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 Southeast Asia, March–July 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

24 October 2008

LGL Report TA4553-2

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 Southeast Asia, March–July 2009

SUMMARY

Lamont-Doherty Earth Observatory (L-DEO), with research funding from the National Science Foundation (NSF), plans to conduct a marine seismic survey in Southeast (SE) Asia during March–July 2009 as part of the Taiwan Integrated Geodynamics Research (TAIGER) program. The survey will take place in the Exclusive Economic Zones (EEZ) of Taiwan, China, Japan, and the Philippines, in water depths ranging from <100 to >1000 m. The seismic study will use a towed array of 36 airguns with a total discharge volume of ~6600 in^3. L-DEO requests that it be issued an Incidental Harassment Authorization (IHA) allowing non-lethal takes of marine mammals incidental to the planned seismic survey. This request is submitted pursuant to Section 101 (a) (5) (D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371 (a) (5).

Numerous species of marine mammals inhabit the proposed survey area in SE Asia. Several of these species are listed as ***endangered*** under the U.S. Endangered Species Act (ESA), including the western North Pacific gray, North Pacific right, sperm, humpback, sei, fin, and blue whales. With the exception of humpback and sperm whales, these species are also considered ***endangered*** by the International Union for Conservation of Nature and Natural Resources (IUCN) 2008 Red List of Threatened species. In addition, the western North Pacific gray whale is listed as ***critically endangered*** on the 2008 IUCN Red List of Threatened Species, the Indo-Pacific humpback dolphin is considered ***near threatened,*** and the finless porpoise is considered ***vulnerable***. Other ESA-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 SE Asia along the Taiwan arc-continental collision in the China and Philippine seas as part of the TAIGER program. The survey will encompass the area 17°30'–26°30'N, 113°30'–126°E within the EEZs of Taiwan, China, Japan, and the Philippines (Fig. 1). The project is scheduled to occur 21 March–14 July 2009. Some minor deviation from these dates is possible, depending on logistics and weather.

Taiwan is one of only a few sites of arc-continent collision worldwide — one of the primary tectonic environments for large-scale mountain building. The primary purpose of the TAIGER project is to investigate the processes of mountain building, a fundamental set of processes which plays a major role in shaping the face of the Earth. The vicinity of Taiwan is particularly well-suited for this type of study, because the collision can be observed at different stages of its evolution, from incipient, to mature, and finally to post-collision.

As a result of its location in an ongoing tectonic collision zone, Taiwan experiences a great number of earthquakes; most are small, but many are large and destructive. This project will provide a great deal of information about the nature of the earthquakes around Taiwan and will lead to a better assessment of earthquake hazard in the area. The information obtained from this study will help the people and government of Taiwan to better prepare for future seismic events and may thus mitigate some of the loss of life and economic disruptions that will inevitably occur.

The source vessel, the R/V *Marcus G. Langseth*, will deploy an array of 36 airguns as an energy source at a tow depth of 6–9 m. The receiving system will consist of a hydrophone streamer and ~100 ocean bottom seismometers (OBSs). The *Langseth* will deploy an 8-km long streamer for most transects requiring a streamer; however, a shorter streamer (500 m to 2 km) will be used during surveys in Taiwan (Formosa) Strait. As the airgun array is towed along the survey lines, the hydrophone streamer will receive the returning acoustic signals and transfer the data to the on-board processing system. The OBSs record the returning acoustic signals internally for later analysis. The OBSs to be used for the 2009 program will be deployed and retrieved numerous times by a combination of four or five Taiwanese support vessels, as well as perhaps the *Langseth*. The *Langseth* will also retrieve 20 OBSs that were deployed in the study area during previous years to record earthquake activity.

The planned seismic survey will consist of ~15,902 km of transect lines within the South and East China seas as well as the Philippine Sea, with the majority of survey effort occurring in the South China Sea (Fig. 1). The survey will take place in water depths ranging from ~25 to 6585 m, but most of the survey effort (~80%) will take place in water >1000 m, 13% will take place in intermediate-depth waters (100–1000 m), and 7% will occur in shallow water (<100 m deep).

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. Francis Wu (State University of New York at Binghamton) and Dr. Kirk McIntosh (University of Texas at Austin, Institute of Geophysics). The vessel will be self-contained, and the crew will live aboard the vessel for the entire cruise.

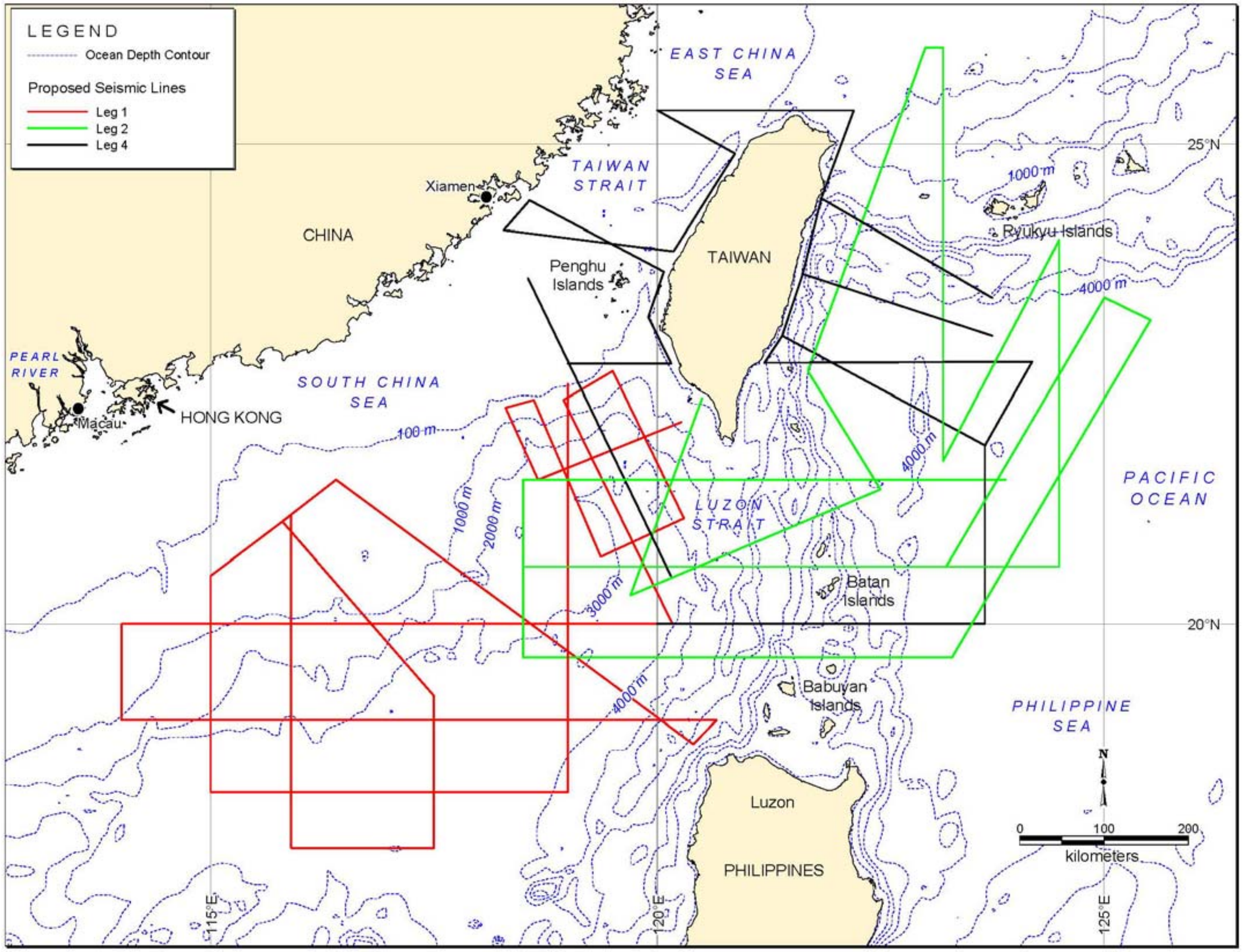

FIGURE 1. Study area and proposed seismic transect lines along the Taiwan arc-continental collision in Southeast Asia. Different colored lines correspond to the various legs of the cruise [see text in Section II, below]. Leg 3 is not shown as it does not involve seismic acquisition.

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. 1). The *Langseth* will also tow the hydrophone streamer, retrieve OBSs, and may also deploy OBSs. When the *Langseth* is towing the airgun array as well as the hydrophone streamer, the turning rate of the vessel while the gear is deployed is limited to five degrees per minute. Thus, the maneuverability of the vessel is limited during operations with the streamer.

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

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

Other details of the *Langseth* include the following:

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

Airgun Description

During the survey, the airgun array to be used will consist of 36 airguns, with a total volume of ~6600 in^3. The airgun array will consist of a mixture of Bolt 1500LL and Bolt 1900LLX airguns. The airguns will be configured as four identical linear arrays or "strings" (Fig. 2). Each string will have ten airguns; the first and last airguns in the strings are spaced 16 m apart. Nine airguns in each string will be fired simultaneously, whereas the tenth is kept in reserve as a spare, to be turned on in case of failure of another airgun. The four airgun strings will be distributed across an area of ~24×16 m behind the *Langseth* and will be towed ~140 m behind the vessel. The shot interval will vary from ~25 to 125 m during the study. The shot interval will be relatively short (~25–50 m or ~10–25 s) for multichannel seismic surveying with the hydrophone streamer, and relatively long (~100–125 m or ~45–60 s) when recording data on the OBSs. The firing pressure of the array is 1900 psi. During firing, a brief (~0.1 s) pulse of sound is emitted. The airguns will be silent during the intervening periods.

The tow depth of the array will be 6–9 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 9 m, the effective source level for sound propagating in near-horizontal directions is higher than if the array is towed at shallow depths (see Fig. 3–5 and Table 1, later). However, the nominal source levels of the array (or the estimates of the sound that would be measured from a

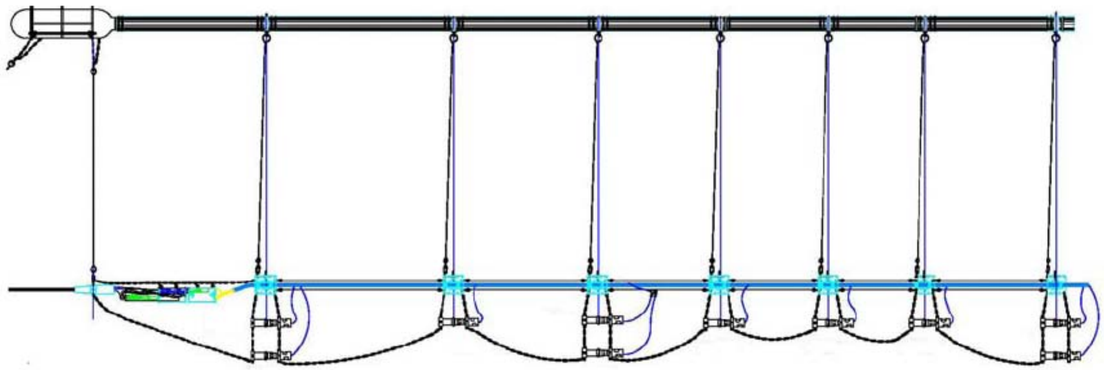

FIGURE 2. One linear airgun array or string with ten airguns, nine of which would be operating.

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

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 9 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.

Acoustic Measurement Units

Received sound levels have been predicted by L-DEO, in relation to distance and direction from the airguns, for the 36-airgun array (Fig. 3 and 4) and for a single 1900LL 40-in^3 airgun, which will be used during power downs (Fig. 5). 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 $\mu Pa^2 \cdot s$. SEL is a measure of the received energy in the pulse and represents the sound pressure level (SPL) that would be measured if the pulse energy were spread evenly across a 1-s period. Because actual seismic pulses are less than 1 s in duration in most situations, this means that the SEL value for a given pulse is usually lower than the SPL calculated for the actual duration of the pulse (see Appendix B of 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.

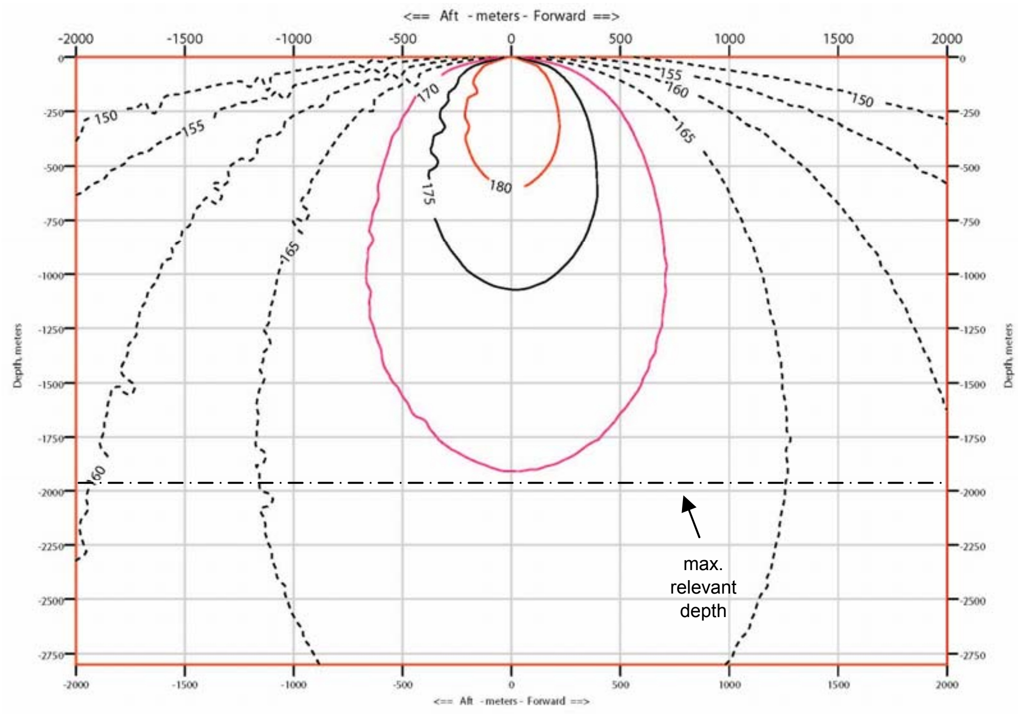

FIGURE 3. Modeled received sound levels (SELs) from the 36-airgun array operating in deep water at a ***6-m*** tow depth, planned for use during the TAIGER survey, 21 March–14 July 2009. Received rms levels (SPLs) are expected to be ~10 dB higher. Maximum relevant depth is applicable to marine mammals.

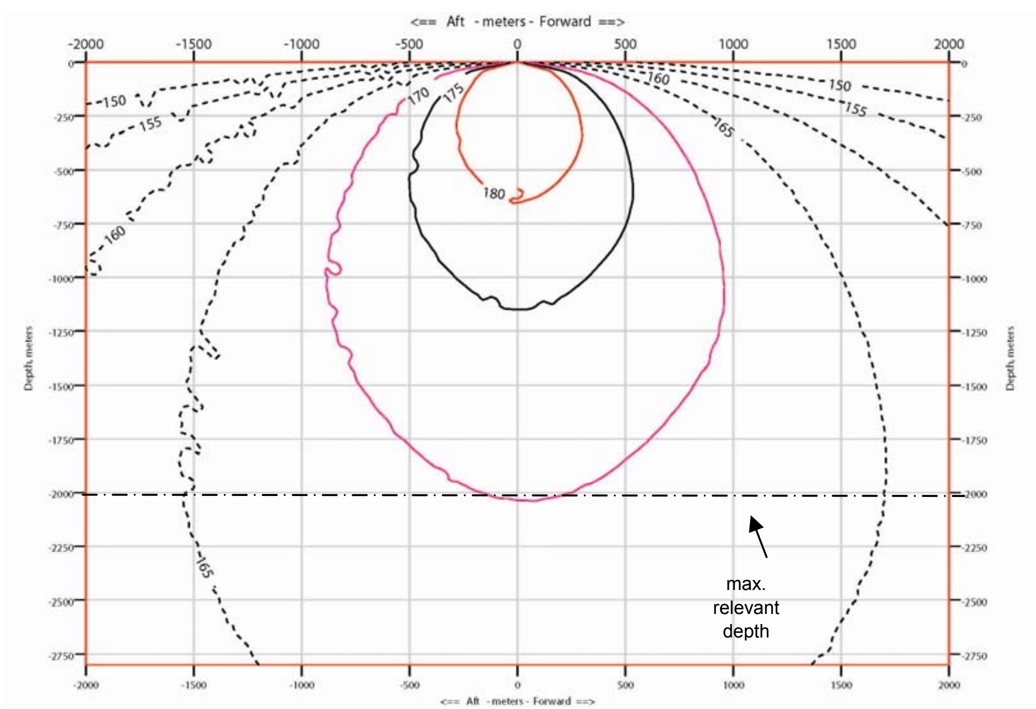

FIGURE 4. Modeled received sound levels (SELs) from the 36-airgun array operating in deep water at a ***9-m*** tow depth, planned for use during the TAIGER survey, 21 March–14 July 2009. Otherwise as above.

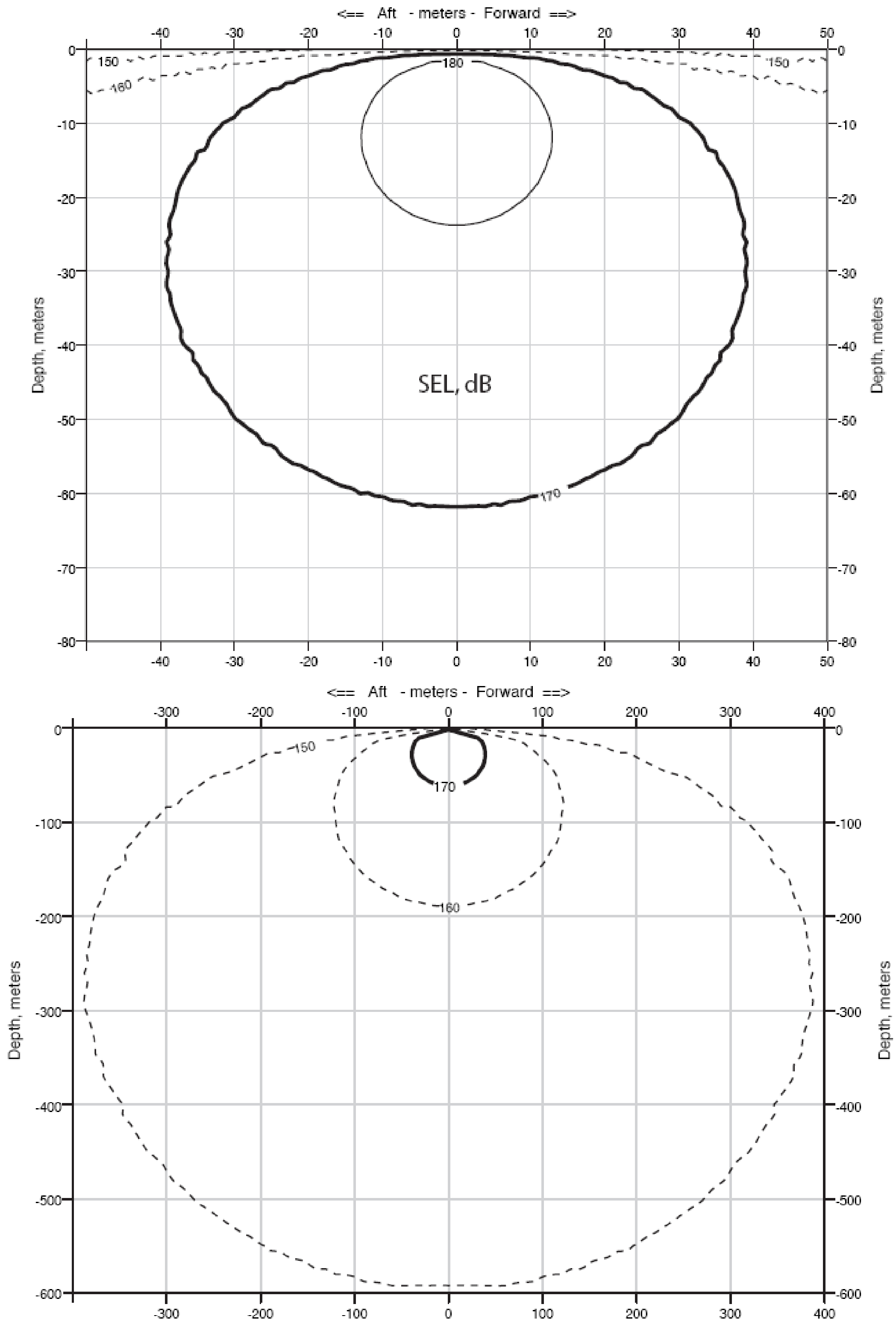

FIGURE 5. Modeled received sound levels (SELs) from a single 40-in^3 airgun operating in deep water, which is planned for use during the TAIGER survey, 21 March–14 July 2009. Received rms levels (SPLs) are expected to be ~10 dB higher.

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 ≈ 180 dB re 1 μPa_{rms}.

It should be noted that neither the SEL nor the SPL (=rms) measure is directly comparable to the peak or peak-to-peak pressure levels normally used by geophysicists to characterize source levels of airguns. Peak and peak-to-peak pressure levels for airgun pulses are always higher than the rms dB referred to in much of the biological literature (Greene 1997; McCauley et al. 1998, 2000a). For example, a measured received level of 160 dB re 1 μPa_{rms} in the far field typically would correspond to a peak measurement of ~170–172 dB re 1 μPa, and to a peak-to-peak measurement of ~176–178 dB re 1 μPa, as measured for the same pulse received at the same location (Greene 1997; McCauley et al. 1998, 2000a). (The SEL value for the same pulse would normally be 145–150 dB re 1 $\mu Pa^2 \cdot s$) 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 L-DEO model does not allow for bottom interactions, and thus is most directly applicable to deep water and to relatively short ranges. During the TAIGER study, most survey effort (80%) will take place in deep (>1000 m) water, but intermediate-depth and shallow waters will also be surveyed.

- The empirical data indicated that, for ***deep water*** (>1000 m), the L-DEO model (as applied to the *Ewing*'s airgun configurations) ***overestimated*** the measured received sound levels at a given distance (Tolstoy et al. 2004a,b). However, to be conservative, the modeled distances shown in Figures 3–5 for the planned *Langseth* airgun configuration will be applied to deep-water areas during the proposed study (Table 1). As very few, if any, mammals are expected to occur below 2000 m, this depth was used as the maximum relevant depth.
- Empirical measurements of sounds from the *Ewing*'s airgun arrays were not conducted for ***intermediate depths*** (100–1000 m). On the expectation that results would be intermediate between those from shallow and deep water, a correction factor of 1.1 to 1.5× was applied to the estimates provided by the model for deep-water situations to obtain estimates for intermediate-depth sites. Corresponding correction factors, applied to the modeled radii for the *Langseth*'s airgun configuration, will be used during the proposed study for intermediate depths (Table 1).

TABLE 1. Predicted distances to which sound levels ≥190, 180, 170 and 160 dB re 1 μPa_{rms} could be received in shallow (<100 m), intermediate (100–1000 m), and deep (>1000 m) water from the 36-airgun array, as well as a single airgun, planned for use during the TAIGER survey, 21 March–14 July 2009 (based on L-DEO modeling). Predicted radii are based on Figures 3–5, assuming that received levels on an RMS basis are, numerically, 10 dB higher than the SEL values shown in Figures 3–5, and that mammals would not typically occur at depths >2000 m.

Source and Volume	Tow Depth (m)	Water Depth	Predicted RMS Distances (m)			
			190 dB	180 dB	170 dB	160 dB
		Deep	12	40	120	385
Single Bolt airgun	6-9*	Intermediate	18	60	180	578
40 in^3		Shallow	150	296	500	1050
4 strings		Deep	220	710	2100	4670
36 airguns	6-7	Intermediate	330	1065	3150	5189
6600 in^3		Shallow	1600	2761	5654	6227
4 strings		Deep	300	950	2900	6000
36 airguns	8-9	Intermediate	450	1425	4350	6667
6600 in^3		Shallow	2182	3694	7808	8000

* 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, 9 m) are shown.

- Empirical measurements near the *Ewing* indicated that in ***shallow water*** (<100 m), the L-DEO model ***underestimates*** actual levels. In previous L-DEO projects, the exclusion zones were typically based on measured values and ranged from 1.3 to 15× higher than the modeled values depending on the size of the airgun array and the sound level measured (Tolstoy et al. 2004b). During the proposed cruise, similar factors will be applied to derive appropriate shallow-water radii from the modeled deep-water radii for the *Langseth*'s airgun configuration (Table 1).

Using the modeled distances and various correction factors, 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 in three different water depths. The 180- and 190-dB re 1 μPa_{rms} distances are the safety criteria as specified by NMFS (2000) and are applicable to cetaceans and pinnipeds, respectively. The 180-dB distance will also be used as the exclusion zone for sea turtles, as required by NMFS in most other recent seismic projects (e.g., Smultea et al. 2004; Holst et al. 2005b; Holst and Beland 2008; Holst and Smultea 2008). 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.

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 6–9 m. The receiving system for the returning acoustic signals will consist of ~100 OBSs as well as a hydrophone streamer. The *Langseth* will deploy an 8-km long streamer for most transects requiring a streamer; however, a shorter streamer (500 m to 2 km) will be used during surveys in Taiwan (Formosa) Strait. As the airgun array is towed along the survey lines, the hydrophone streamer will receive the returning acoustic signals and transfer the data to the on-board processing system. The OBSs record the returning acoustic signals internally for later analysis.

The planned seismic survey will consist of ~15,902 km of transect lines within the South and East China seas as well as the Philippine Sea. Most survey effort (79.3%) will occur in deep (>1000 m) water, 13.4% will take place in intermediate-depth waters (100–1000 m), and the remaining effort will occur in shallow water (<100 m deep). 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 TAIGER cruise.

OBS Description and Deployment

Approximately 100 OBSs will be deployed during the survey. OBSs will likely be deployed and retrieved by the R/V *Langseth* as well as by a combination of four to five Taiwanese vessels. The Taiwanese vessels to be used include two 30-m vessels (the R/V *Ocean Researcher 2* and the R/V *Ocean Researcher 3*) and two vessels >60 m in length (*Fisheries Research I* and the Navy ship *Taquan*). The R/V *Ocean Researcher I* may also be used if the R/V *Langseth* is not used to deploy OBSs. The OBS deployment spacing will vary depending on the number of instruments available and shiptime. The nominal spacing is 15 km, but this will vary from as little as 5 km to perhaps as much as 25 km. The OBSs will be deployed and recovered several (2 to 4) times. Sixty of the 100 OBSs may be deployed from the *Langseth*. All OBSs will be retrieved at the end of the study. The *Langseth* will retrieve 20 OBSs that were deployed during previous years in the study area.

Up to three different types of OBSs may be used during the 2009 program. 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 LC4x4 OBS from the Scripps Institution of Oceanography has a volume of ~1 m^3, with an anchor that consists of a large piece of steel grating (~1 m^2). Taiwanese OBSs will also be used; their anchor is in the shape of an ‘x’ with dimensions of 51 to 76 cm^2. Once the OBS is ready to be retrieved, an acoustic release transponder interrogates the OBS at a frequency of 9–11 kHz, and a response is received at a frequency of 9–13 kHz. The burn wire release assembly is then activated, and the instrument is released from the anchor to float to the surface.

Multibeam Echosounder

The Simrad EM120 MBES operates at 11.25–12.6 kHz and is hull-mounted on the *Langseth*. The beamwidth is 1° fore–aft and 150° athwartship. The maximum source level is 242 dB re 1 μPa · m_{rms}. For deep-water operation, each “ping” consists of nine successive fan-shaped transmissions, each 15 ms in duration and each ensonifying a sector that extends 1° fore–aft. The nine successive transmissions span an overall cross-track angular extent of about 150°, with 16 ms gaps between the pulses for 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.

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

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 17°30'–26°30'N, 113°30'–126°E within the EEZs of Taiwan, China, Japan, and the Philippines (Fig. 1). The vessel will approach mainland Taiwan within 1 km and China within 10 km. The closest approach to the Ryukyu Islands will be 16 km. Although the survey will occur at least 32 km from Luzon, Philippines, survey lines will take place ~8 km from some of the Babuyan and Batan islands. Water depths in the survey area range from ~25 to 6585 m. The TAIGER program consists of four legs, each starting and ending in Kao-hsiung, Taiwan. The first leg is expected to occur from ~21 March to 19 April 2009 and will include the survey lines in the South China Sea (shown in red in Fig. 1). The second leg is scheduled for 20 April to 7 June and will include survey lines in Luzon Strait and the Philippine Sea (green lines in Fig. 1). The third leg (8–20 June; not shown on Fig. 1) will involve OBS recovery by the *Langseth* only; no seismic acquisition will occur during this leg. The fourth leg, consisting of the survey lines immediately around Taiwan (shown in black in Fig. 1), is scheduled to occur from 21 June 14 July. The program will consist of ~103 days of seismic acquisition. The exact dates of the activities depend on logistics and weather conditions.

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-four cetacean species, including 25 odontocete (dolphins and small- and large-toothed whales) species and nine mysticetes (baleen whales) are known to occur in the proposed TAIGER study area. Information on the occurrence, distribution, population size, and conservation status for each of the

34 marine mammal species that may occur in the proposed project area is presented in Table 2. The status of these species is based on the ESA, the IUCN Red List of Threatened Species, and the Convention on International Trade in Endangered Species (CITES). Several species are listed under the ESA as ***endangered***: the Western North Pacific gray whale, North Pacific right whale, sperm, humpback, fin, sei, and blue whales. In addition to those seven species, the Indo-Pacific humpback dolphin is listed as ***near threatened*** and the finless porpoise is listed as ***vulnerable*** under the 2008 IUCN Red List of Threatened Species (IUCN 2008).

Although the dugong (*Dugong dugon*) may have inhabited waters of Taiwan, it is no longer thought to occur there (Marsh et al. n.d.; Chou 2004; Perrin et al. 2005). Similarly, although the dugong was once widespread throughout the Philippines, current data suggest that it does not inhabit the Batan or Babuyan islands or northwestern Luzon (Marsh et al. n.d.; Perrin et al. 2005), where seismic operations will occur. However, the dugong does occur off northeastern Luzon (Marsh et al. n.d.; Perrin et al. 2005) outside of the study area. In China, it is only known to inhabit the waters off Guangxi and Guangdong and the west coast of Hanain Island (Marsh et al. n.d.; Perrin et al. 2005), which do not occur near the study area. It is rare in the Ryukyu Islands, but can be sighted in Okinawa, particularly off the east coast of the island (Yoshida and Trono 2004; Shirakihara et al. 2007); some individuals may have previously occurred in the southernmost of the Ryukyu Islands, Yaeyama (Marsh et al. n.d.), but these animals have not been documented there recently (Shirakihara et al. 2007).

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.

Wang et al. (2001a) noted that during the spring/summer off southern Taiwan, the highest number of sightings and species occur during April and June. The number of sightings per survey effort and the number of species were highest directly west of the southern tip of Taiwan and northeast off the southern tip (Wang et al. 2001a).

Mysticetes

Western North Pacific Gray Whale

There are two separate populations of gray whales in the North Pacific (LeDuc et al. 2002): the eastern Pacific and the western North Pacific (or Korean-Okhotsk) stock. The western North Pacific population is listed as ***endangered*** under the ESA, ***critically endangered*** on the 2008 IUCN Red List of Threatened Species (IUCN 2008), and it is listed in CITES Appendix I (UNEP-WCMC 2008) (Table 2). The western North Pacific population is estimated to be at least 131 individuals (Vladimirov et al. 2008). Population models indicate a high probability of population increase; however, if extra mortalities occur, such as recent bycatch deaths on the Pacific coast of Japan, a population decline and potential extirpation may occur (Cooke et al. 2008).

TABLE 2. The habitat, occurrence, regional population sizes, and conservation status of marine mammals that could occur in or near the proposed TAIGER seismic survey area in SE Asia.

Species	Habitat	Occurrence in study area in SE Asia	Regional population size	U.S. ESA[a]	IUCN[b]	CITES[c]
Mysticetes						
Western North Pacific gray whale (*Eschrichtius robustus*)	Coastal	Rare	131[d]	EN	CR	I
North Pacific right whale (*Eubalaena japonica*)	Pelagic and coastal	Rare	few 100[e]	EN	EN	I
Humpback whale (*Megaptera novaeangliae*)	Mainly nearshore waters and banks	Uncommon	938–1107 [f]	EN	LC	I
Minke whale (*Balaenoptera acutorostrata*)	Pelagic and coastal	Uncommon	25,000 [g]	-	LC	I
Bryde's whale (*Balaenoptera brydei*)	Pelagic and coastal	Common?	20,000–30,000[e,h]	-	DD	I
Omura's whale (*Balaenoptera omurai*)	Pelagic and coastal	Uncommon	N.A.	-	DD	II
Sei whale (*Balaenoptera borealis*)	Primarily offshore, pelagic	Uncommon	7260–12,620 [i]	EN	EN	I
Fin whale (*Balaenoptera physalus*)	Continental slope, mostly pelagic	Uncommon	13,620–18,680 [j]	EN	EN	I
Blue whale (*Balaenoptera musculus*)	Pelagic and coastal	Uncommon	N.A.	EN	EN	I
Odontocetes						
Sperm whale (*Physeter macrocephalus*)	Usually pelagic and deep seas	Uncommon	29,674 [k]	EN	VU	I
Pygmy sperm whale (*Kogia breviceps*)	Deep waters off the shelf	Uncommon	N.A.	-	DD	II
Dwarf sperm whale (*Kogia sima*)	Deep waters off the shelf	Common?	11,200 [e] ETP	-	DD	II
Cuvier's beaked whale (*Ziphius cavirostris*)	Pelagic	Likely common	20,000 [e] ETP	-	LC	II
Longman's beaked whale (*Indopacetus pacificus*)	Deep water	Rare	N.A.	-	DD	II
Blainville's beaked whale (*Mesoplodon densirostris*)	Pelagic	Uncommon?	25,300 [l]	-	DD	II
Ginkgo-toothed beaked whale (*Mesoplodon ginkgodens*)	Pelagic	Rare	N.A.	-	DD	II
Rough-toothed dolphin (*Steno bredanensis*)	Deep water	Common	146,000 ETP [e]	-	LC	II
Indo-Pacific humpback dolphin (*Sousa chinensis*)	Coastal	Uncommon	1680 China+ Taiwan [e]	-	NT[m]	I
Common bottlenose dolphin (*Tursiops truncatus*)	Coastal and oceanic, shelf break	Common	243,500 ETP [e]	-	LC	II
Indo-Pacific bottlenose dolphin (*Tursiops aduncus*)	Coastal and shelf waters	Common?	N.A.	-	DD	II
Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)	Coastal and pelagic	Rare	930,000–990,000 [e]	-	LC	II
Pantropical spotted dolphin (*Stenella attenuata*)	Coastal and pelagic	Common	800,000 ETP [e]	-	LC	II

Species	**Habitat**	**Occurrence in study area in SE Asia**	**Regional population size**	**U.S. ESA**[a]	**IUCN**[b]	**CITES**[c]
Spinner dolphin (*Stenella longirostris*)	Coastal and pelagic	Common	800,000 [e] ETP	-	DD	II
Striped dolphin (*Stenella coeruleoalba*)	Off continental shelf	Uncommon	1 million ETP [e]	-	LC	II
Fraser's dolphin (*Lagenodelphis hosei*)	Waters >1000 m	Common	289,000 ETP [e]	-	LC	II
Short-beaked common dolphin (*Delphinus delphis*)	Shelf and pelagic, seamounts	Rare	3 million ETP [e]	-	LC	II
Long-beaked common dolphin (*Delphinus capensis*)	Coastal	Uncommon	N.A.	-	DD	II
Risso's dolphin (*Grampus griseus*)	Waters >1000 m, seamounts	Common	175,000 ETP [e]	-	LC	II
Melon-headed whale (*Peponocephala electra*)	Oceanic	Common?	45,000 ETP [e]	-	LC	II
Pygmy killer whale (*Feresa attenuata*)	Deep, pantropical waters	Uncommon	39,000 ETP [e]	-	DD	II
False killer whale (*Pseudorca crassidens*)	Pelagic	Common?	40,000 [n]	-	DD	II
Killer whale (*Orcinus orca*)	Widely distributed	Uncommon?	8500 [e] ETP	-	DD	II
Short-finned pilot whale (*Globicephala macrorhynchus*)	Mostly pelagic, high-relief topography	Common?	500,000 ETP [e]	-	DD	II
Porpoise Finless porpoise (*Neophocaena phocaenoides*)	Coastal	Common?	5220–10,220 Japan+HK[e]	-	VU	I

N.A. - Data not available or species status was not assessed. ? indicates uncertainty. ETP = Eastern Tropical Pacific. HK = Hong Kong.

[a] U.S. Endangered Species Act; EN = Endangered, - = Not listed

[b] Codes for IUCN classifications; CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; (IUCN 2008). Classifications are from 2008 IUCN *Red List of Threatened Species* (IUCN 2008).

[c] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2008): Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled.

[d] Vladimirov et al. (2008).

[e] North Pacific unless otherwise indicated (Jefferson et al. 2008).

[f] Western North Pacific (Calambokidis et al. 2008).

[g] Northwest Pacific and Okhotsk Sea (IWC 2007a).

[h] Kitakado et al. (2008).

[i] Tillman (1977).

[j] Ohsumi and Wada (1974).

[k] Western North Pacific (Whitehead 2002b).

[l] ETP; all *Mesoplodon* spp. (Wade and Gerrodette 1993).

[m] IUCN states that this species should be re-assessed following taxonomic classification of the two forms. The *chinensis*-type would be considered *vulnerable* (IUCN 2008).

[n] ETP (Wade and Gerrodette 1993).

The western population is known to feed in the Okhotsk Sea along the northeast coast of Sakhalin Island (Weller et al. 1999, 2002a, 2008), Eastern Kamchatka, and the northern Okhotsk Sea in the summer and autumn (Vladimirov et al. 2008). Winter breeding grounds are not known. It was postulated that gray whale wintering grounds occur along the south coast of the Korean Peninsula, but it is more likely that wintering areas are located in the South China Sea, along the coast of Guangdong province and Hainan (Wang 1984 and Zhu 1998 *in* Weller et al. 2002a; Rice 1998). Gray whales were hunted between November and May, with a peak in December and January in the "East Sea Area" of Korea (Mizue 1951 *in* Reeves et al. 2008), which may represent a movement of migrating animals towards southern breeding ground(s) (Reeves et al. 2008). The gray whale ranges as far south as southern China (Wang 1984 and Zhu 1998 *in* Weller et al. 2002b). Whaling records from 1868-69 indicate that American ships sighted gray whales near the Chinese mainland coast, middle of the Taiwan Strait, and off northern Taiwan during winter (Henderson 1990 *in* Reeves et al. 2008). Winter records also exist for Japan, North Korea, and South Korea (Weller et al. 2002a,b), as well as Taiwan (Parsons et al. 1995; Chou 2004). Five whales (all female) have been caught (at least four) in fishing gear or found dead on the Pacific coast of Japan in 2005-2007 (see Cooke et al. 2008). These whale mortalities occurred in May, July, August and January.

The migration route of gray whales is ill defined but very likely extends through Taiwanese waters, probably through the Taiwan Strait. Their occurrence there is possible from December–April. Migration into the Sea of Okhotsk may occur through the Sea of Japan via the Tatar Strait and/or La Perouse Strait (see Reeves et al. 2008). If migration timing is similar to that of the better-known eastern gray whale, southbound migration probably occurs mainly in December–January, and northbound migration mainly in February–April, with northbound migration of newborn calves and their mothers probably concentrated at the end of that period. However, Mizue (1951 *in* Reeves et al. 1998) speculated that northward migration from Korea through the Tatar Strait occurred in May or June. Even during migration, gray whales are found primarily in shallow coastal waters.

North Pacific Right Whale

The North Pacific right whale is listed as ***endangered*** under the ESA, ***endangered*** on the 2008 IUCN Red List of Threatened Species (IUCN 2008), and it is listed in CITES Appendix I (UNEP-WCMC 2008) (Table 2). It is considered by NMFS (1991) to be the most endangered baleen whale in the world. Although protected from commercial whaling since 1935, there has been little indication of recovery. The pre-exploitation stock may have exceeded 11,000 animals (NMFS 1991). There are no reliable population estimates for this species. Wada (1973; see also Braham and Rice 1984) provided an estimate of 100–200 right whales in the North Pacific, and Jefferson et al. (2008) indicate that there are "no more than a few hundred right whales alive today".

North Pacific right whales summer in the northern North Pacific and Bering Sea, apparently feeding off southern and western Alaska from May to September (e.g., Tynan et al. 2001). Wintering areas are unknown, but have been suggested to include the Hawaiian Islands and the Ryukyu Islands (Allen 1942; Banfield 1974; Gilmore 1978; Reeves et al. 1978; Herman et al. 1980). In April 1996, a right whale was sighted off Maui, the first documented sighting of a right whale in Hawaiian waters since 1979 (Herman et al. 1980; Rowntree et al. 1980).

Whaling records indicate that right whales in the North Pacific once ranged across the entire North Pacific north of 35ºN and occasionally occurred as far south as 20ºN. In the western Pacific, most sightings in the 1900s were reported from Japanese waters, followed by the Kuril Islands, and the Okhotsk Sea (Brownell et al. 2001). However, since the 1960s sightings have been relatively rare (e.g., Clapham et al. 2004; Shelden et al. 2005). Nonetheless, in the western Pacific, significant numbers of right whales have been seen in the Okhotsk Sea during the 1990s, suggesting that the adjacent Kuril Islands and Kamchatka coast are a major feeding ground (Brownell et al. 2001). Right whales were also seen near Chichi-jima Island (Bonin Island), Japan, in the 1990s (Mori et al. 1998). Several breeding grounds have been proposed, including the Ryukyu Islands and the Sea of Japan (Omura 1986), offshore waters (Scarff 1991), and off Guangdong province, southern China (Rudolph and Smeenk 2002). Although there are no recent sightings of right whales from Taiwan, historically, small numbers were caught in the Taiwan Strait (Townsend 1935). Thus, right whales may occur in the proposed study area. However, Chou (2004) did not include right whales on the list of cetaceans occurring in Taiwanese waters.

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, ***least concern*** on the 2008 IUCN Red List of Threatened Species (IUCN 2008), 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). Calambokidis et al. (1997) provided a population estimate of over 6000 for the North Pacific stock, but the IWC (2007a) reported that this population numbers at least 10,000. Based on a collaborative study involving numerous jurisdictions, the North Pacific stock has been recently estimated at 18,302 whales (excluding calves; Calambokidis et al. 2008; IUCN 2008). Overall, the North Pacific stock is considered to be increasing. The western Pacific stock is estimated at 938–1107 animals (Calambokidis et al. 2008). The low population estimate for the western North Pacific subpopulation is a cause for concern for the IUCN (2008).

Although considered to be mainly a coastal species, humpback whales often traverse deep pelagic areas while migrating. 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 (Baker et al. 1998; Clapham 2002; Garrigue et al. 2002). On winter breeding grounds, humpback dives have been recorded at depths >100 m (Baird et al. 2000). In summer feeding areas, humpbacks typically forage in the upper 120 m of the water column, with a maximum recorded dive depth of 500 m (Dolphin 1987; Dietz et al. 2002). Humpback whales are often sighted singly or in groups of two or three; however, while on their breeding and feeding ranges, they may occur in groups of up to 15 (Leatherwood and Reeves 1983; Donoghue 1996).

North Pacific humpback whales migrate between summer feeding grounds along the Pacific Rim, and the Bering and Okhotsk Seas, and winter calving and breeding areas in subtropical and tropical waters (Pike and MacAskie 1969; Rice 1978). North Pacific humpback whales are known to assemble in three different winter breeding areas: (1) the eastern North Pacific along the coast of Mexico and central America, and near the Revillagigedo Islands; (2) around the main Hawaiian Islands; and (3) in the west Pacific, particularly around Ogasawara and Ryukyu Islands in southern Japan and the northern Philippines (Perry et al. 1999a; Calambokidis et al. 2008).

In the western North Pacific, most humpback whales winter and calve near Okinawa (Ryukyu Island) and Ogasawara (Bonin Islands) (Nishiwaki 1959; Rice 1989). Darling and Mori (1993) reported that the occurrence of humpbacks off Taiwan, the Mariana Islands, and the Marshall Islands is unknown or uncommon. More recently, Calambokidis et al. (2008) include the waters of Taiwan and the Mariana Islands as part of the humpback winter range. Rudolph and Smeenk (2002) noted that humpbacks have been sighted in the South China Sea and Taiwan; and Chou (2004) also reports on records of this species in Taiwan. Humpback whales have in fact been sighted in southern Taiwan waters off Hualien City and Orchid Island from 1994 to 2003 (Wang et al. 2001a; J.Y. Wang and S. Yang, per. comm. *in* Acebes et al. 2007).

The same population likely uses both Ogasawara and Okinawa (Darling and Mori 1993), but interchange between these two winter subareas is low, given the distance (1500 km) between these locations (Calambokidis et al. 2001). In Okinawa, sightings were centered around Kerama Retto and towards the main island of Okinawa (Darling and Mori 1993). In 1987–90, they were commonly sighted from December to May throughout the Ogasawara archipelago and near the Kerama Islands, Okinawa (Darling and Mori 1993). During 1987–90, humpbacks were not seen regularly in the Northern Mariana Islands or near Kenting, Taiwan (Darling and Mori 1993). There is potential for the mixing of the western and eastern North Pacific humpback populations, as several individuals have been seen in the wintering areas of Japan and Hawaii in separate years (Darling and Cerchio 1993; Salden et al. 1999; Calambokidis et al. 2001). Whales from these wintering areas have been shown to travel to summer feeding areas in British Columbia, Canada, and Kodiak Island, Alaska (Darling et al. 1996; Calambokidis et al. 2001), but feeding areas in Russian waters may be most important (Calambokidis et al. 2008). There appears to be a very low level of interchange between Asian wintering or feeding areas and those in the eastern and central Pacific (Calambokidis et al. 2008).

A small population of humpbacks winters and calves in the Babuyan Islands in Luzon Strait (Acebes and Lesaca 2003; Acebes et al. 2007). Photo-identification studies have catalogued at least 69 individuals, 12 of which match with whales that visit the breeding area in Ogasawara and Okinawa; Ogasawara and the Babuyan Islands are located ~2700 to 3000 km apart (Acebes et al. 2007). Only on one occasion was a humpback whale seen in both locations within the same season (Yamaguchi et al. 2002). In the Babuyan Islands, humpback whales have most often been sighted within the 200-m depth contour around the leeward side of Camiguin, Fuga and Calayan Island (Acebes et al. 2007). Sightings were also made on the northwestern side of Palaui Island off the coast of Luzon (Acebes et al. 2007). The whales may arrive in the area as early as November and leave in May or even June, with a peak occurrence during February through March or April (Acebes et al. 2007). Some whales spend up to 40 days in the area (Acebes et al. 2007). The Babuyan Islands, perhaps the southernmost breeding areas of the humpback whale, are being recommended as a humpback whale sanctuary (Perrin et al. 2005).

Minke Whale

The minke whale has a cosmopolitan distribution that spans ice-free latitudes (Stewart and Leatherwood 1985). In the Northern Hemisphere, minke whales are usually seen in coastal areas, but can also be seen in pelagic waters during northward migrations in spring and summer, and southward migration in autumn (Stewart and Leatherwood 1985). Two subspecies are recognized: the North Pacific minke whale (*Balaenoptera acutorostrata scammoni*) and the North Atlantic minke whale (*B. a. acutorostrata*).

Minke whales are relatively solitary, but may occur in aggregations of up to 100 when food resources are concentrated (Perrin and Brownell 2002). The small size, inconspicuous blows, and brief surfacing times of minke whales mean that they are easily overlooked in heavy sea states, although they are known to approach vessels in some circumstances (Stewart and Leatherwood 1985). Little is known about the diving behavior of minke whales, but they are not known to make prolonged deep dives (Leatherwood and Reeves 1983).

North Pacific minke whales are known to occur in the Yellow, East China and South China Seas (Parsons et al. 1995), although reports from Vietnam and the Philippines have yet to be confirmed

(Rudolph and Smeenk 2002). Minke whale abundance in the Yellow Sea was estimated at 1685 and 1287 individuals in 2001 and 2004, respectively; these are likely underestimates (An et al. 2008). Chou (2004) also included the minke whale on the list of species occurring in Taiwan. Minke whales that occur in SE Asia are likely from the same population that winters off the coast of Japan (see Parsons et al. 1995).

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). In fact, the smaller *Balaenoptera edeni* (the pygmy Bryde's or Eden's whale) may be a distinct species from the larger *B. brydei* or Bryde's whale (Wada et al. 2003; Sasaki et al. 2006).

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 ETP. The durations of Bryde's whale dives are 1–20 min (Cummings 1985).

Bryde's whales are known to occur in the Yellow, East China, and South China Seas, including the waters of Taiwan (Parsons et al. 1995; Chou 2004). The small form is known to occur in southwestern Japan, Hong Kong/Macau, and Australia, but this form has not been distinguished from the common Bryde's whale (Jefferson et al. 2008). In addition, whales in the East China Sea and coastal waters of Kochi, Japan, differ from the whales in offshore waters of the western North Pacific, perhaps at the subspecific level (Yoshida and Kato 1999). However, the reclassification of Bryde's whales remains unresolved (Jefferson et al. 2008). Leatherwood et al. (1992) and Alava et al. (1993 both *in* Parsons et al. 1999) reported the presence of Bryde's whales in the Philippines. Parsons et al. (1995) and Jefferson and Hung (2007) reported on the occurrence of this species in the waters of Hong Kong. Tissues from a stranded 'pygmy' Bryde's whale was found to have elevated levels of lead and DDT (Parsons et al. 1999).

Omura's Whale

Omura's whale was first described in 2003 from records from the eastern Indian Ocean, Indonesia, the Philippines, the Sea of Japan, and the Solomon Islands (Wada et al. 2003). Wada and Numachi (1991) and Yoshida and Kato (1999) had noted that whales in the Solomon Islands were distinct from Bryde's whales from offshore waters of the western North pacific and the East China Sea. In fact, this species is not as closely related to Bryde's, Eden's, or Sei whales as previously thought (Sasaki et al. 2006).

Omura's whale is found in the tropical and subtropical waters of the western Pacific and eastern Indian Oceans (Jefferson et al. 2008). It mostly occurs over the continental shelf in nearshore waters, and is generally seen alone or in pairs (Jefferson et al. 2008). It is possible that this species may occur in the proposed study area.

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 2008 IUCN Red List of Threatened Species (IUCN 2008), 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).

Sei whale migrations are less extensive than those of other baleen whales. In the western North Pacific, the sei whale can be found across the Bering Sea and off the coasts of Japan and Korea in the summer. Its occurrence in the South China Sea is unconfirmed (Rudolph and Smeenk 2002), although Chou (2004) reports on records for this species in Taiwan. Its winter distribution is concentrated at about 20°N.

The sei whale is pelagic and generally not found in coastal waters (Harwood and Wilson 2001). It is found in deeper waters characteristic of the continental shelf edge region (Hain et al. 1985) and in other regions of steep bathymetric relief such as canyons or basins situated between banks and ledges (DoN 2007). The sei whale usually occurs in groups of up to six, and larger groups sometimes form on feeding grounds (Gambell 1985a). 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).

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 2008 IUCN Red List of Threatened Species (IUCN 2008), and it is listed in CITES Appendix I (UNEP-WCMC 2008) (Table 2). Northern and southern fin whale populations are distinct, and are sometimes recognized as different subspecies (Aguilar 2002). The current distribution of fin whales in the western North Pacific is largely unknown.

Fin whales occur in coastal, shelf, and oceanic waters. Sergeant (1977) proposed that fin whales tend to follow steep slope contours, either because they detect them readily or because biological productivity is high along steep contours because of tidal mixing and perhaps current mixing. 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).

Fin whales migrate in the open oceans and their winter breeding areas are uncertain. However, they are known to winter in the Yellow, East China, and South China Seas (Parsons et al. 1995; Rudoph and Smeenk 2002). Records exist for Taiwan (Chou 2004). Fin whales may be resident in the East China Sea (Jefferson et al. 2008). They could be present in Taiwanese waters during winter months. De Boer (2000) reported a fin whale sighting for the South China Sea, and suggested that Balabac Strait may be a migration route for fin whales between the Sulu Sea and the South China Sea.

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 2008 IUCN Red List of Threatened Species (IUCN 2008), and it is listed in CITES Appendix I (UNEP-WCMC 2008) (Table 2). All blue whale populations have been exploited commercially, and many have been severely depleted as a result. The worldwide population has been estimated at 15,000, with 10,000 in the Southern Hemisphere (Gambell 1976), 3500 in the North Pacific, and up to 1400 in the North Atlantic (NMFS 1998). Blue whale calls monitored from the U.S. Navy

Sound Surveillance System (SOSUS) and other offshore hydrophones suggest that separate populations occur in the eastern and western North Pacific (Stafford et al. 1999, 2001, 2007; Watkins et al. 2000a; Stafford 2003).

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). Some individuals may stay in low or high latitudes throughout the year (Reilly and Thayer 1990; Watkins et al. 2000b). Moore et al. (2002) reported that blue whale calls are received in the North Pacific year-round. Little information is available on blue whale wintering areas (Perry et al. 1999a).

The current distribution of blue whales in the western North Pacific is largely unknown. The North Pacific stock of blue whales is reported to winter off Taiwan, Japan, and Korea. The waters off eastern Taiwan are included in their historical distribution, and Chou (2004) reports records of this species in Taiwan. However, modern-day sightings of the species in the western North Pacific seem to be very rare. Strandings and sightings have been reported for southern China (Rudolph and Smeenk 2002).

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 2008 IUCN Red List of Threatened Species (IUCN 2008), 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). Female and immature sperm whales could occur in the survey area at any time of the year, whereas large male sperm whales likely are not found in the area at all. There currently is no accurate 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 29,674 for the western North Pacific.

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).

Sperm whales are known to occur in the waters of Hong Kong (Parsons et al. 1995; Jefferson and Hung 2007), the Philippines (Acebes et al. 2000 *in* Perrin et al. 2005; Acebes and Lesaca 2003), and Taiwan (Chou 2004). De Boer (2000) and suggested that Balabac Strait may be a migration route for sperm whales between the Sulu Sea and the South China Sea.

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).

Pygmy sperm whales may inhabit waters beyond the continental shelf edge, whereas dwarf sperm whales are thought to inhabit the shelf-edge and slope waters (Rice 1998). 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. *Kogia* are thought to occur throughout SE Asia, and confirmed records exist for the East and South China seas off mainland China and Taiwan (Parsons et al. 1995; Zhou et al. 1995; Perrin et al. 2005; Chou 2004), as well for Hong Kong (Parsons et al. 1995; Jefferson and Hung 2007). In the Philippines, only *K. sima* has been confirmed to occur (e.g., Acebes 2005 *in* Perrin et al. 2005; Acebes and Lesaca 2003; Perrin et al. 2005).

A group of four to five *Kogia* sp. was seen during surveys off the central-eastern coast of Taiwan in water ~800 m deep (Yang et al. 1999). Wang et al. (2001a) reported one unidentified *Kogia* and six *K. sima* during surveys in the offshore waters of southeastern and southwestern Taiwan. Although the cephalopod prey items of both *Kogia* spp. are similar, the proportion in which they were fed on support the view that pygmy sperm whales live seaward of the continental shelf whereas dwarf sperm whales inhabit more coastal waters (Wang et al. 2002). *K. sima* is likely to feed in shallow water than *K. breviceps* (McAlpine 2002). *Kogia* are harpooned in Taiwan and occur as bycatch in driftnets there (Perrin et al. 2005). Strandings of dwarf and pygmy sperm whales occurred in Taiwan in 2005 (Yang et al. 2008).

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). Stomach contents from stranded whales in Taiwan included cephalopod beaks, crustacean parts, and fish otoliths (Wang et al. 1995a). Its dives generally last 30–60 min, but dives of 85 min have been recorded (Tyack et al. 2006).

In the western Pacific, Cuvier's beaked whales are known to occur in the waters of Japan (Nishiwaki and Oguro 1972 *in* Wang et al. 1995a) and parts of SE Asia (Heyning 1989). They occur in the East and South China seas off China and Taiwan (Wang et al. 1995a; Zhou et al. 1995; Chou 2004; Perrin et al. 2005), and in the Philippines (Rudolph and Smeenk 2002; Perrin et al. 2005). It also occurs in the waters of Taiwan and is thought to be common along the east coast, where the 1000-m isobath is relatively near shore (Wang et al. 1995a). During surveys off southern Taiwan, Wang et al. (2001a) observed a single Cuvier's beaked whale off the southwestern tip of Taiwan. Sightings of this species were also made during recent surveys off the southeast coast of Taiwan (J.Y. Wang, pers. comm., August 2008). Wang et al. (1995a) reported on strandings in Taiwan, and seven of nine strandings occurred on the east coast; two strandings occurred on the shallower west coast. All strandings have occurred in non-summer months, with most strandings during the winter (Wang et al. 1995a). Cuvier's beaked whales are also taken by harpoon there (Perrin et al. 2005). They occur in bycatch in the Philippines and possibly in Taiwan (Perrin et al. 2005).

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). Records of this species exist within an area from 10ºS to 40ºN.

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

Sightings of Longman's beaked whale have occurred at many locations in tropical waters of the Indo-Pacific region (Rudolph and Smeenk 2002; Jefferson et al. 2008). In SE Asia and the surrounding area, records for this species exist for Japan (Yamada et al. 2004), the Philippines (Acebes et al. 2005), and Taiwan, where two whales stranded in 2005 (Yang et al. 2008). Unconfirmed sighting records also exist for Taiwan (Chou 2004). Wang et al. (2001a) reported a sighting of large unidentified beaked whales off southeastern Taiwan, which may have been Longman's beaked whales. During recent surveys in the southeastern waters of Taiwan, probable Longman's beaked whales were observed; the identification is currently being confirmed (J.Y. Wang, pers. comm., August 2008).

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 SE Asia.

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. Beaked whales are occasionally harpooned in Taiwan (Perrin et al. 2005). As many as 100 beaked whales per year may be taken in large-mesh driftnets in Taiwan (Perrin et al. 2005). A group of three to five unidentified beaked whales was seen during surveys off the central-eastern coast by Yang et al. (1999), and one sighting was made by Wang et al. (2001a) in the offshore waters off southwestern Taiwan. During recent surveys in the southeastern waters of Taiwan, probable ginkgo-toothed beaked whales were observed; the identification is currently being confirmed (J.Y. Wang, pers. comm., August 2008). It is thought that this area may be a "hotspot" for mesoplodonts.

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 1989). 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).

Sighting records exist for Blainville's beaked whale for the East China Sea off mainland China and for the Philippines (Perrin et al. 2005). They are also known to occur off Taiwan (Zhou et al. 1995; Chou 2004; Perrin et al. 2005). Two Blainville's beaked whales stranded in Taiwan in 2005 (Yang et al. 2008). One group of four Blaineville's beaked whales were seen during surveys off the central-eastern coast of Taiwan (Yang et al. 1999).

Ginkgo-toothed beaked whale.—This species is only known from stranding records (Mead 1989; Jefferson 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 1989; 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), and its occurrence has been confirmed in the Yellow and East China seas off mainland China (Perrin et al. 2005), as well as off Taiwan (Yang 1976 *in* Zhou et al. 1995; Chou 2004; Wang and Yang 2006).

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). Rough-toothed dolphins generally occur in deep, oceanic waters, but can be found in shallower coastal waters in some regions (Jefferson et al.2008). Rough-toothed dolphins are deep divers and can dive for up to 15 min (Jefferson et al. 2008). They usually form groups of 10–20, but aggregations of hundreds have been seen (Jefferson et al. 2008). Wade and Gerrodette (1993) reported a mean group size of 14.7 for the ETP.

Rough-toothed dolphins are known to occur in the Philippines (Acebes 2005 *in* Perrin et al. 2005; Acebes and Lesaca 2003; Perrin et al. 2005) and in the East and South China seas off China and Taiwan (Parsons et al. 1995; Zhou et al. 1995; Chou 2004; Perrin et al. 2005), as well as in Hong Kong (Parsons et al. 1995; Jefferson and Hung 2007). The rough-toothed dolphin is the most commonly encountered species during surveys in the Babuyan Islands, off northern Philippines (Perrin et al. 2005).

Indo-Pacific Humpback Dolphin

The Indo-Pacific humpback dolphin (including both the *chinensis*-type and the *plumbea*-type together), is listed on the 2008 IUCN Red List of Threatened species as ***near threatened*** (IUCN 2008). The IUCN states that this species should be re-assessed following taxonomic classification of the two forms. The *chinensis*-type, which occurs in the TAIGER study area, would be considered ***vulnerable*** (IUCN 2008). This dolphin generally occurs in warm, shallow (<20 m) water and is often associated with mangroves, river deltas and estuaries (Parsons et al. 1995; Jefferson et al. 2008). It generally occurs within several kilometers from shore and is frequently seen in water <5 m deep (Wang et al. 2004b). During surveys by Wang et al. (2007) all dolphins were seen within 2 km from shore, with a mean distance of 0.9 km from shore. Although groups are generally small (<10 individuals; Jefferson et al. 2008), groups of 20 to 40 animals have been seen in Chinese waters (Wang et al. 2004b; Jefferson et al. 2008).

Its distribution is fragmented in SE Asia, but extends from Zhejiang Province, China, to Taiwan and the Philippines (Parsons et al. 1995; Zhou et al. 1995; Perrin et al. 2005). It is estimated that about eight populations occur along the coast of China, mostly centered around the mouths of large rivers (Jefferson 2000). It is the most commonly observed species in Hong Kong (Parsons et al. 1995; Jefferson and Hung 2007), and it is abundant between February and May in Xiamen (Parsons et al. 1995). Humpback dolphins are also known to swim up rivers (Jefferson et al. 2008).

In 2002, a small population of Indo-Pacific humpback dolphins was discovered along the west coast of Taiwan (Wang et al. 2004a). This population occurs along a ~100 km stretch of the west coast of Taiwan, from Taixi to Tongshiao (Wang et al. 2007). The habitat spans an area of ~515 km^2 off central-western Taiwan, with a density of ~19.3 individuals/100 km^2 (Wang et al. 2007). This population consists of ~100 individuals (Wang et al. 2007). A sighting has also been made outside this area, near Jiang-Jyun port in the SW of Taiwan, but this is thought to be outside the regular range of this species (Wang et al. 2007). A sighting record also exists for Fugang (SE Taiwan); however, as the east coast does not have suitable habitat for this species, it is believed that this animal may have been sick or a vagrant individuals (Wang et al. 2007). The animals are thought to occur in the area year-round, and have been seen during spring and summer surveys (Wang et al. 2007).

Another small population of ~80 individuals inhabits the coast of China, near the Jiulong River estuary and adjacent waters of Xiamen (Jefferson and Hung 2004). The animals occur year-round throughout a 700 km^2 area around Xiamen Island. It is thought that the mating season for this population occurs from April to June (Wang 1965 and Wang and Sun 1982 *in* Jefferson and Hung 2004).

The largest known population near the survey area occurs in the waters of Hong Kong, Macau, and the Pearl River Estuary (Jefferson 2000). This population numbers ~1500 individuals (Jefferson and Hung 2004). Densities of this population have been estimated at 60 to 280 individuals per 100 km^2 for high-density areas, 15 to 50 in medium-density areas, and <10 in low-density areas (T.A. Jefferson, SWFSC, unpubl. data *in* Wang et al. 2007).

Individual Indo-Pacific humpback dolphins (*n* = 40 dolphins) in Hong Kong waters and Lingding Bay have been shown to range over areas 24 km^2 to 304 km^2, with an average range of 99.5 km^2 (Hung and Jefferson 2004). The authors of this paper caution that further study is needed to identify ranging patterns and home range characteristics. The diet of Indo-Pacific humpback dolphins is primarily fish which are demersal, estuarine species; there is little evidence for feeding on cephalopods or crustaceans (Jefferson and Hung 2004).

Common Bottlenose Dolphin

The bottlenose dolphin is distributed worldwide. It is found mainly where surface temperatures range from 10–32ºC (Reeves et al. 2002). Generally, there are two distinct bottlenose dolphin types: a shallow water type, mainly found in coastal waters, and a deep water type, mainly found in oceanic waters (Duffield et al. 1983; Hoelzel et al. 1998; Walker et al. 1999). As well as inhabiting different areas, these ecotypes differ in their diving abilities (Klatsky 2004) and prey types (Mead and Potter 1995). In SE Asia, the common bottlenose dolphin (*Tursiops truncates*) is typically of the offshore form (see Zhou 1987 *in* Barros et al. 2000). The common bottlenose dolphin occurs in the Yellow and East China Sea and is replaced by the sympatric form (*T. aduncus*) in coastal waters of the South China Sea (Gao et al. 1995; Zhou et al. 1995; Yang et al. 2005). The two species are known to overlap in Taiwan Strait (Yang et al. 2005), and mixed school are seen around the Penghu Islands, Taiwan (Zhou and Qian 1985). However, genetic interchange between the two species has not been shown (Yang et al. 2005). Stranded common bottlenose dolphins off Hong Kong had been feeding on both pelagic as well as neritic fish and cephalopod species (Barros et al. 2000).

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). 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 2002).

In the western Pacific, the bottlenose dolphin is distributed from Japan to Australia and New Zealand. Bottlenose dolphins are known to occur in the Philippines (Acebes 2005 *in* Perrin et al. 2005; Acebes and Lesaca 2003; Perrin et al. 2005), in the Yellow, East and South China seas off China and Taiwan (Parsons et al. 1995; Zhou et al. 1995; Chou 2004; Perrin et al. 2005), as well as Hong Kong (Parsons et al. 1995; Jefferson and Hung 2007). The minimum density of common bottlenose dolphins in the area between 25° and 30°N, west of 125°E in the East China Sea was estimated at 0.14 individuals/km^2 (Yang et al. 1997 *in* Perrin et al. 2005). Chen (2001 *in* Perrin et al. 2005) reported a population estimate of 193 common bottlenose dolphins in the waters northeast of Taiwan. For southwestern Taiwan, the population has been estimated at 672 dolphins, with a density of 0.20268 (Huang 1996 *in* Chou 2004), although this estimate is uncertain (Perrin et al. 2005). These dolphins occur in both coastal and deep-water offshore areas off Taiwan (Perrin et al. 2005).

During surveys off central-eastern Taiwan, bottlenose dolphins were generally seen near ports beyond the 800-m isopleth (Yang et al. 1999). The mean group size was 23.5, and sightings were made at a rate of 0.04 per hour (Yang et al. 1999). Wang et al. (2001a) reported one bottlenose dolphin sighting during surveys off southern Taiwan. Common bottlenose dolphins are also known to occur by the Penghu Islands (Wang et al. 1995b).

Indo-Pacific Bottlenose Dolphin

Indo-Pacific bottlenose dolphins are only found in the warm temperate to tropical waters of the Indo-Pacific, from South Africa to southern Japan and central Australia (Jefferson et al. 2008). They occur over the continental shelf, mainly in shallow coastal and inshore waters (Wang et al. 2001a; Jefferson et al. 2008). Records for this species in SE Asia include the South and East China Seas off mainland China (Zhou and Qian 1985; Zhou et al. 1995; Perrin et al. 2005), Taiwan Strait (Zhou and Qian 1985; Chou 2004), and Hong Kong (Parsons et al. 1995; Jefferson and Hung 2007). There have been no confirmed sightings of this species in the Philippines (Perrin et al. 2005). The density of Indo-Pacific bottlenose dolphins in Xiamen-Dongshan waters of the Taiwan Strait was estimated at 0.0436 ± 0.0286 individuals/km^2 (Yang et al. 2000 *in* Perrin et al. 2005). Off southern Taiwan, near Nan Wan, the abundance estimate for Indo-Pacific bottlenose dolphins is 24 (Wang and Yang 2005); this is believed to be a functional unit isolated from others during at least part of the year. These dolphins appear to occur in shallow-water areas with rocky reefs, such as at Nan Wan at the southern tip of Taiwan and at the Penghu Islands (Wang et al. 1995b; Yang et al. 2000 *in* Perrin et al. 2005). It is unlikely that this species occurs along the east coast of Taiwan, where the shelf is narrow (Wang et al. 2001a).

Pacific white-sided Dolphin

The Pacific white-sided dolphin is found throughout the temperate North Pacific, in a relatively narrow distribution between 38°N and 47°N (Brownell et al. 1999). The species is common both on the high seas and along the continental margins (Leatherwood et al. 1984). Although it has been reported to occur in the East China Sea (Zhou et al. 1995) and in the South China Sea (Parsons et al. 1995), Perrin et al. (2005) did not include it in the species known to occur in SE Asia, and Jefferson et al. (2008) noted that records from Taiwan were misidentifications. Chou (2004) did not include the Pacific white-sided dolphin on the list of cetacean species occurring in Taiwan. Strandings (Ogino et al. 2005) and sightings of this species occur in Japan. Thus, this species could be sighted in the northern part of the study area, near the Ryukyu Islands. Buckland et al. (1993) estimated that there were a total of 931,000 Pacific white-sided dolphins, rangewide, from surveys conducted in the North Pacific.

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). This species is found primarily in deeper waters, and rarely over the continental shelf or continental shelf edge (Davis et al. 1998). Pantropical spotted dolphins are extremely gregarious, forming groups of hundreds or even thousands. 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 2002).

In the western Pacific, Pantropical spotted dolphins occur from Japan south to Australia. They are known to occur in the Philippines (Acebes et al. 2000 *in* Perrin et al. 2005; Acebes and Lesaca 2003; Perrin et al. 2005), in the East and South China seas off China (Parsons et al. 1995; Zhou et al. 1995; Perrin et al. 2005), in Taiwan (Parsons et al. 1995; Zhou et al. 1995; Chou 2004), as well as off Hong Kong (Parsons et al. 1995; Jefferson and Hung 2007). Pantropical spotted dolphins occur in the eastern and western waters off Taiwan (Yao et al. 2004). Yao et al. (2004) examined the genetic structure and population differentiation of spotted dolphins in Taiwan and the South China Sea. They found that spotted dolphins from the east and west coasts of Taiwan were genetically similar, but some population differentiation was apparent in the animals from the South China Sea.

Chen (2001 *in* Perrin et al. 2005) reported a population estimate of 1280 pantropical spotted dolphins in the waters northeast of Taiwan. During surveys off central-eastern Taiwan, pantropical spotted dolphins were distributed evenly throughout the study area, mostly in water >800 m deep (Yang et al. 1999). The mean group size was 84.3, and sightings were made at a rate of 0.05 per hour (Yang et al. 1999). Wang et al. (2001a) reported three sightings of pantropical spotted dolphins during surveys off southern Taiwan. Off eastern Taiwan, pantropical spotted dolphins have been shown to prey mainly on laternfishes and squid (Wang et al. 2003).

Spinner Dolphin

The spinner dolphin is distributed in oceanic and coastal tropical waters between 40ºN and 40ºS (Jefferson et al. 2008). In SE Asian, spinner dolphins are known to occur in the Philippines (Acebes et al. 2000 *in* Perrin et al. 2005; Acebes and Lesaca 2003; Perrin et al. 2005), in the East and South China seas off China and Taiwan (Parsons et al. 1995; Zhou et al. 1995; Perrin et al. 2005), as well as Hong Kong (Parsons et al. 1995; Jefferson and Hung 2007).

Two subspecies of spinner dolphin occur in the western Pacific: the widespread, offshore spinner dolphin (*Stenella longirostris longirostris*) and the dwarf spinner dolphin (*S. l. roseiventris*). There is little or no genetic interchange between the two subspecies (Dizon et al. 1991). *S. l. longirostris* feeds on small mesopelagic fish and squid, whereas *S. l. roseiventris* preys on benthic and coral reef fishes and invertebrates (Perrin et al. 1999). *S. l. longirostris* occurs in the deep inner waters of the Philippines as well as Japan, whereas *S. l. roseiventris* inhabits the shallow waters of inner SE Asia (Perrin et al. 1999).

Spinner dolphins are most often encountered in the shallow waters off the southern and eastern coasts of Taiwan (Yang et al. 1999; Wang et al. 2001a). Chen (2001 *in* Perrin et al. 2005) reported a population estimate of 1490 spinner dolphins in the waters northeast of Taiwan. During surveys off central-eastern Taiwan, spinner dolphins were generally seen near port within and outside of the 800-m isopleth (Yang et al. 1999). The mean group size was 43.8, and sightings were made at a rate of 0.11 per hour (Yang et al. 1999). Wang et al. (2001a) reported three sightings of spinner dolphins offshore southern Taiwan, and one sighting in coastal waters of southern Taiwan.

Striped Dolphin

The striped dolphin has a cosmopolitan distribution in tropical to warm temperate waters (Perrin et al. 1994a) and is 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.

Striped dolphins are not considered common in SE Asia (Perrin et al. 2005). However, they are known to occur in the Philippines (Perrin et al. 2005), in the East and South China seas off China and Taiwan (Parsons et al. 1995; Zhou et al. 1995; Chou 2004; Perrin et al. 2005), as well as Hong Kong (Parsons et al. 1995; Jefferson and Hung 2007). However, sightings in Taiwan are relatively rare (Wang and Yang 2006). One striped dolphin stranded in Taiwan in 2004 (Wang and Yang 2006), and two striped dolphins stranded there 2005 (Yang et al. 2008).

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. In the ETP, its abundance has been estimated at about 289,000 (Wade and Gerrodette 1993). In the eastern Sulu Sea adjacent to the Philippines, the abundance estimate is 8700 (Dolar 1999 *in* Perrin et al. 2003).

In SE Asia, Fraser's dolphins are known to occur in the Philippines (Acebes 2005 *in* Perrin et al. 2005; Acebes and Lesaca 2003; Perrin et al. 2005), in the East and South China seas off China and Taiwan (Parsons et al. 1995; Zhou et al. 1995; Chou 2004; Perrin et al. 2005), as well as Hong Kong (Parsons et al. 1995; Jefferson and Hung 2007). Perrin et al. (2003) have suggested that animals off Japan belong to a different population than those in the Philippines. During surveys off central-eastern Taiwan (Yang et al. 1999) and southern Taiwan (Wang et al. 2001a), the majority of individual cetaceans seen were Fraser's dolphins. Off central-eastern Taiwan, most animals were seen near Shih-ti, in water >800 m deep (Yang et al. 1999). The mean group size was 224.4, and sightings were made at a rate of 0.03 per hour (Yang et al. 1999). This species is also known to strand often in Taiwan (Perrin et al. 2005). Off southern Taiwan, Risso's dolphins are often seen in mixed groups with Fraser's dolphins (Wang et al. 2001a).

Long- and 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 moves 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*). The long-beaked common dolphin is distributed from central Japan southward to Australia and New Zealand. It is known to occur off mainland China in the Yellow, East China and South China seas, in waters of Taiwan (Parsons et al. 1995; Zhou et al. 1995; Chou 2004; Perrin et al. 2005), as well as Hong Kong (Parsons et al. 1995; Jefferson and Hung 2007).

There have not been any sightings in the Philippines (Perrin et al. 2005). Most common dolphins in SE Asia appear to be the extremely long-beaked form (*D. capensis tropicalis*) although standard long-beaked form (*D. c. capensis*) also occurs in the temperate areas near Taiwan and possibly central and northern China (Jefferson and Van Waerebeek 2002). It is uncertain whether short-beaked common dolphins occur off Hong Kong (Parsons et al. 1995; Jefferson and Hung 2007) or Taiwan (Zhou et al. 1995; Chou 2004). Zhou et al. (1995) reported that it does not occur in Chinese waters, but Rudolph and Smeenk (2002) noted that it has been reported off Taiwan and southern Japan, and its distributional range appears to include Taiwan (Jefferson et al. 2008). Yang (1976) noted the presence of both species in the waters of Taiwan.

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.

In the western Pacific, Risso's dolphins range from the Kuril Islands to New Zealand and Australia. They are known to occur in the Philippines (Perrin et al. 2005), off mainland China in the Yellow, East and South China seas (Parsons et al. 1995; Zhou et al. 1995; Perrin et al. 2005), around Taiwan (Parsons et al. 1995; Zhou et al. 1995; Chou 2004; Wang and Yang 2006) as well as Hong Kong (Parsons et al. 1995; Jefferson and Hung 2007). Risso's dolphin is the most commonly encountered cetacean species off southeastern Taiwan (Wang et al. 2001a; Perrin et al. 2005). The populations are estimated at 218 Risso's dolphins off northeastern Taiwan (Chen 2001 *in* Perrin et al. 2005), and 153 dolphins off southwestern Taiwan (Huang 1996 *in* Perrin et al. 2005), although the latter estimate is uncertain. Huang (1996 *in* Chou 2004) gave a density estimate of 0.046. During surveys off central-eastern Taiwan, Risso's dolphins were the most frequently encountered cetacean (Yang et al. 1999). The were distributed evenly within the study area, but mainly in waters >800 m deep (Yang et al. 1999). The mean group size was 23.2, and sightings were made at a rate of 0.13 per hour (Yang et al. 1999).

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-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. Melon-head whales are commonly seen in mixed groups with other cetaceans (Jefferson and Barros 1997).

Melon-headed whales are known to occur off mainland China in the East and South China seas, Taiwan, and around the Babuyan Islands in the Philippines (Zhou et al. 1995; Acebes 2005 *in* Perrin et al. 2005; Acebes and Lesaca 2003; Chou 2004; Perrin et al. 2005). Several recent sightings have been made in Taiwan waters (Wang et al. 2001a,b).

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 2002). 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.

The pygmy killer whale is known to occur off mainland China in the East China Sea (Perrin et al. 2005), in Taiwan (Zhou et al. 1995; Chou 2004; Wang and Yang 2006), and in the Philippines (Perrin et al. 2005). Wang et al. (2001a) reported one sighting of pygmy killer whales during offshore surveys off southern Taiwan in 2000. Eight pygmy whales stranded at Tainan in 2005 (Hsieh et al. 2005).

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.

In the west Pacific, the false killer whale is distributed from Japan to Australia. The false killer whale is known to occur in the Philippines (Acebes 2005 *in* Perrin et al. 2005; Acebes and Lesaca 2003; Perrin et al. 2005), in the Yellow, East and South China seas off China and Taiwan (Parsons et al. 1995; Zhou et al. 1995; Chou 2004; Perrin et al. 2005), as well as Hong Kong (Parsons et al. 1995; Jefferson and Hung 2007). Yang et al. (1999) noted an encounter rate of 0.01 sightings per hour of surveys off the central-eastern coast of Taiwan. Wang et al. (2001a) reported two sightings of false killer whales during offshore surveys off southern Taiwan.

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 are known to occur off China in the Yellow and East China seas (Zhou et al. 1995; Perrin et al. 2005), off Taiwan (Zhou et al. 1995; Chou 2004; Chou et al. 2007), and in the Philippines (Perrin et al. 2005). They do not appear to be common or resident in Taiwan (Wang et al. 2001a). One killer whale sighting was made by Yang et al. (1999) during surveys off the central-eastern coast of Taiwan. Twenty killer whale sightings (incidental) were reported between 1996-2005 from the eastern and southwestern waters of Taiwan (Chou et al. 2007).

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 known to occur off mainland China in the South China Sea (Perrin et al. 2005), off Taiwan (Miyashita et al. 1995 *in* Zhou et al. 1995; Chou 2004), and in the Philippines (Acebes et al. 2000 *in* Perrin et al. 2005; Acebes and Lesaca 2003; Perrin et al. 2005). Wang et al. (2001a) reported two sightings of short-finned pilot whales during offshore surveys off the southern coast of Taiwan. Short-finned pilot whales have also stranded in Taiwan (Wang and Yang 2006; Yang et al. 2008). Short-finned pilot whales have been seen to follow large-amplitude internal waves in the Luzon Strait; the whales are thought to take advantage of the upwelling caused by these waves, which may make potential prey items like fish and squid more available (Moore and Lien 2007).

Finless Porpoise

The finless porpoise has a fragmented distribution throughout the coastal waters of the Indo-Pacific. The species is listed as ***vulnerable*** on the 2008 IUCN Red List of Threatened Species (IUCN 2008) (Table 2). Its range extends from northern Japan (Shirakihara et al. 1992) south to the waters of Taiwan and China (Parsons et al. 1995; Zhou et al. 1995; Parsons and Wang 1998; Perrin et al. 2005), to Indonesia (Parsons and Wang 1998), and along coastal SE Asia and the Indian Ocean to the Arabian Gulf (Parsons and Wang 1998).

Parsons et al. (1995) and Jefferson and Hung (2007) reported on resident finless porpoise in Hong Kong. Only unconfirmed sightings exist for the Philippines (Parsons and Wang 1998). The finless porpoise inhabits warm, shallow coastal and estuarine waters, where it typically occurs in water depths <50 m (Shirakihara et al. 1992). Although it is rarely encountered more than 5 km from shore, finless porpoises have been seen in shallow water (<200 m deep) up to 240 km from shore in the Yellow and East China Seas (Kasuya 1999; Jefferson et al. 2008). Finless porpoise have also been sighted ~135 km (73 miles) offshore in the South China Sea (De Boer 2000). This shallow-water species is known on the west coast of Taiwan but is unlikely to occur off the east coast of Taiwan (Zhou et al. 1995; Wang et al. 2001a), and it was not seen during surveys off southern Taiwan in 2000 (Wang et al. 2001a). A finless porpoise specimen was found in the Ryukyu archipelago, which is located in the northern portion of the TAIGER survey area (Uchida 1994 *in* Reeves et al. 1997). This species occurs primarily in areas with sandy or soft bottoms and is less likely to occur in areas with hard bottoms (Reeves et al. 1997). Finless porpoise are known to feed on crustaceans, particularly shrimp, squid and octopus, and small fish (reviewed in Reeves et al. 1997).

There are three populations of finless porpoise in SE Asia: the Yangtze River population (*Neophocaena phocaeniodes asiaeorientalis*), the East and Yellow Sea population (*N. p. sunameri*), and the South China Sea population (*N. p. phocaenoides*) (Gao and Zhou 1993; Amano 2002). Gao and Zhou (1993) and Wang et al. (2008) reported on the morphological differences between these populations. The distributions of *N. p. phocaenoides* and *N. p. usunameri* overlap in the Taiwan Strait, and based on genetic analyses, these two forms are actually two different species (Wang et al. 2008). The calving season is quite variable amongst different populations of the finless porpoise. In the South China Sea, the finless porpoise gives birth from June to March, with a peak between August and December (Gao and Zhou 1993); in Hong Kong, parturition occurs from November through March (Parsons and Wang 1998); and in the Yangtze River calving occurs from March to May (see Jefferson et al. 2002). Abundance is estimated at >220 off Hong Kong, <2000 in the Yangtze River, and 5000–10,000 in Japanese waters (Jefferson et al. 2008). The Yangtze River population is undergoing a new assessment but was classified as ***endangered*** in 1996 (IUCN 2008).

Pinnipeds

There are no pinnipeds that occur within the TAIGER study area in SE Asia.

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 TAIGER seismic survey in SE Asia during March–July 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 TAIGER survey in SE Asia during March–July 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 $\mu Pa \cdot m_{p-p}$. McCauley et al. (1998) documented that avoidance reactions began at 5–8 km from the array, and that those reactions kept most pods ~3–4 km from the operating seismic boat. McCauley et al. (2000a) noted localized displacement during migration of 4–5 km by traveling pods and 7–12 km by more sensitive resting pods of cow-calf pairs. Avoidance distances with respect to the single airgun were smaller but consistent with the results from the full array in terms of the received sound levels. The mean received level for initial avoidance of an approaching airgun was 140 dB re 1 μPa_{rms} for humpback pods containing females, and at the mean closest point of approach (CPA) distance the received level was 143 dB re 1 μPa_{rms}. The initial avoidance response generally occurred at distances of 5–8 km from the airgun array and 2 km from the single airgun. However, some individual humpback whales, especially males, approached within distances of 100–400 m, where the maximum received level was 179 dB re 1 μPa_{rms}.

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

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

There are no data on reactions of *right whales* to seismic surveys, but results from the closely-related *bowhead whale* show that their responsiveness can be quite variable depending on their activity (migrating vs. feeding). Bowhead whales migrating west across the Alaskan Beaufort Sea in autumn, in particular, are unusually responsive, with substantial avoidance occurring out to distances of 20–30 km from a medium-sized airgun source at received sound levels of around 120–130 dB re 1 μPa_{rms} [Miller et al. 1999; Richardson et al. 1999; see Appendix B (5)]. 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.

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 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)

[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).

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 μPa^2·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 will be operated from the source vessel during the planned study. Details about this equipment were provided in § I. Sounds from the sub-bottom profiler are very short pulses, occurring for

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 TAIGER seismic program. 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 used during ~15,902 km of seismic surveys in the waters of the TAIGER study area. The sources of distributional and numerical data used in deriving the estimates are described in the next subsection.

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

Basis for Estimating "Take by Harassment"

No systematic aircraft- or ship-based surveys have been conducted for marine mammals in waters near Taiwan, and the species of marine mammals that occur there are not well known. A few surveys have been conducted from small vessels (~10–12 m long) with low observation platforms (~3 m above sea level), as follows:

- off the east-central coast of Taiwan to a maximum of ~20 km from shore in water ~4000 m deep, with most effort within ~10 km of shore in water depths up to ~1200 m deep between June 1996 and July 1997 (all cetaceans; Yang et al. 1999);
- off the south coast of Taiwan to a distance of ~50 km and depths >1000 m during 13 April–9 September 2000 (all cetaceans; Wang et al. 2001a);
- off the west coast of Taiwan close to shore during early April–early August 2002–2006 (Indo-Pacific humpback dolphins; Wang et al. 2007); and
- around and between the Babuyan Islands off northern Philippines in waters <1000 m deep during late February–May 2000–2003 (humpback whales; Acebes et al. 2007)

The only density calculated by the authors was for the Indo-Pacific humpback dolphin (Wang et al. 2007). In addition, a density estimate was also available for the Indo-Pacific bottlenose dolphin (Yang et al. 2000 *in* Perrin et al. 2005).

In the absence of any other density data, we used the survey effort and sightings in Yang et al. (1999) and Wang et al. (2001a) to estimate densities of marine mammals in the TAIGER study area. To correct for detection bias (bias associated with diminishing sightability with increasing lateral distance from the trackline), we used mean group sizes given by or calculated from Wang et al. (2001a, 2007) and Yang et al. (1999), and a value for $f(0)$ of 5.32 calculated from the data and density equation in Wang et al. (2007); Yang et al. (1999) and Wang et al. (2001a) did not give an value for $f(0)$, but they used a vessel and methods similar to those of Wang et al. (2007). To correct for availability and perception bias, which are attributable to the <100% probability of sighting an animal present along the survey trackline, we used $g(0)$ values calculated using surfacing and dive data from Erickson (1976), Barlow and Sexton (1996), Forney and Barlow (1998), and Barlow (1999): 0.154 for *Mesoplodon* sp., 0.102 for Cuvier's beaked whale, 0.193 for the dwarf sperm whale and *Kogia* sp., 0.238 for the killer whale, and 1.0 for delphinids.

The surveys of Yang et al. (1999) and Wang et al. (2001a) were carried out in areas of steep slopes and complex bathymetric features, where many cetacean species are known to concentrate. It did not seem reasonable to extrapolate those densities to the overall survey area, which is predominantly in areas of deep water without complex bathymetry. For the latter areas, we used density data from two 5º x 5º blocks in the ETP surveyed by Ferguson and Barlow (2001): Blocks 87 and 88[2], bounded by 20ºN–25ºN (the same latitudes as the proposed survey area) and 115ºW–125ºW, in deep water just offshore from Mexico. We then calculated an overall density estimate weighted by the estimated lengths of seismic lines over complex bathymetry or slope (~1250 km) and over deep, flat or gently sloping bottom (~14,652 km).

The density estimate for the Indo-Pacific hump-backed dolphin is from Wang et al. (2007) and applies only to the population's limited range on the west coast of Taiwan. No density data were available for the Pacific-white sided or short-beaked common dolphin for the study area. As these species are rare in the area, densities are expected to be near zero. In addition, density data were unavailable for striped and long-beaked common dolphins. As these two species were not seen during the above-mentioned surveys and are considered uncommon in the TAIGER study area, we assigned these two species 10% of the density estimate of the delphinid occurring in similar habitat in the area with the lowest density (i.e., pygmy killer whale). Also, no density estimate was available for finless porpoise. As this species was not sighted during surveys off southern Taiwan in 2000 (Wang et al. 2001a), we assigned it 10% of the density estimate of the species occurring in similar habitat (shallow water) in the area with the lowest density (i.e., Indo-Pacific bottlenose dolphin). Density data were unavailable for Longman's beaked and ginkgo-toothed beaked whales; however, these two species are represented by densities for unidentified beaked whales.

Large whales were not sighted during the surveys by Yang et al. (1999) or Wang et al. (2001a). The only available abundance estimate for large whales in the area (except that for humpbacks, see below) is that of Shimada et al. (2008), who estimated abundances of Bryde's whales in several blocks in the northwestern Pacific based on surveys in 1998–2002, the closest of which to the proposed survey area is the block bounded by 10ºN–25ºN and 130ºE–137.5ºE. The resulting abundance and area were used to calculate density. Sperm, sei, Omura's, fin, minke, and blue whales are less common than Bryde's whales in these waters (see § III & IV), so we assigned a density of 10% of that calculated for Bryde's whale. North Pacific right, and Western North Pacific gray whales are unlikely to occur in the TAIGER study area; thus, densities were estimated to be zero.

For humpback whales in the Babuyan Islands, we used the population estimate of Acebes et al. (2007) and applied it to an area of ~78,000 km^2, extending from the north coast of Luzon to just south of Orchid Island to derive a density estimate. That area is an historically well-documented breeding ground that whaling records indicate was used until at least the 1960s (Acebes et al. 2007), and an area where humpbacks have been sighted more recently (see § III & IV).

There is some uncertainty about the representativeness of the density data and the assumptions used in the calculations. For example, the timing of the surveys of Indo-Pacific humpback dolphins (early April–early August) and humpback whales (late February–May) overlaps the timing of the proposed surveys, but the Bryde's whale surveys (August and September), and those of Yang et al. (1999) (year-round) include different seasons, and would not be as representative if there are seasonal density differences. Perhaps the greatest uncertainty results from using survey results from the northeast Pacific Ocean. 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

[2] For cryptic species (*Kogia* spp. and beaked whales), only Block 88 (pooled with Block 106 directly to the south) was used because Block 87 was pooled with a block that included coastal waters. Blocks are pooled when survey effort is low; only data from calm (Beaufort 0–2) days are used for cryptic species.

present and numbers of marine mammals potentially affected have been derived. Best estimates for most species are based on average densities from the surveys of Yang et al. (1999), Wang et al. (2001a), and Ferguson and Barlow (2001), weighted by effort, whereas maximum estimates are based on the higher of the two densities from the Taiwan surveys and the eastern Pacific survey blocks. For the sperm whale, mysticetes, two delphinids (Indo-Pacific humpback and Indo-Pacific bottlenose dolphins), as well as for the finless porpoise, the maximum estimates are 1.5 x the best estimates. Densities calculated or estimated as described above are given in Table 3.

The estimated numbers of individuals potentially exposed on each leg of the survey 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 (Table 4). It is assumed that marine mammals exposed to airgun sounds that strong might change their behavior sufficiently to be considered "taken by harassment".

It should be noted that the following estimates of exposures to various sound levels assume that the surveys will be completed. 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 down 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.

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 expected density of animals in the area along with the total marine area that would be within the 160-dB radius around the operating airgun array on at least one occasion. The number of possible exposures (including repeated exposures of the same individuals) can be estimated by considering the total marine area that would be within the 160-dB radius around the operating airguns, including areas of overlap. In the proposed survey, the seismic lines are widely spaced in the survey area, and are further spaced in time because the proposed survey is planned in discrete legs separated by several days. Thus, an individual mammal would not be exposed numerous times during the survey; the areas including overlap are only 1.1–1.3 x the areas excluding overlap, depending on leg, so numbers of exposures are not discussed further. Moreover, it is unlikely that a particular animal would stay in the area during the entire survey.

TABLE 3. Density estimates (#/1000 km²) of cetaceans in the TAIGER study area. Slope means steep slopes and areas of complex bathymetry, basin means flat or gently sloping bathymetry, and overall is a mean weighted according to the length of seismic lines in each bathymetry type. See text for sources of estimates. Species in italics are listed under the ESA as *endangered*.

	Best Density (#/1000 km²)				Maximum Density (#/1000 km²)			
Species	**Coastal[1]**	**Slope[2]**	**Non-slope[3]**	**Overall**	**Coastal[1]**	**Slope[2]**	**Non-slope[3]**	**Overall**
Mysticetes								
North Pacific right whale		*0*	*0*	*0*		*0*	*0*	*0*
Humpback whale		*0.89*	*0.89*	*0.89*		*1.33*	*1.33*	*1.33*
Minke whale		0.03	0.03	0.03		0.04	0.04	0.04
Bryde's whale		0.27	0.27	0.27		0.41	0.41	0.41
Omura's whale		0.03	0.03	0.03		0.04	0.04	0.04
Sei whale		*0.03*	*0.03*	*0.03*		*0.04*	*0.04*	*0.04*
Fin whale		*0.03*	*0.03*	*0.03*		*0.04*	*0.04*	*0.04*
Blue whale		*0.03*	*0.03*	*0.03*		*0.04*	*0.04*	*0.04*
Odontocetes								
Sperm whale		*0.03*	*0.03*	*0.03*		*0.04*	*0.04*	*0.04*
Dwarf sperm whale		24.76	2.50	4.25		55.70	2.5	6.68
Kogia sp.		3.27	0.00	0.26		5.10	0	0.40
Cuvier's beaked whale		4.27	0.00	0.34		9.60	0.00	0.75
Longman's beaked whale					NA			
Blainville's beaked whale		11.28	0.00	0.89		20.30	0.00	1.60
Ginkgo-toothed beaked whale					NA			
Mesoplodon sp. (unidentified)		19.72	0.00	1.55		20.30	0.00	1.60
Unidentified beaked whale		2.18	0.60	0.72		4.90	0.60	0.94
Rough-toothed dolphin		0.00	1.44	1.33		0.00	5.90	5.44
Indo-Pacific humpback dolphin[4]	192.80				289.20			
Bottlenose dolphin		143.98	14.08	24.30		238.90	18.00	35.36
Indo-Pacific bottlenose dolphin	43.60				65.40			
Pacific white-sided dolphin					NA			
Pantropical spotted dolphin		874.31	56.52	120.80		1120.60	57.40	140.97
Spinner dolphin		697.23	0.04	54.84		1130.20	0.05	88.89
Striped dolphin		0.69	0.16	0.20		1.56	0.21	0.32
Fraser's dolphin		1231.95	0.00	96.84		1579.20	0.00	124.14
Short-beaked common dolphin					NA			
Long-beaked common dolphin		0.69	0.00	0.05		1.56	0.00	0.12
Risso's dolphin		501.24	2.69	41.88		725.70	11.00	67.18
Melon-headed whale		43.43	10.80	13.37		97.70	14.30	20.86
Pygmy killer whale		6.94	1.59	2.01		15.60	2.10	3.16
False killer whale		58.03	0.00	4.56		60.70	0.00	4.77
Killer whale		10.94	0.15	1.00		19.70	0.20	1.73
Short-finned pilot whale		18.67	2.57	3.83		42.00	3.40	6.43
Finless porpoise	4.36				6.54			

NA = density not available for the TAIGER study area.

[1] Species shown under this column are only found in shallow coastal waters.

[2] Slope consists of complex topography.

[3] Non-slope waters include offshore and nearshore waters that have non-complex bottoms.

[4] Density given only for the population's small range on the west coast of Taiwan.

TABLE 4. Estimates of the possible numbers of marine mammals exposed to the different sound levels during L-DEO's proposed TAIGER seismic survey during March–July 2009. The proposed sound source is a 36-airgun array with a total discharge volume of ~6600 in³. 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*.

	Number of Individuals Exposed to Sound Levels <160 dB (<170 db, Delphinids)																	Requested Take Author-ization
	Best Estimate[1]									Maximum Estimate[1]								
Species	Leg 1		Leg 2		Leg 4		Total		% pop'n[2]	Leg 1		Leg 2		Leg 4		Total		
Balaenopteridae																		
Western North Pacific gray whale	*0*		*0*		*0*		*0*		*0*	*0*		*0*		*0*		*0*		***0***
North Pacific right whale	*0*		*0*		*0*		*0*		*0*	*0*		*0*		*0*		*0*		***0***
Humpback whale[3]	*1*		*9*		*0*		*10*		0.94	*1*		*13*		*0*		*14*		***14***
Minke whale	2		2		2		5		0.02	3		2		2		8		**8**
Bryde's whale	19		16		16		51		0.20	29		24		24		77		**77**
Omura's whale	2		2		2		5		NA	3		2		2		8		**8**
Sei whale	*2*		*2*		*2*		*5*		*0.05*	*3*		*2*		*2*		*8*		***8***
Fin whale	*2*		*2*		*2*		*5*		*0.03*	*3*		*2*		*2*		*8*		***8***
Blue whale	*2*		*2*		*2*		*5*		*NA*	*3*		*2*		*2*		*8*		***8***
Physeteridae																		
Sperm whale	*2*		*2*		*2*		*5*		*0.02*	*3*		*2*		*2*		*8*		***8***
Dwarf sperm whale	301		251		254		806		7.19	473		395		399		1267		**806**
Kogia sp.	18		15		15		49		NA	28		24		24		76		**49**
Ziphiidae																		
Cuvier's beaked whale	24		20		20		64		0.32	53		45		45		143		**64**
Blainville's beaked whale	63		52		53		168		0.66	113		94		95		303		**168**
Mesoplodon sp. (unidentified)[4]	110		92		93		294		1.16	113		94		95		303		**294**
Unidentified beaked whale[5]	51		43		43		137		NA	66		55		56		178		**137**
Delphinidae																		**0**
Rough-toothed dolphin	94	(49)	79	(40)	79	(52)	252	(141)	0.17	385	(200)	322	(165)	325	(213)	1031	578	**252**
Indo-Pacific humpback dolphin	68	(67)	0		0		68	(67)	4.03							99		**68**
Bottlenose dolphin	1719	(895)	1437	(736)	1450	(951)	4606	(2582)	1.89	2502	(1303)	2092	(1071)	2111	(1385)	6704	(3758)	**4606**
Indo-Pacific bottlenose dolphin	677	(642)	0		0		677	(642)	NA	1015	(964)	0		0		1015	(964)	**677**
Pacific white-sided dolphin	0		0		0		0		0.00	0		0		0		0		**0**
Pantropical spotted dolphin	8546	(4450)	7145	(3658)	7211	(4730)	22902	(12838)	2.86	9973	(5193)	8338	(4269)	8415	(5519)	26726	(14981)	**22902**
Spinner dolphin	3880	(2020)	3244	(1661)	3274	(2147)	10397	(5828)	1.30	6288	(3274)	5257	(2692)	5306	(3480)	16852	(9446)	**10397**
Striped dolphin	14	(7)	12	(6)	12	(8)	38	(21)	0.01	22	(12)	19	(10)	19	(12)	60	(34)	**38**
Fraser's dolphin	6851	(3567)	5728	(2932)	5781	(3791)	18359	(10291)	6.35	8782	(4573)	7342	(3759)	7410	(4860)	23534	(13192)	**18359**
Short-beaked common dolphin	0		0		0		0		0.00	0		0		0		0		**0**
Long-beaked common dolphin	4	(2)	3	(2)	3	(2)	10	(6)	0.01	9	(5)	7	(4)	7	(5)	23	(13)	**10**
Risso's dolphin	2963	(1543)	2477	(1268)	2500	(1640)	7940	(4451)	4.54	4753	(2475)	3973	(2034)	4010	(2630)	12736	(7139)	**7940**
Melon-headed whale	946	(492)	791	(405)	798	(523)	2534	(1420)	5.63	1475	(768)	1234	(632)	1245	(817)	3954	(2216)	**2534**
Pygmy killer whale	142	(74)	119	(61)	120	(79)	380	(213)	0.98	224	(116)	187	(96)	189	(124)	599	(336)	**380**
False killer whale	323	(168)	270	(138)	272	(179)	865	(485)	2.16	338	(176)	282	(144)	285	(187)	905	(507)	**865**
Killer whale	71	(37)	59	(30)	60	(39)	189	(106)	2.23	123	(64)	102	(52)	103	(68)	329	(184)	**189**
Short-finned pilot whale	271	(141)	227	(116)	229	(150)	727	(407)	0.15	455	(237)	381	(195)	384	(252)	1220	(684)	**727**
Phocoenidae																		
Finless porpoise	68		0		0		68		0.66	101		0		0		101		**68**

[1] Best estimate and maximum estimates of density are from Table 3. There will be no seismic acquisition during Leg 3; thus, it is not included here.
[2] Regional population size estimates are from Table 2; NA means not available..
[3] Estimates for humpback whales for leg 4 (21 June–14 July) are 0 because they will have left the wintering area by then.
[4] Requested takes include Cuvier's, Blainville's and ginkgo-toothed beaked whales.
[5] Requested takes include Cuvier's, Blainville's, ginkgo-toothed, and Longman's beaked whales.

The numbers of different individuals potentially exposed to ≥160 dB re 1 μPa_{rms} were calculated by multiplying

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

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 of overlap were included only once when estimating the number of individuals exposed.

Applying the approach described above, ~168,315 km^2 would be within the 160-dB isopleth 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. However, the approach assumes that no cetaceans will move away from or toward the trackline as the *Langseth* approaches in response to increasing sound levels prior to the time the levels reach 160 dB, which will result in overestimates for those species known to avoid seismic vessels.

Table 4 shows the best and maximum estimates of the number of exposures and the number of different individual marine mammals that potentially could be exposed to ≥160 dB re 1 μPa_{rms} during the different legs of the seismic survey if no animals moved away from the survey vessel. The ***Requested Take Authorization***, given in the far right column of Table 4, is based on the maximum estimates rather than the best estimates of the numbers exposed for large whales (sperm and baleen whales), because of uncertainties associated with the method of estimating their densities. The ***Requested Take Authorization*** for other species is based on the best estimates rather than the maximum estimates of the numbers exposed; although there are uncertainties associated with the method of estimating their densities, they are based in part on surveys around Taiwan, and the resulting estimates for the overall survey area are reasonable when compared with surveys of similar areas in other parts of the world, e.g., the California Current ecosystem (Barlow and Forney 2007).

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 71,621 (Table 4). That total includes 86 baleen whales, 25 of which are considered ***endangered*** under the ESA: 10 humpback whales (0.94% of the regional population), 5 sei whales (0.05%), 5 fin whales (0.03%), and 5 blue whales (regional population not known) (Table 4).

In addition, five sperm whales (also listed as ***endangered under*** the ESA) or 0.02% of the regional population could be exposed during the survey, as well as 68 Indo-Pacific humpback dolphins (4.03% of the regional population but 68.7% of the eastern Taiwan Strait (ETC) population[3]), 68 finless porpoise (0.7% of the population), and 663 beaked whales including Longman's and ginkgo-toothed beaked whales (Table 4). Most (97.7%) of the cetaceans potentially exposed are delphinids; pantropical spotted, Fraser's, and spinner dolphins are estimated to be the most common species in the area, with best estimates of 22,902 (2.86% of the regional population), 18,359 (6.35%), and 10,397 (1.30%) exposed to ≥160 dB re 1 μPa_{rms}, respectively. However, a more meaningful estimate is the one for sound levels ≥170

[3] The ETC population numbers 99, which would be classified by the IUCN Red List criteria as ***Critically Endangered*** (Dr. John Wang, pers. comm., August 2008).

dB (see below). The 'Maximum Estimate' column in Table 4 shows an estimated total of 98,294 cetaceans. Again, most of these consist of dolphins.

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

The best and maximum estimates of the numbers of individual delphinids that could be exposed to ≥170 dB during the survey are 39,499 and 54,032, 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 survey will involve towing an airgun array that introduces pulsed sounds into the ocean, along with simultaneous operation of an MBES and SBP. The survey will employ a 36-airgun array similar to the airgun arrays used for typical high-energy seismic surveys. The total airgun discharge volume is ~6600 in^3. Routine vessel operations, other than the proposed airgun operations, are conventionally assumed not to affect marine mammals sufficiently to constitute "taking". No "taking" of marine mammals is expected in association with echosounder operations given the considerations discussed in § I, i.e., sounds are beamed downward, the beam is narrow, and the pulses are extremely short.

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

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".

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 Taiwan, China, or the Philippines, so the proposed activities will not have any impact on the availability of the species or stocks for subsistence users. Japan still hunts whales and dolphins for 'scientific' purposes. Up until 1990, a drive fishery of false killer whales occurred in the Penghu Islands, Taiwan, where dozens of whales were taken. Although killing and capturing of cetaceans has been prohibited in Taiwan since August 1990 under the Wildlife Conservation Law (Zhou et al. 1995; Chou 2004), illegal harpooning still occurs (Perrin et al. 2005). Until the 1990s, there was a significant hunt of around 200 to 300 dolphins annually in the Philippines. Catches included dwarf sperm, melon-headed, and short-finned pilot whale, as well as bottlenose, spinner, Fraser's, and Risso's dolphins (Rudolph and Smeenk 2002). Reports also indicate that perhaps five Bryde's whales were caught annually (Rudolph and Smeenk 2002), although the last Bryde's whales were caught in 1996 (Reeves 2002). Successive bans on the harvesting of whales and dolphins were issued by the Philippine Government during the 1990s.

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. 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. North Pacific humpback whales are known to winter and calve around Ogasawara and Ryukyu Islands in southern Japan and in the Babuyan Islands in Luzon Strait in the northern Philippines (Perry et al. 1999a; Acebes et al. 2007; Calambokidis et al. 2008). In the Luzon Strait, the whales may arrive in the area as early as November and leave in May or even June, with a peak occurrence during February through March or April (Acebes et al. 2007). The *Langseth* will attempt to avoid these wintering areas at the time of peak occurrence, by surveying the lines near the Ryukyu Islands and Babuyan Islands as late as possible during each leg of the cruise. Seismic operations in areas where humpbacks breed will be avoided at least during the month of March, when peak numbers of animals occur there.

A total of ~100 OBSs will be deployed during the study. Up to three different types of OBSs will be used. The 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 LC4x4 OBS from the Scripps Institution of Oceanography has a volume of ~1 m^3; its anchor consists of a 1-m^2 piece of steel grating. Taiwanese OBS units will also be used; their anchor is in the shape of an 'x' with dimensions of 51 to 76 cm^2. 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 TAIGER study area in SE Asia. To minimize the likelihood that impacts will occur to the species and stocks, airgun operations will be conducted in accordance with all applicable laws of Taiwan, China, Japan, and the Philippines, as well as 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. 3 and 4) and for a single 1900LL 40-in^3 airgun (which will be used during power downs; Fig. 5), 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 water depth and range up to 3694 m and 2182 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 TAIGER survey include (1) power-down procedures, (2) shut-down procedures, (3) ramp-up procedures, and (4) spatial and temporal avoidance of sensitive species and areas.

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 24 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 in deep water, 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.

Considering the conservation status for North Pacific right whales and Western North Pacific gray whales, the airgun(s) will be shut down immediately if either of these species are observed, regardless of the distance from the *Langseth*. Ramp up will only begin if the gray or right whale has not been seen for 30 min.

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.

Temporal and Spatial Avoidance.— The *Langseth* will not acquire seismic data in the humpback winter concentration areas during the early part of the seismic program, if practicable. North Pacific humpback whales are known to winter and calve around Ogasawara and Ryukyu Islands in southern Japan and in the Babuyan Islands in Luzon Strait in the northern Philippines (Perry et al. 1999a; Acebes et al. 2007; Calambokidis et al. 2008). In the Luzon Strait, the whales may arrive in the area as early as November and leave in May or even June, with a peak occurrence during February through March or April (Acebes et al. 2007). The *Langseth* will attempt to avoid these wintering areas at the time of peak occurrence, by surveying the lines near the Ryukyu Islands and Babuyan Islands as late as possible during each leg of the cruise.

Due to conservation status of Indo-Pacific humpback dolphins in Taiwan Strait, seismic operation will not occur in water depths <20 m and within at least 2 km from the Taiwanese shore. Also, when at all possible, seismic surveying will only take place at least 8–10 km from the Taiwanese coast, particularly the central western coast (~from Taixi to Tongshiao), to minimize the potential of exposing these threatened dolphins to SPLs >160 dB re 1 μPa_{rms}.

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 SE Asia, 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 effectiveness of detecting animals near the source vessel. 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 TAIGER seismic survey in SE Asia (as summarized in § XI and XIII) with other parties that may have interest in the area and/or be conducting marine mammal studies in the same region during the proposed seismic survey. L-DEO and NSF will coordinate with Taiwan, China, Japan, and the Philippines, as well as applicable U.S. agencies (e.g., NMFS), and will comply with their requirements.

XV. LITERATURE CITED

Marine Mammals and Acoustics

Acebes, J.M.V. and L.A.R. Lesaca. 2003. Research and conservation of humpback whales and other cetacean species in the Babuyan islands, northern Luzon. p. 34-42 *In:* J. Van der Ploeg, A. Masipiquena and E.C. Bernardo (eds.) The Sierra Madre Mountain Range: global relevance, local realisties. Papers presented at the 4th regional conference on Environment and Development. Cagayan Valley Program for Environment and Development, Godlen Press, Tuguegarao City.

Acebes, J.M.V., J.D. Darling, and M. Yamaguchi. 2007. Status and distribution of humpback whales (*Megaptera novaeangliae*) in northern Luzon, Philippines. **J. Cetacean Res. Manage.** 9(1):37-43.

Acebes, J.M.V., A.L. Bautista, T.K. Yamada, L. Dolar, and F. Perrin. 2005. Stranding of *Indopacetus pacificus* in Davao, Philippines. Abstracts of 16th Biennial conference on the Biology of Marine Mammals, San Diego, CA, 12-16 December 2005.

Acebes, J.M.V., C.A. Coronado, J.H. Sumangil, A.S. Silayan, E.Z. Dolumbal, G.M. Sano, R.C. Baltazar, and J.G. Davies. 2000. Humpback whale (*Megaptera novaeangliae*) survey in the Babuyan Islands, Cagayan province, Philippines. Unpubl. Rep. to the Cetacean Research and Conservation Project Phase Two, WWW-Philippines.

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.

Alava, M.N.R., M.L.L. Dolar, S. Leatherwood, and C.J. Wood. 1993. Marine mammals of the Philippines. **Asian Life Sci.** 2:227-234.

Allen, G.M. 1942. Extinct and vanishing mammals of the Western Hemisphere with the marine species of all oceans. **Spec. Publ. Am. Comm. Intern. Wildl. Protection** No.11. 620 p.

Amano, M. 2002. Finless porpoise *Neophocaena phocaenoides*. p. 432-435 *In:* W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.) Encyclopedia of Marine Mammals. Academic Press, San Diego, CA. 1414 p.

An, Y.-R., Z-G. Kim, S.-G. Choi, and K.-J. Park. 2008. Abundance estimation of northwest Pacific minke whales using the Korean sighting data in the Yellow Sea and the East Sea. Pap. SC/60/NPM6 presented to the Int. Whal. Comm.

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, 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., 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.

Banfield, A.W.F. 1974. The mammals of Canada. Univ. Toronto Press, Toronto, Ont. 438 p.

Barlow, J. 1999. Trackline detection probability for long-diving whales. p. 209-221 *In*: G.W. Garner, S.C Amstrup, J.L Laake, B.F.J. Manly, L.L. McDonald, and D.G. Robertson (eds.) Marine mammal survey and assessment methods. A.A Balkema, Brookfield, VT. 187 p.

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

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

Barlow, J. and S. Sexton. 1996. The effect of diving and searching behavior on the probability of detecting trackline groups, g_0, of long-diving whales during line-transect surveys. Admin. Rep. LJ-96-14. Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, CA. 21 p.

Barros, N., E.C.M. Parsons, and T.A. Jefferson. 2000. Prey of offshore bottlenose dolphins from the South China Sea. **Aquat. Mamm.** 26(1):2-6.

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:* H.E. Winn and B.L. Olla (eds.) Behavior of Marine Animals, Vol. 3. Plenum, New York, NY.

Braham, H.W. and D.W. Rice. 1984. The right whale, *Balaena glacialis*. **Mar. Fish. Rev.** 46(4):38-44.

Brownell, R.L., W.A. Walker, and K.A. Forney. 1999. Pacific white-sided dolphin - *Lagenorhynchus obliquidens* (Gray, 1828). p. 57-84 *In*: S.H. Ridgway and S.R. Harrison (eds.) Handbook of marine mammals, Vol. 6: The second book of dolphins and porpoises. Academic Press, San Diego, CA. 486 p.

Brownell, R.L., Jr., P.J. Clapham, T. Miyashita, and T. Kasuya. 2001. Conservation status of North Pacific right whales. **J. Cetac. Res. Manage. Spec. Iss.** 2:269-286.

Buckland, S.T., K.L. Cattanach, and R.C. Hobbs. 1993. Abundance estimates of Pacific white-sided dolphin, northern right whale dolphin, Dall's porpoise and northern fur seal in the North Pacific, 1987/90. p. 387-407 *In:* W. Shaw, R.L. Burgner, and J. Ito (eds.) Biology, distribution and stock assessment of species caught in the high seas driftnet fisheries in the North Pacific Ocean. Intl. North Pac. Fish. Comm. Symp., 4–6 Nov. 1991, Tokyo, Japan.

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.

Calambokidis, J., G.H. Steiger, J.M. Straley, L.M. Herman, S. Cerchio, D.R. Salden, J. Urbán R., J.K. Jacobsen, O. von Ziegesar, K.C. Balcomb, C.M. Gabrielle, M.E. Dahlheim, S. Uchida, G. Ellis, Y. Miyamura, P.L. de Guevara P., M. Yamaguchi, F. Sato, S.A. Mizroch, L. Schlender, K. Rasmussen, J. Barlow, and T.J. Quinn II. 2001. Movements and population structure of humpback whales in the North Pacific. **Mar. Mamm. Sci** 17(4):769-794.

Calambokidis, J., G.H. Steiger, J.M. Straley, T. Quinn, L.M. Herman, S. Cerchio, D.R. Salden, M. Yamaguchi, F. Sato, J.R. Urban, J. Jacobsen, O. von Ziegesar, K.C. Balcomb, C.M. Gabriele, M.E. Dahlheim, N. Higashi, S. Uchida, J.K.B. Ford, Y. Miyamura, P. Ladron de Guevara, S.A. Mizroch, L. Schlender, and K. Rasmussen. 1997. Abundance and population structure of humpback whales in the North Pacific basin. Final Contract Report 50ABNF500113 to Southwest Fisheries Science Center, P.O. Box 271, La Jolla, CA, 92038. 72. p.

Calambokidis, J., E.A. Falcone, T.J. Quinn, A.M Burdin, P.J. Clapham, J.K.B. Ford, C.M. Gabriele, R. LeDuc, D. Mattila, L. Rojas-Bracho, J.M. Straley, B.L. Taylor, J. Urban R., D. Weller, B.H. Witteveen, M. Yamaguchi, A. Bendlin, D. Camacho, K. Flynn, A. Havron, J. Huggins, and N. Maloney. 2008. SPLASH: Structure of populations, levels of abundance and status of humpback whales in the North Pacific. Rep. AB133F-03-RP-0078 for U.S. Dept. of Comm., Seattle, WA.

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.

Chen, Y.-A. 2001. Ecological aspects of cetaceans in Ilan waters of Taiwan: abundance, distribution, habitat partitioning and acoustics. Master's thesis, Univ. Charleston, SC, USA. 147 p.

Chou, L.-S. 1994. Guide to the Cetaceans of Taiwan. National Museum of Marine Biology, Taipei. (In Chinese).

Chou, L.-S. 2004. History of the marine mammal study in Taiwan. p. 129-138 *In:* S. Akiyama et al. (eds.) Proceedings of the 5th and 6th Symposium on Collection Building and Natural History Studies in Asia and the Pacific Rim. **National Science Museum Monographs** 24:129-138.

Chou, L.-S., H.-Y. Yu, and R.L. Brownell, Jr. 2007. Killer whales in Taiwanese waters: population identity biology, and conservation status. Pap. SC/59/SM1 presented to the Int. Whal. Comm.

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

Clapham, P.J., C. Good, S.E. Quinn, R.R. Reeves, J.E. Scarff, and R.L. Brownell Jr. 2004. Distribution of North Pacific right whales (*Eubalaena japonica*) as shown by 19th and 20th century whaling catch and sighting records. **J. Cetac. Res. Manage.** 6(1):1-6.

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

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

Cooke, J.G., D.W. Weller, A.L. Bradford, A.M. Burdin, and R.L. Brownell, Jr. 2008. Population assessment of western gray whales in 2008. Pap. SC/60/BRG11 presented to the Int. Whal. Comm.

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.

Darling, J.D. and S. Cerchio. 1993. Movement of a humpback whale (*Megaptera novaeangliae*) between Japan and Hawaii. **Mar. Mamm. Sci.** 9:84-89.

Darling, J.D. and K. Mori. 1993. Recent observations of humpback whales (*Megaptera novaeangliae*) in Japanese waters off Ogasawara and Okinawa. **Can. J. Zool.** 71:325-333.

Darling, J.D., J. Calambokidis, K.C. Balcomb, P. Bloedel, K. Flynn, A. Mochizuki, K. Mori, F. Sato, H. Suganuma, and M. Yamaguchi. 1996. Movement of a humpback whale (*Megaptera novaeangliae*) from Japan to British Columbia and return. **Mar. Mamm. Sci.** 12(2):281-287.

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.

De Boer, M.N. 2000. A note on cetacean observations in the Indian Ocean Sanctuary and the South China Sea, Mauritius to the Philippines, April 1999. **J. Cetacean Res. Manage.** 2(3):197-200.

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.

Dizon, A.E., S.O. Southern, and W.F. Perrin. 1991. Molecular analuysis of mtDNA typies in exploited populations of spinner dophins (*Stenella longirostris*). **Rep. Int. Whal. Comm. Spec. Iss.** 15:355-363.

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.

Dolar, M.L.L. 1999. Abundance, distribution and feeding ecology of small cetaceans in the eastern Sulu Sea and Tañon Strait, Philippines. Ph.D. dissertation, Scripps Institution of Oceanography, University of California, San Diego, CA. 241 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.

DoN (Department of the Navy). 2007. Marine resource assessment for the Southeastern Florida and the AUTEC-Andros Operating Areas, Final Report. Naval Facilities Engineering Command, Atlantic; Norfolk, VA. Contract No. N62470-02-D-9997, CTO. 0034. Prepared by GeoMarine, Inc., Hampton, VA, for U.S Fleet Forces Command.

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. Comm.** 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.

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.

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.

Forney, K.A. and J. Barlow. 1998. Seasonal patterns in the abundance and distribution of California cetaceans, 1991–92. **Mar. Mam. Sci.** 14:460-489.

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

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. 2002. 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.

Gao, A. and K. Zhou. 1993. Growth and reproduction of three populations of finless porpoise, *Neophocaena phocaenoides,* in Chinese waters. **Aquat. Mamm.** 19(1):3-12.

Gao, A., K. Zhou and Y. Wang. 1995. Geographical variation in morphology of bottlenose dolphins (*Tursiops* sp.) in Chinese waters. **Aquat. Mamm.** 21:121-135.

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.

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.

Gilmore, R.M. 1978. Right whale. *In:* D. Haley (ed.) Marine mammals of eastern North Pacific and arctic waters. Pacific Search Press, Seattle, WA.

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.

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.

Hain, J.H.W., W.A.M. Hyman, R.D. Kenney, and H.E. Winn. 1985. The role of cetaceans in the shelf-edge region of the U.S. **Mar. Fish. Rev.** 47(1):13-17.

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.

Harwood, J. and B. Wilson. 2001. The implications of developments on the Atlantic Frontier for marine mammals. **Cont. Shelf Res.** 21:1073-1093.

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.

Henderson, D.A. 1990. Gray whales and whalers on the China coast in 1869. **Whalewatcher** 24(4):14-16.

Herman, L.M., C.S. Baker, P.H. Forestell, and R.C. Antinoja. 1980. Right whale, *Balaena glacialis*, sightings nears Hawaii: a clue to the wintering grounds? **Mar. Ecol. Prog. Ser.** 2(4):271-275.

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.) River dolphins and the larger toothed whales, Vol. 4. 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.

Hsieh, Y.-C., M.-P. Wu, W.-C. Chuang, C.-H. Wang, C.-N. Hung, K.-Y. Tsai, and S.-S. Tsai. 2005. Case report of stranded pygmy killer whales. **Taiwan Veterinary J.** 31(4):259-266.

Huang, C.-C. 1996. Fauna and distribution of cetaceans in Taiwan and abundance estimate of small cetaceans in southwestern Taiwan waters. Master's thesis, Department of Fishery Science, National Ocean Taiwan University, Keelung, Taiwan. (In Chinese with English abstract).

Hung, S.K. and T.A. Jefferson. 2004. Ranging patterns of Indo-Pacific humpback dolphins (*Sousa chinensis*) in the Pearl River estuary, People's Republic of China. **Aquat. Mamm.** 30(1):159-174.

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). 2008. 2008 IUCN Red List of Threatened Species. http://www.iucnredlist.org.

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. 2000. Population biology of the Indo-Pacific Hump-backed dolphin in Hong Kong waters. **Wildl. Monogr.** 144:1-65.

Jefferson, T.A. and N.B. Barros. 1997. *Peponocephala electra*. **Mammal. Spec.** 553:1-6.

Jefferson, T.A. and S.K. Hung. 2004. A review of the status of the Indo-Pacific humpback dolphin (*Sousa chinensis*) in Chinese waters. **Aquat. Mamm.** 30(1):149-158.

Jefferson, T.A. and S.K. Hung. 2007. An updated, annotated checklist of the marine mammals of Hong Kong. **Mammalia** 2007:105-114.

Jefferson, T.A. and K. Van Waerebeek. 2002. The taxonomic status of the nominal dolphin species *Delphinus tropicalis* Van Bree, 1971. **Mar. Mamm. Sci.** 18(4):787-818.

Jefferson, T.A., K.M. Robertson, and J.Y. Wang. 2002. Growth and reproduction of the finless porpoise in southern China. **Raff. Bull. Zool. Supp.** 10:105-113.

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

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.

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.

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.

Kasuya, T. 1999. Finless propoise *Neophocaena phocaenoides* (G. Cuvier, 1829). p. 411-412 *In:* S.H. Ridgway and R.J. Harisson (eds.) Handbook of Marine Mammals, Vol. 1. Academic press, New York.

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.

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.

Kitakado, T., H. Shimada, H. Okamura, and T. Miyashita. 2008. CLA abundance estimates for western North Pacific Bryde's whales and their associated CVs with taking additional variance into account. Pap. SC/60/PFI3 presented to the Int. Whal. Comm.

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, and 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 16^{th} 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.

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

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

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

Leatherwood, S., M.M.L. Dolar, C.J. Wood, L.V. Aragones, and C.L. Hill. 1992. Marine mammal species confirmed from Philippine waters. **Silliman J.** 36:65-86.

Leatherwood, S., R.R. Reeves, A.E. Bowles, B.S. Stewart, and K.R. Goodrich. 1984. Distribution, seasonal movements, and abundance of Pacific white-sided dolphins in the eastern North Pacific. **Sci. Rep. Whales Res. Inst. Tokyo**. 35:129-157.

LeDuc, R.G., D.W. Weller, J. Hyde, A.M. Burdin, P.E. Rosel, R.L. Brownell, Jr., B. Würsig, and A.E. Dizon. 2002. Genetic differences between western and eastern gray whales (*Eschrichtius robustus*). **J. Cetacean Res. Manage.** 4(1):1-5.

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*: D.J. Aidley (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.

Marsh, H., H. Penrose, C. Eros, and J. Hugues. n.d. Dugong status report and action plans for countries and territories. Early warnging and assessment report series. UNEP/DEWA/RS.02-1.

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. 1989. 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.

Miyashita, T. T. Kirhiro, N. Higashi, F. Sato, K. Mori, and H. Kato. 1995. Winter distribution of cetaceans in the western North Pacific observed from sighting cruises 1993-1995. 13 p. Unpublished International Whaling Commission Scientific Committee Report SC/47/NP16.

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.

Mizue, K. 1951. Grey whales in the East Sea Area of Korea. **Sci. Rep. Whales Res. Inst. Tokyo** 5:71-79.

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.

Moore, S.E. and R.C. Lien. 2007. Pilot whales follow internal solitary waves in the South China Sea. **Mar. Mamm. Sci.** 23(1):193-196.

Moore, S.E., J.M. Waite, N.A. Friday, and T. Honkalehto. 2002. Distribution and comparative estimates of cetacean abundance on the central and south-eastern Bering Sea shelf with observations on bathymetric and prey associations. **Prog. Oceanogr.** 55(1-2):249-262.

Mori, K., F. Sato, and A. Mochizuki. 1998. recent observation records onf the northern right whale in the waters of Ogasaw Ara (Bonin Islands), Japan. Abstact p. 93-94 *In:* The World Marine Mammal Scince Conference, Monaco, January 1998.

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.

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.

Nishiwaki, M. 1959. Humpback whales in Ryukyuan waters. **Sci. Rep. Whales Res. Inst. Tokyo** 14:49-87.

Nishiwaki, M. and N. Oguro. 1972. Catch of the Cuvier's beaked whales off Japan in recent years. **Sci. Rep. Whales Res. Inst. Tokyo** 24:35-41.

NMFS (National Marine Fisheries Service). 1991. Recovery plan for the northern right whale (*Eubalaena glacialis*). Prepared by the Right Whale Recovery Team for the National Marine Fisheries Service, Silver Spring, MD. 86 p.

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

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

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

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

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

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

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.

Ogino, M., R. MacDougall, and M. Kume. 2005. Live and mass strandings of marine mammals in Japan and their status and conservation. p. 149 *In:* W.F. Perrin, R.R. Reeves, M.L.L. Dolar, T.A. Jefferson, H. March, J.Y. Wang, and J. Estacion (eds.) Report of the second workshop on the biology and conservation of small cetaceans and dugongs of SE Asia. Silliman University, Dumaguete City, Philippines. 24-26 July 2002.

Ohsumi, S. and S. Wada. 1974. Status of whale stocks in the North Pacific, 1972. **Rep. Int. Whal. Comm.** 25:114-126.

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.

Omura, H. 1986. History of right whale catches in the waters around Japan. **Rep. Int. Whal. Comm. Spec. Iss.** 10:35-41.

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. Working Pap. SC/58/E41 prepared for the Int. Whal. Comm. 16 p.

Parsons, E.C.M. and J.Y. Wang. 1998. A review of finless propoises (*Neophocaena phocaenoides*) from the South China Sea. p. 287-306 *In:* B. Morton (ed.) The Marine Biology of the South China Sea. Proceedings of the Third International Conference on the Marin eBiology of the South China Sea, Hong Kong, 28 October – 1 November 1996. Hong Kong Univsersity Press, Hong Kong.

Parsons, E.C.M., M.L. Felley, and L.J. Porter. 1995. An annotated checklist of cetaceans recorded from Hong Kong's territorial waters. **Asian Mar. Biol.** 12:79-100.

Parsons, E.C.M., H.M. Chan, and R. Kinoshita. 1999. Trace metal and organochlorine concentrations in a pygmy Bryde's whale (*Balaenoptera edeni*) from the South China Sea. **Mar. Poll. Bull**. 38(1):51-55.

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 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.

Perrin, W.F., L.L. Dolar, and D. Robineau. 1999. Spinner dolphins (*Stenella longirostris*) of the western Pacific and Southeast Asia: pelagic and shallow-water forms. **Mar. Mamm. Sci.** 15(4):1029-1053.

Perrin, W.F., M.L.L. Dolar, M. Amano, and A. Hayano. 2003. Cranial sexual dimorphism and geographic variation in Fraser’s dolphin, *Lagenodelphis hosei*. **Mar. Mamm. Sci.** 19(3):484-501.

Perrin, W.F., R.R. Reeves, M.L.L. Dolar, T.A. Jefferson, H. Marsh, J.Y. Wang, and J. Estacion (eds). 2005. Report of the second workshop on the biology and conservation of small cetaceans and dugongs of south-east Asia. CMS Technical Series Publication No. 9. 161 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.

Pike, G.C. and I.B. MacAskie. 1969. Marine mammals of British Columbia. **Bull. Fish. Res. Board Can.** 171. 54 p.

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., J.G. Mead, and S. Katona. 1978. The right whale, *Eubalaena glacialis*, in the western North Atlantic. **Rep. Int. Whal. Comm.** 28:303-12.

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.

Reeves, R.R., T.D. Smith, and E.A. Josephson. 2008. Observations of western gray whales by ship-based whalers in the 19th century. Pap. SC/60/BRG7 prepared for the Int. Whal. Comm.

Reeves, R.R., J.Y. Wang, and S. Leatherwood. 1997. The finless porpoise, *Neophocaena phocaenoides* (G. Cuvier, 1829): a summary of current knowledge and recommendations for conservation action. **Asian Mar. Biol.** 14:111-143.

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.

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

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. 1978. The humpback whale in the North Pacific: distribution, exploitation and numbers. Pages 29-44 *In:* K.S. Norris and R.R. Reeves (eds.) Report on a workshop on problems related to humpback whales (*Megaptera novaeangliae*) in Hawaii. National Technical Information Service PB 280 794, U.S. Department of Commerce

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.

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

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

Richardson, W.J., 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.

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.

Rowntree, V., J. Darling, G. Silber, and M. Ferrari. 1980. Rare sighting of a right whale (*Eubalaena glacialis*) in Hawaii. **Can. J. Zool.** 58(2):308-312.

Rudolph, P. and C. Smeenk. 2002. Indo-West Pacific marine mammals. p. 617-624 *In:* W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.) Encyclopedia of Marine Mammals. Academic Press, San Diego, CA. 1414 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.

Salden, D.R., L.M. Herman, M. Yamaguchik, and F. Sato. 1999. Mulitple visits of individual humpback whales (*Megaptera novaeangliae*) between the Hawaiian and Japanese winter grounds. **Can. J. Zool.** 77:504-508.

Sasaki, T., M. Nikaido, S. Wada, T.K. Yamada, Y. Cao, M. Hasegawa, and N. Okada. 2006. *Balaenoptera omurai* is a newly discovered baleen whale that represents an ancient evolutionary lineage. **Mol. Phylogenet. Evol.** 41:40-52.

Scarff, J.E. 1991. Historic distribution and abundance of the right whale (*Eubalaena glacialis*) in the North Pacific, Bering Sea, Sea of Okhotsk and Sea of Japan from the Maury Whale Charts. **Rep. Int. Whal. Comm.** 41:467-489.

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.

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

Shelden, K.E.W., S.E. Moore, J.M. Waite, P.R. Wade, and D.J. Rugh. 2005. Historic and current habitat use by North Pacific right whales *Eubalaena japonica* in the Bering Sea and Gulf of Alaska. **Mamm. Rev.** 35(2):129-155.

Shimada, H., H. Okamura, T. Kitakado, and T. Miyashita. 2008. Abundance estimate of western North Pacific Bryde's whales for the estimation of additional variance and CLA application. Working Pap. SC/60/FF12. Int. Whal. Comm., Cambridge, U.K. 32 p.

Shirakihara, K., H. Yoshida, M. Shirakihara, and A. Takemura. 1992. A questionnaire survey on the distribution of the finless porpoise, *Neophocaena phocaenoides*, in Japanses waters. **Mar. Mamm. Sci.** 8:160-164.

Shirakihara, K., H. Yoshida, H. Yokochi, H. Ogawa, T. Hosokawa, N. Higashi, and T. Kasuya. 2007. Current status and conservation needs of dugongs in southern Japan. **Mar. Mamm. Sci.** 23(3):694-706.

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).

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.

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.

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

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

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

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

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

Tillman, M.F. 1977. Estimates of population size for the North Pacific sei whale. **Rep. Int. Whal. Comm., Spec. Iss.** 1:98-106.

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

Townsend, C.H. 1935. The distribution of certain whales as shown by logbook records of American whaleships. **Zoologica** (NY) 19(1-2):1-50+6 maps.

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.

Tynan, C.T., D.P. DeMaster, and W.T. Peterson. 2001. Endangered right whales on the southeastern Bering Sea shelf. **Science** 294(5548):1894.

Uchida, S. 1994. Cetaceans in the Ryukyu waters. Nago museum, Japan.

UNEP-WCMC. 2008. UNEP-WCMC Species Database: CITES-Listed Species. Available at http://www.cites.org/

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

Vladivirov, V.A., S.P. Starodymov, A.G. Afanasyev-Grigoryev, J.E. Muir, O.Y. Tyurneva, Y.M. Yakovlev, V.I. Fadeev, and V.V. Vertyankin. 2008. Distribution and abundance of Western gray whales off the northeast coast of Sakhalin Island (Russia), 2007. Pap. SC/60/BRG9 presented to the Int. Whal. Comm. 9 p.

Wada, S. 1973. The ninth memorandum on the stock assessment of whales in the North Pacific. **Rep. Int. Whal. Comm.** 23:164-169.

Wada, S. and K. Numachi. 1991. Allozyme analysis of genetic differentiation among the populations and species of the Balaenoptera. **Rep. Int. Whal. Comm. Spec. Iss.** 13:125-154.

Wada, S., M. Oishi, and T. Yamada. 2003. A newly discovered species of living baleen whale. **Nature** 426(6969):278-281.

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

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

Wang, J.Y., and S.-C. Yang. 2005. Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) of Nan Wan and adjacent waters in southern Taiwan. Doc. 8 *In:* W.F. Perrin, R.R. Reeves, M.L.L. Dolar, T.A. Jefferson, H. March, J.Y. Wang, and J. Estacion (eds.) Report of the second workshop on the biology and conservation of small cetaceans and dugongs of SE Asia. Silliman University, Dumaguete City, Philippines. 24-26 July 2002.

Wang, J.Y. and S.-C. Yang. 2006. Unusual cetacean stranding events of Taiwan in 2004 and 2005. **J. Cetacean Res. Manage.** 8(3):283-292.

Wang, J.Y., L.-S. Chou, C.-J. Yao, A.S. Neimanis, and W.-H. Chou. 1995a. Records of Cuvier's beaked whales (*Ziphius cavirostris*) from Taiwan, Republic of China. **Asian Mar. Biol.** 12:111-118.

Wang, J.Y., L. Chou, and B.N. White. 1995b. Sympatric forms of bottlenose dolphins (*Tursiops* spp.) around the Penghu Archipelago (Pescadores): a preliminary report. p. 35-39 *In:* L. Chou (ed.) The Third Symposium on Cetacean Ecology and Conservation. National Taiwan University, Taipei.

Wang, J.Y., S.-C. Yang, and H.-C. Liao. 2001a. Species composition, distribution and relative abundance of cetaceans in the waters of southern Taiwan: implications for conservation and eco-tourism. **J. National Parks Taiwan** 11(2):137-158.

Wang, J.Y., S.-C. Yang, and H.-C. Liao. 2001b. Records of melon-headed whales, *Peponocephala electra* (Gray, 1846) , from the waters of Taiwan. **Bull. National Museum of Nat. Sci. No.** 14:85-91.

Wang, J.Y., S.-C. Yang, and R.R. Reeves (eds.). 2004a. Research Action Plan for the Humpback Dolphins of Western Taiwan. National Museum of Marine Biology and Aquarium, Checheng, Pingtung County, Taiwan. 3 p. (Chinese) + 4 p. (English).

Wang, J.Y., S.K. Hung, and S.-C. Yang. 2004b. Records of Indo-Pacific humpback dolphins, *Sousa chinensis* (Osbeck, 1765), from the waters of western Taiwan. **Aquat. Mamm.** 30:187-194.

Wang, J.Y., S.C. Yang, S.K. Hung, and T.A. Jefferson. 2007. Distribution, abundance and conservation status of the eastern Taiwan Strait population of Indo-Pacific humpback dolphins, *Sousa chinensis*. **Mammalia** 2007:157-165.

Wang, J.Y., T.R. Frasier, S.-C. Yang, and B.N. White. 2008. Detecting recent speciation events: the case of the finless porpoise (genus *Neophocaena*). **Heredity** 101:145-155.

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

Wang, M.-C., W.A. Walker, K.-T. Shao, and L.-S. Chou. 2003. Feeding habits of the pantropical spotted dolphin, *Stenella attenuata*, off the Eastern Coast of Taiwan. **Zool. Studies** 42(2):368-378.

Wang, P. 1984. Distribution of gray whales in the seas near China. Compiled abstracts of papers form the 15th annual meeting of the Chinese Zoological Society and the 11th meeting of members delegates. **Chinese Zool. Soc.** 309. (In Chinese).

Wang, P. and J. Sun. 1982. Studies on the Zhonghua white dolophin, *Sousa chinensis* from the South China Sea. **Trans. Liaoning Zool. Soc.** 3:67-74. (In Chinese).

Wang, W. 1965. Preliminary observations on *Sotalia sinensis* off the coast fo Xiamen. **Newsl. Fujian Fish. Soc.** 3-4:16-21. (In Chinese).

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.

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

Watkins, W.A., J.E. George, M.A. Daher, K. Mullin, D.L. Martin, S.H. Haga, and N.A. DiMarzio. 2000b. Whale call data from the North Pacific, November 1995 through July 1999: occurrence of calling whales and source locations from SOSUS and other acoustic systems. Tech. Rep. WHOI-00-02. Woods Hole Oceanographic Inst., Woods Hole, MA. 160 p.

Weir, C.R. 2008. Overt responses of humpback whales (*Megaptera novaeangliae*), sperm whales (*Physeter macro-cephalus*), 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.

Weller, D.W., B. Wursig, A.L. Bradford, A.M. Burdin, S.A. Blokhin, H. Minakuchi, and R.L. Bronwell, Jr. 1999. Gray whales (*Eschrichtius robustus*) off Sakhalin island, Russia: seasonal and annual patterns of occurrence. **Mar. Mamm. Sci.** 15(4):1208-1227.

Weller, D.W., S.H. Reeve, A.M. Burdin, B. Würsig, and R.L. Brownell, Jr. 2002a. A note on spatical distribution of western gray whales (*Eschrichtius robustus*) off Sakhalin island, Russia in 1998. **J. Cetacean Res. Manage.** 4(1):13-17.

Weller, D.W., A.M. Burdin, B. Würsig, B.L. Taylor, and R.L. Brownell, Jr. 2002b. The western gray whale: a review of past exploitation, current status and potential threats. **J. Cetacean Res. Manage.** 4(1):7-12.

Weller, D.W., A.L. Bradford, A.R. Lang, H.W. Kim, M. Sidorenko, G.A. Tsidulko, A.M. Burdin, and R.L. Brownell, Jr. 2008. Status of western gray whales off northeastern Sakhalin Island, Russia, in 2007. Pap. SC/60/BRG3 presented to the Int. Whal. Comm. 9 p.

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.

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.

Yamada, T.K., T. Kakuda, N. Kubo, and M.L. Dalebout. 2004. Kagoshima specimen of Longman's beaked whale. Proceedings of the 18th Conference of the European Cetacean Society, Kolmården, Sweden, 28-31 March 2004.

Yamaguchi, M., J.M. Acebes, and Y. Miyamura. 2002. The breeding ground distribution of the humpback whales, Megaptera novaeangliae, in the western North Pacific and their trans-movements among the Ogasawara Islands, the Ryukyu Islands and the Philippines. Paper presented *In:* W.F. Perrin, R.R. Reeves, M.L.L. Dolar, T.A. Jefferson, H. March, J.Y. Wang, and J. Estacion (eds.) Report of the second workshop on the biology and conservation of small cetaceans and dugongs of SE Asia. Silliman Uniersity, Dumaguete City, Philippines. 24-26 July 2002.

Yang, G., G. Ji, W. Ren, and K. Zhou. 2005. Pattern of genetic variation of bottlenose dolphins in Chinese waters. **Raff. Bull. Zool.** 53(1):157-164.

Yang, G., K.-Y. Zhou, and X.-R. Xu. 2000. Population density, distribution, and incidental catches of bottlenose dolphins in Xiamen-Dongshan waters of the Taiwan Strait. **Acta Ecologica Sinica** 20:1002–1008.

Yang, G., K.-Y. Zhou, H. Kato, and T. Miyashita. 1997. An initial study on the population size and distribution of bottlenose dolphin in the East China Sea. **Acta Theirologica Sinica** 17:241-247.

Yang, H. 1976. Studies on the whales, propoises and dolphins of Taiwan. **Ann. Rep. Sci., Taiwan Museum** 19:131-178. (In Chinese).

Yang, S.-C., H.-C. Liao, C.-L. Pan, and J.Y. Wang. 1999. A survey of cetaceans in the waters of central-eastern Taiwan. **Asian Mar. Biol.** 16:23-34.

Yang, W.-C., L.-S. Chou, P.D. Jepson, R.L. Brownell, D. Cowan, P.-H. Chang, H.-I. Chiou, C.-J. Yao, T.K. Yamada, J.-T. Chiu, S.-C. Chin, P.-J. Wang, and A. Fernández. 2008. Unusual cetacean mortality event in Taiwan: caused by naval activities? **Vet. Rec.** 162.

Yao, C.-J., L._S. Chou, and Y.-J. Yang. 2004. Population genetic structure of pantropical spotted dolphin, *Stenella attenuata*, in waters of Taiwan and South China Sea based on mitochondrial DNA control region sequences. **Taiwania** 49(2):80-94.

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.

Yoshida, H. and H. Kato. 1999. Phylogenetic relationships of Bryde's whales in the watern north Pacific and adjacent waters inferred from mitochondrial DNA sequences. **Mar. Mamm. Sci.** 15(4):1269-1286.

Yoshida, H. and R.B. Trono. 2004. Dugong conservation network in Asia and Pacific. Knowledge Marketplace Reports. The 3rd IUCN World Conservation Congress, 17-25 November 2004, Bangkok, Thailand.

Zhou, K. 1987. Notes on two species of dolphins of the genus *Tursiops* in Chinese waters. **Acta Theriologica Sinica** 7:246-254. (In Chinese with English summary).

Zhou, K. and W. Qian. 1985. Distribution of the dolphins of the genus *Tursiops* in the China Seas. **Aquat. Mamm.** 1:16-19.

Zhou, K., S. Leatherwood, and T.A. Jefferson. 1995. Records of small cetaceans in Chinese waters: a review. **Asian Mar. Biol.** 12:119-139.

Zhu, Q. 1998. Strandings and sightings of the western Pacific stock of gray whale Eschrichtius robustus in Chinese coastal waters. Paper SC/50/AS5 presented to the IWC Scientific Committee, April 1998, Oman (unpublished). [Paper available from the Office of this Journal].

Sea Turtles, Seabirds, Fish, 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, 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.

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.

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

Dalen, J., 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.

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

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

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

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.

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.

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.