in the Eastern Tropical Pacific Ocean off Central America, November–December 2004. LGL Rep. TA2822-30. 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. 125 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 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., 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.

Horwood, J. 2002. Sei whale. p. 1069-1071 *In*: Perrin, W.F., B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals. Academic Press, San Diego, CA. 1414 p.

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

IUCN (The World Conservation Union). 2007. 2007 IUCN Red List of Threatened Species. http://www.iucnredlist.org.

IWC (International Whaling Commission). 2006. Southern Hemispere humpback whale comprehensive assessment, Hobart, April 2006: Table 1 (SC/57/SH11 revised). 16 p.

IWC (International Whaling Commission). 2007a. Whale population estimates. http://www.iwcoffice.org /conservation/ stimate.htm#assessment

IWC (International Whaling Commission). 2007b. 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.

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., S. Leatherwood, and M.A. Webber. 1993. FAO Species identification guide. Marine mammals of the world. UNEP/FAO, Rome, Italy.

Jefferson, T.A., M.A. Webber, and R.L. Pitman. 2008. Marine mammals of the world: a comprehensive guide to their identification. Academic Press, New York. 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, D. Engelhaupt, J. Gordon, N. Jaquet, M. Johnson, R. Leben, B. Mate, P. Miller, J. Ortega-Ortiz, A. Thode, P. Tyack, J. Wormuth, and B. Würsig. 2006. Sperm whale seismic study in the Gulf of Mexico; summary report, 2002–2004. OCS Study MMS 2006-0034. 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. 345 p.

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.

Johnston, S.J. and D.S. Butterworth. 2005. A Bayesian assessment of the west and east Australian breeding populations (Stocks D and E) of southern hemisphere humpback whales. Paper SC/57/SH15 presented to the IWC Scientific Committee, June 2006 (unpublished). 25 p. Paper available from the IWC Secretariat: secretariat@iwcoffice.org.

Kanda, N., M. Goto, H. Kato, M.V. McPhee, and L.A. Pastene. 2007. Population genetic structure of Bryde’s whales (*Balaenoptera brydei*) at the inter-oceanic and trans-equatorial levels. **Conserv. Genet.** 8:853-864.

Kasamatsu, F, G.G. Joyce, P. Ensor, and J. Mermoz. 1990. Current occurrence of cetacea in the Southern Hemisphere: results from the IWC/ICDR Southern Hemisphere minke whale assessment cruises, 1978/79–1987/88. Paper SC/42/O 15 preseneted to the International Whaling Commission Scientific Committee. 77 p.

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. Reichmut. 2005. Underwater temporary threshold shift in pinnipeds: effects of noise level and duration. **J. Acoust. Soc. Amer.** 118(5):3154-3163.

Kasuya, T. 1986. Distribution and behavior of Baird's beaked whales off the Pacific coast of Japan. **Sci. Rep. Whales Res. Inst.** 37:61-83.

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

Kemper, C.M. 2002a. Pygmy right whale *Caperea marginata*. p. 1010-1012 *In:* W.F. Perrin, B. Würsig and J.G.M. Thewissen (eds.), Encyclopedia of Marine Mammals. Academic Press, San Diego, CA. 1414 p.

Kemper, C.M. 2002b. Distribution of the pygmy right whale, *Caperea marginata*, in the Australasian region. **Mar. Mamm. Sci.** 18(1):99-111.

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.

Klatsky, L.J. 2004. Movement and dive behavior of bottlenose dolphins (*Tursiops truncatus*) near the Bermuda Pedestal. M.Sc. Thesis. San Diego State University, CA. 31 p.

Klatsky, L., R. Wells, J. Sweeney. 2005. Bermuda's deep diving dolphins – movements and dive behavior of offshore bottlenose dolphins in the Northwest Atlantic Ocean near Bermuda. Abstracts of the 16th Biennial Conference on the Biology of Marine Mammals, San Diego, CA, 12-16 December 2005.

Kongsberg Maritime. 2005. Hydroacoustics, echosounders multibeam: EM 120 Multibeam echo sounder. http://www.km.kongsberg.com/KS/WEB/NOKBG0397.nsf/AllWeb/6B7656717DD9FE01C1256D4A0031824C?OpenDocument. Accessed 20 Nov. 2005.

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.

Krieger, K.J. and B.L. Wing. 1984. Hydroacoustic surveys and identification of humpback whale forage in Glacier Bay, Stephens Passage, and Frederick Sound, southeastern Alaska, summer 1983. NOAA Tech. Memo. NMFS F/NWC-66. U.S. Natl. Mar. Fish. Serv., Auke Bay, AK. 60 p. NTIS PB85-183887.

Krieger, K.J. and B.L. Wing. 1986. Hydroacoustic monitoring of prey to determine humpback whale movements. NOAA Tech. Memo. NMFS F/NWC-98. U.S. Natl. Mar. Fish. Serv., Auke Bay, AK. 63 p. NTIS PB86-204054.

Kruse, S. 1991. The interactions between killer whales and boats in Johnstone Strait, B.C. p 148-159 *In*: Pryor, K. and K.S. Norris (eds.), Dolphin societies/discoveries and puzzles. Univ. Calif. Press, Berkeley, CA.

Kruse, S., D.K. Caldwell, and M.C. Caldwell. 1999. Risso's dolphin *Grampus griseus* (G. Cuvier, 1812). p. 183-212 *In:* Ridgway, S.H. 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.

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

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.

Laws, R.M. 1961. Reproduction, growth and age of southern fin whales. **Disc. Rep.** 31:327-486.

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

LGL Ltd. 2006. Request by Lamont-Doherty Earth Observatory for an Incidental Harassment Authorization to allow the incidental take of marine mammals during seismic testing in the northern Gulf of Mexico, fall 2006. LGL Rep. TA4295-1. Rep. by LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY.

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*: Aidley, D.J. (ed.), Animal migration. Soc. Exp. Biol. Seminar Ser. 13, Cambridge University Press, U.K.

Lucke, K., P.A. Lepper, M.-A. Blanchet, and U. Siebert. 2007. Testing the auditory tolerance of harbour porpoise hearing for impulsive sounds. Poster Paper presented at Conference on Noise and Aquatic Life, Nyborg, Denmark, Aug. 2007.

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. Cetac. Res. Manage.** 7(3):211-221.

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

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.

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.

McAlpine, D.F., L.D. Murison, and E.P. Hoberg. 1997. New records for the pygmy sperm whale, *Kogia breviceps* (Physeteridae) from Atlantic Canada with notes on diet and parasites. **Mar. Mamm. Sci.** 13(4):701-704.

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, 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 (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. 1989a. Bottlenose whales *Hyperoodon ampullatus* (Forster, 1770) and *Hyperoodon planifrons* Flower, 1882. p. 321-348 *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.

Mead, J.G. 1989b. Beaked whales of the genus *Mesoplodon*. p. 349-430 *In:* Ridgway, S.H. 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.

Mead, J.G. and C.W. Potter. 1995. Recognizing two populations of the bottlenose dolphins (*Tursiops truncatus*) off the Atlantic coast of North America: morphological and ecological considerations. IBI Reports 5:31-44.

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., P.L. Tyack, M.P. Johnson, P.T. Madsen, and R. King. 2006. Techniques to assess and mitigate the environmental risk posed by use of airguns: recent advances from academic research program. 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. 125 p.

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.

Moein, S.E., J.A. Musick, J.A. Keinath, D.E. Barnard, M. Lenhardt, and R. George. 1994. Evaluation of seismic sources for repelling sea turtles from hopper dredges. Rep. from Virginia Inst. Mar. Sci., [Gloucester Point], VA, for U.S. Army Corps of Engineers. 33 p.

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, NL, 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.

Murase, H. T. Tamura, K. Matsuoka, T. Hakamada, and K. Konishi. 2005. First attempt of estimation of feeding impact on krill standing stock by three baleen whale species (Antarctic minke, humpback and fin whales) in Areas IV and V using JARPA data. Paper JA/J05/JR12 presented to the Japan-sponsored meeting to review data and results from the Japanese Whale Research Program under special permit in the Antarctic (JARPA) (Pre-JARPA review meeting, January 2005. 7 p.

Neumann, D.R. 2001. Seasonal movements of short-beaked common dolphins (*Delphinus delphis*) in the north-western Bay of Plenty, New Zealand: influence of sea surface temperature and El Niño/La Niña. **N.Z. J. Mar. Freshw. Res.** 35:371-374.

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). 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. Available at http://www.nmfs.noaa.gov/pr/pdfs/acoustics/ bahamas_stranding.pdf.

Noad, M.J., D. Paton, and D.H. Cato. 2006. Absolute and relative abundance estimates of Australian east coast humpback whales (*Megaptera novaeangliae*). IWC Sci. Comm. Rep. SC/A06/HW27.

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.

Olavarría, C., M. Poole, N. Hauser, C. Garrigue, S. Caballero, M. Brasseur, K. Martien, K. Russell, M. Oremus, R. Dodemont, L. Flórez-González, J. Capella, H. Rosenbaum, D. Moro, C. Jenner, M.-N. Jenner, J. Bannister, and C.S. Baker. 2003. Population differentiation of humpback whales from far Polynesia (Group F breeding grounds) based on mitochondrial DNA sequences. Paper SH/55/SH11 presented to the IWC Scientific Committee, 26 May–6 June 2003. Available at http://www.whaleresearch.org/Grafix/olavarria.pdf.

Olavarría, C., C.S. Baker, C. Garrigue, M. Poole, N. Hauser, S. Caballero, L. Flórez-González, M. Brasseur, J. Bannister, J. Capella, P. Clapham, R. Dodemont, M. Donoghue, C. Jenner, M.-N. Jenner, D. Moro, M. Oremus, D. Paton, H. Rosenbaum, K. Russell. 2007. Population structure of South Pacific humpback whales and the origin of the eastern Polynesian breeding grounds. **Mar. Ecol. Prog. Ser.** 330:257-268.

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

Orams, M.B. 2002. Humpback Whales in Tonga: An Economic Resource for Tourism. Coastal Management 30(4):361–380.

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

Panigada, S., M. Zanardelli, S. Canese, and M. Jahoda. 1999. Deep diving performances of Mediterranean fin whales. p. 144 *In*: Abstracts, 13th Bienn. Conf. Biol. Mar. Mamm. 28 November–3 December 1999, Wailea, Maui, HI.

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. Intern. Whal. Commis. Working Pap. SC/58/E41. 16 p.

Payne, R. 1978. Behavior and vocalizations of humpback whales (*Megaptera* sp.). *In*: Norris, K.S. and R.R. Reeves (eds.), Report on a workshop on problems related to humpback whales (*Megaptera novaeangliae*) in Hawaii. MCC-77/03. Rep. by Sea Life Inc., Makapuu Pt., HI, for U.S. Mar. Mamm. Comm., Washington, DC.

Perrin, W.F. 2002a. Pantropical spotted dolphin *Stenella attenuata*. p. 865-867 *In*: W.F. Perrin, B. Würsig and J.G.M. Thewissen (eds.), Encyclopedia of Marine Mammals. Academic Press, San Diego, CA. 1414 p.

Perrin, W.F. 2002b. Common dolphins *Delphinus delphis*, *D. capensis*, and *D. tropicalis*. p. 245-248 *In*: W.F. Perrin, B. Würsig and J.G.M. Thewissen (eds.), Encyclopedia of Marine Mammals. Academic Press, San Diego, CA. 1414 p.

Perrin, W.F. and R.L. Brownell, J. 2002. Minke Whales. p. 750-754 *In*: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals. Academic Press, San Diego, CA. 1414 p.

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., 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. Academic Press, London, U.K. 416 p.

Perry, S.L., D.P. DeMaster, and G.K. Silber. 1999a. 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):7-23.

Perry, S.L., D.P. DeMaster, and G.K. Silber. 1999b. The fin whale. **Mar. Fish. Rev.** 61(1):44-51.

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, Volume 5. The First Book of Dolphins. Academic Press. 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, London, 23–25 June 1998.

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., 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.

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.

Psarakos, S., D.L. Herzing, and K. Marten. 2003. Mixed-species associations between pantropical spotted dolphins (*Stenella attenuata*) and Hawaiian spinner dolphins (*Stenella longirostris*) off Oahu, Hawaii. **Aquat. Mamm.** 29(3):390-395.

Reeves, R.R. 2002. The origins and character of 'aboriginal subsistence' whaling: a global review. **Mammal Rev.** 32(2):71–106.

Reeves, R.R., S. Leatherwood, G.S. Stone, and L. G. Eldredge. 1999. Marine mammals in the area served by the South Pacific Regional Environment Programme (SPREP). SPREP, Apia, Samoa. 55 p.

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.

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 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.

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

Richter, C.F., S.M. Dawson and E. Slooten. 2003. Sperm whale watching off Kaikoura, New Zealand: effects of current activities on surfacing and vocalisation patterns. Science for Conserv. 219. Dep. of Conserv., Wellington, N.Z. 78 p.

Richter, C., S. Dawson and E. Slooten. 2006. Impacts of commercial whale watching on male sperm whales at Kaikoura, New Zealand. **Mar. Mamm. Sci.** 22(1):46-63.

Robbins, J., L. Dalla Rosa, J.M. Allen, D.K. Mattila, and E.R. Secchi. 2008. Humpback whale photo-identification reveals exchange between American Samoa and the Antarctic Peninsula, and a new mammalian distance record. SC/60/SH Abstract presented to the IWC Scientific Committee, May 2008.

Rock, J., L.A. Pastene, G. Kaufman, P. Forestell, K. Matsuoka, and J. Allen. 2006. A note on East Australia Group V Stock humpback whale movement between feeding and breeding areas based on photo-identification. **J. Cetacean Res. Manage.** 8(3):301-305.

Rogers, T.L. 2002. Leopard seal *Hydrurga leptonyx*. p. 692-693 *In:* W.F. Perrin, B. Würsig and J.G.M. Thewissen (eds.), Encyclopedia of Marine Mammals. Academic Press, San Diego, CA. 1414 p.

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.

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.

Salden, D.R. 1993. Effects of research boat approaches on humpback whale behavior off Maui, Hawaii, 1989–1993. p. 94 *In*: Abstr. 10th Bienn. Conf. Biol. Mar. Mamm., Galveston, TX, Nov. 1993. 130 p.

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.

Sears, R. 2002. Blue whale. p. 112-116 *In:* W.F. Perrin, B. Würsig and J.G.M. Thewissen (eds.), Encyclopedia of Marine Mammals. Academic Press, San Diego, CA. 1414 p.

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.

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).

Slip, D.J., G.J. Moore, and K. Green. 1995. Stomach contents of a southern bottlenose whale, *Hyperoodon planifrons*, stranded at Heard Island. **Mar. Mamm. Sci.** 11(4):575-584.

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

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.

SPREP (Secretariat of the Pacific Regional Environment Programme). 2007. Pacific Islands Regional marine species program 2008-2012. SPREP, Apia, Samoa. 48 p.

SPWRC (South Pacific Whale Research Consortium). 2002. Report of the third annual meeting of the South Pacific Whale Research Consortium, 24-28 February 2002, Auckland, New Zealand. Available http://www.whaleresearch.org/update_003.htm.

SPWRC (South Pacific Whale Research Consortium). 2004. Report of the fifth annual meeting of the South Pacific Whale Research Consortium, 2-6 April 2004, Byron Bay, NSW, Australia. For consideration by the Scientific Committee of the International Whaling Commission, Sorrento, Italy, 2004. SC/55/SH7. Available at: http://www.whaleresearch.org/update_006.htm.

SPWRC (South Pacific Whale Research Consortium). 2008. Report of the annual meeting of the South Pacific Whale Research Consortium, 5-8 February 2008, Auckland, New Zealand. Available at: http://www.whaleresearch.org/grafix/SPWRC2008.pdf.

Stacey, P.J. and R.W. Baird. 1991. Status of the false killer whale, *Pseudorca crassidens*, in Canada. **Can. Field-Nat.** 105(2):189-197.

Steel, D., C. Garrigue, M. Poole, N. Hauser, C. Olavarría, L. Flórez-González, R. Constantine, S. Caballero, D. Thiele, P. Clapham, M. Donoghue, and C.S. Baker. 2008. Migratory conncections between humpback whales from South Pacific breeding grounds and Antarctic feeding areas demonstrated by genotype matching. SC/60/SH Abstract presented to the IWC Scientific Committee, May 2008.

Stewart, B.S. and S. Leatherwood. 1985. Minke whale *Balaenoptera acutorostrata* Lacépède, 1804. p. 91-136 *In:* Ridgway, S.H. 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.

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. http://www.nmfs.noaa.gov/pr/readingrm/mmpa_small_take/gom_90d_report_final.pdf

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

Tyack, P., M. Johnson, and P. Miller. 2003. Tracking responses of sperm whales to experimental exposures of airguns. p. 115-120 *In:* Jochens, A.E. 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. 2008. UNEP-WCMC Species Database: CITES-Listed Species. http://www.cites.org/

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

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.

Waring, G.T., E. Josephson, C.P. Fairfield, and K. Maze-Foley (eds.). 2008. U.S. Atlantic and Gulf of Mexico Marine Mammals Stock Assessments – 2007. NOAA Tech. Memo. NMFS-NE-205. 415 p.

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.

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 and Policy**. 10(1):1-27.

Whitehead, H. 1993. The behavior of mature male sperm whales on the Galápagos breeding grounds. **Can. J. Zool**. 71(4):689-699.

Whitehead, H. 2002a. Sperm Whale *Physeter macrocephalus*. p. 1165-1172 *In:* W.F. Perrin, B. Würsig and J.G.M. Thewissen (eds.), Encyclopedia of Marine Mammals. Academic Press, San Diego, CA. 1414 p.

Whitehead, H. 2002b. 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., W.D. Bowen, S.K. Hooker, and S. Gowans. 1998. Marine mammals. p. 186-221 *In:* W.G. Harrison and D.G. Fenton (eds.), The Gully: a scientific review of its environment and ecosystem. Dep. Fish. Oceans, Ottawa, Ont. Canadian Stock Assessment Secretariat Research Document 98/83.

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. Commis., 10 Aug.

Williams, R., D.E. Bain, J.K.B. Ford and A.W. Trites. 2002a. Behavioural responses of male killer whales to a leapfrogging vessel. **J. Cetac. Res. Manage.** 4(3):305-310.

Williams, R., A.W. Trites and D.E. Bain. 2002b. Behavioural responses of killer whales (*Orcinus orca*) to whale-watching boats: opportunistic observations and experimental approaches. **J. Zool., Lond.** 256:255-270.

Williams, T.M, W.A. Friedl, M.L Fong, R.M. Yamada, P. Sideivy, and J.E. Haun. 1992. Travel at low energetic cost by swimming and wave-riding bottlenose dolphins. **Nature** 355(6363):821-823.

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.

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, Invertebrates, and Other

Andriguetto-Filho, J.M., A. Ostrensky, M.R. Pie, U.A. Silva, and W.A. Boeger. 2005. Evaluating the impact of seismic prospecting on artisanal shrimp fisheries. **Cont. Shelf. Res**.25:1720-1727.

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. by 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*). Rep. by LGL Ltd., St. John's, Nfld., for Environmental Studies Research Fund (ESRF), Calgary, Alta. 56 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, Alta. 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*: Merklinger, H.M. (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. (In Norwegian, with an English summary).

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. 2004. 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 sandeel 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. Prepared for 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. Effect of elastic waves generated in marine seismic prospecting on fish eggs on the Black Sea. **Hydrobiol. J.** 9:45-48.

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

Longhurst, A. R. 2007. Ecological geography of the sea, 2nd ed. Academic Press, Elsevier Inc., San Diego. 542 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 (Austral. Petrol. Product. Explor. Assoc.) 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.

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. 74, MAFF Direct. Fish. Res., Lowestoft, U.K. 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. MacGilvray, M.E. Austin, and D.A. Mann. 2005. Effects of exposure to seismic air gun use on hearing of three fish species. **J. Acoust. Soc. Am.** 117(6):3958-3971.

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, La 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.** 38:1105-1114.

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. Aquat. 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.