Request by Lamont-Doherty Earth Observatory for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals During a Marine Seismic Survey in the Gulf of Alaska, Late Summer/Early Autumn 2004

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

12 April 2004

LGL Report TA2822-25

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 Seismic Survey in the Gulf of Alaska, Late Summer/Early Autumn 2004

SUMMARY

Lamont-Doherty Earth Observatory (L-DEO), a part of Columbia University, operates the oceanographic research vessel R/V *Maurice Ewing* (*Ewing*) under a cooperative agreement with the U.S. National Science Foundation (NSF), owner of that vessel. L-DEO plans to conduct a marine seismic survey in the Gulf of Alaska (GOA) during a four-week period within a general time window from late July to October 2004. 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 in the GOA. This request is submitted pursuant to Section 101 (a) (5) (D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371 (a) (5). The seismic survey will be conducted in the territorial waters and Exclusive Economic Zone (EEZ) of the U.S.A.

Numerous species of cetaceans and pinnipeds inhabit the GOA. Several of these species are listed as "Endangered" under the U.S. Endangered Species Act (ESA), including the humpback, sei, fin, blue, North Pacific right, and sperm whales. Steller sea lions, for which the western stock is listed as "Endangered" and the eastern stock is listed as "Threatened", also occur in the area. L-DEO is proposing a marine mammal monitoring and mitigation program to minimize the impacts of the proposed activity on marine mammals present during conduct of the proposed research, and to document the nature and extent of any effects. Special mitigation measures will be implemented for the North Pacific right whale, because of the rarity and sensitive status of this species.

The items required to be addressed pursuant to 50 C.F.R. § 216.104, "Submission of Requests" are set forth below. This includes 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. Appropriate measures will be taken to minimize conflicts between the proposed operation and subsistence hunting in the study area.

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

Lamont-Doherty Earth Observatory (L-DEO), on behalf of the National Science Foundation, plans to conduct a seismic survey in the GOA (Fig. 1) during a four-week period within a general time window from late July to October 2004.

The purpose of the seismic survey is to locate sedimentary records of environmental change in the region, including Holocene climate variability, anthropogenic warming and glacier melting of the past century, and dynamics of erosion and deposition associated with glaciation. This research has important implications for understanding long-term variability of North Pacific ecosystems, with relevance towards managing fisheries, marine mammals and other species. Geophysical site survey and safety information will be used to optimally locate coring sites and to understand regional sedimentation patterns. The marine paleoclimatic record here has received relatively little study because very few suitable cores have been taken. Nevertheless, enough basic knowledge of fjord sedimentation processes exists to support a strategy of targeting deep silled basins of fjords with adequate connections to the open ocean, as well as shelf and slope sediments in the open ocean.

Fjord basins likely contain a rich array of biogenic and sedimentologic evidence for regional climate change. Regions of turbidite sedimentation (i.e., coarse sediments transported down-slope in turbidity currents) will be documented using shipboard geophysical sensing and sedimentological proxies in recovered sediments and will be avoided during coring. However, if some isolated turbidites are present, this may present an opportunity to examine seismically triggered events that provide useful synchronous stratigraphic markers.

Based on available data, sediment accumulation at the target sites is expected to have been rapid, as much as 10^2 to 10^4 cm/ka (centimeters per thousand years), and will span the Holocene. With these sedimentation rates, long piston cores (~20–30 m or 66–98 ft) are needed to develop records of Holocene (or in some cases, even latest-Holocene or neoglacial) climate variability. A few areas, notably some older glacial troughs on the continental shelf or slope that may date to Marine Isotope Stage 4 (~65,000 years ago) or Stage 6 (~150,000 years ago) may have been free of glacier ice during the Last Glacial Maximum (~20,000 years ago). These may offer opportunities to develop long-term records of climate change, regional glacier dynamics, and ecological responses during the waxing and waning of the last ice age. Total sediment accumulations of a few hundred meters are possible in many places.

Relatively few sediment cores have been obtained from Alaskan fjords. Only two, one of which is in the Oregon State University (OSU) collection, are longer than four meters and were collected from the fjord systems south of Icy Bay. Three more cores (all in the OSU collection) were collected from shallow water in Cook Inlet. The proposed study will provide long (~20 m [66 ft], or longer in suitable sediments) piston cores to facilitate reconstruction of climate changes in the region. It will also provide multicores with pristine sediment-water interface samples to assess recent variability within the past few decades at sites of rapid sedimentation. Finally, the study will include geophysical surveys, both to optimize coring locations and to support future drilling.

New long core records will provide an innovative window into relationships of North Pacific and global climate changes of the Holocene and late-glacial time. They will also provide information on the

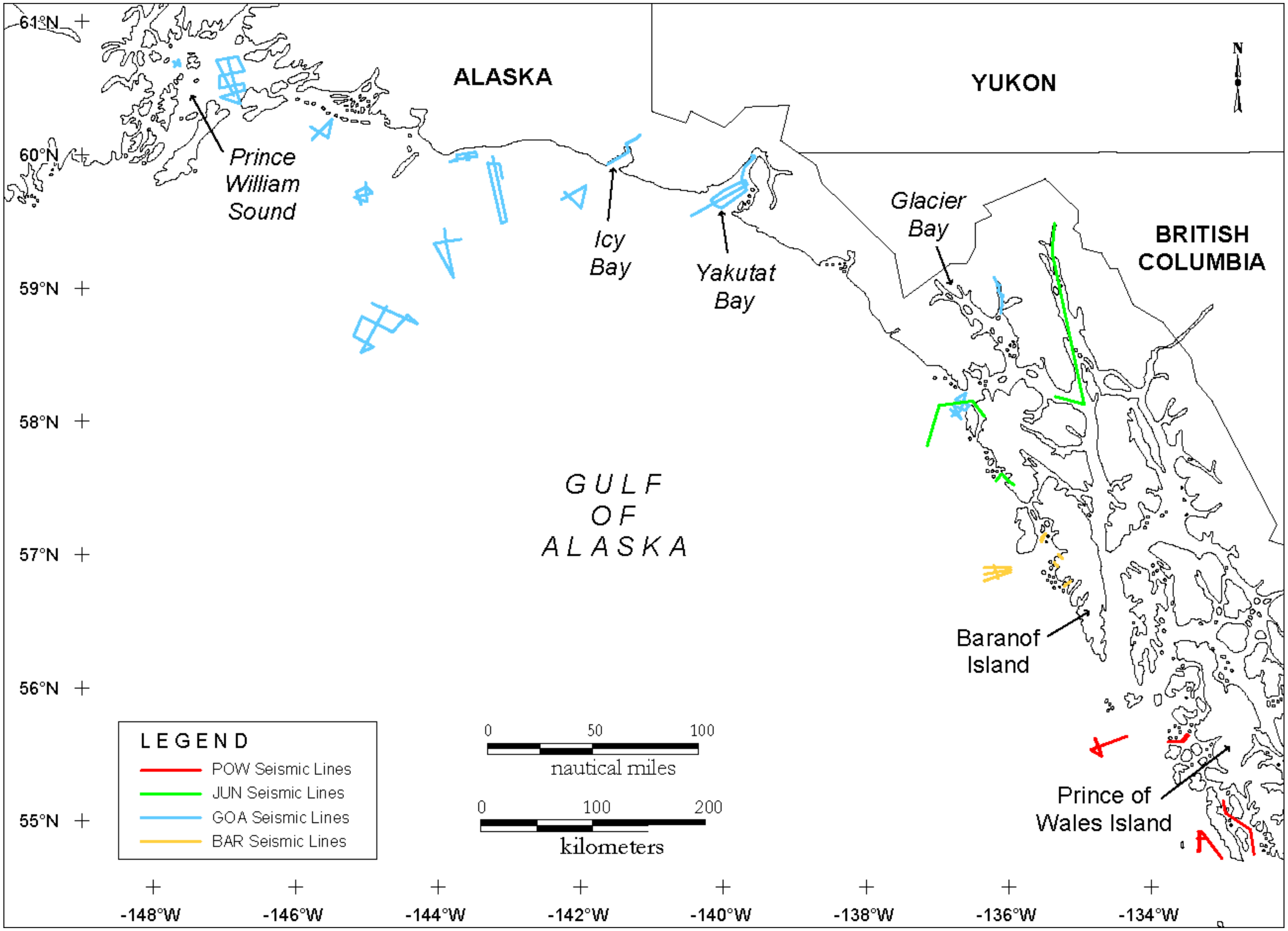

FIGURE 1. Proposed location of survey areas. Seismic lines include those during Stage 1 (POW = Prince of Wales Island), Stage 2 (BAR = Baranof Island), Stage 3 (JUN = Juneau), and Stage 4 (GOA = Gulf of Alaska). The different stages of the survey are described below.

long-term evolution of century-scale and perhaps even decadal-scale climate variations, and on the ecological responses to this natural climate variation. These climate variations may be analogous to regional oscillation of ocean conditions commonly known as the Pacific Decadal Oscillation (PDO).

The seismic survey will involve one vessel. The source vessel, the R/V *Maurice Ewing*, will deploy a pair of low-energy Generator Injector (GI) airguns as an energy source (each with a discharge volume of 105 in^3). The energy to the airguns will be compressed air supplied by compressors on board the source vessel.

The *Ewing* will also tow a hydrophone streamer that is up to 1500 m (4922 ft) long. As the airguns are operated along the survey lines, the hydrophone receiving system will receive and record the returning acoustic signals. In constrained fjord settings, only part of the streamer may be deployed, or a shorter streamer may be used, to increase the maneuverability of the ship.

The program will consist of ~1779 km (~960 n.mi.) of surveys, not including transits (Fig. 1). Water depths within the seismic survey area are ~30–3000 m (~98–9843 ft). There will be additional operations associated with airgun testing, start-up, line changes, and repeat coverage of any areas where initial data quality is sub-standard.

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 chief scientists are Dr. Alan Mix of Oregon State University and Dr. John Jaeger of the University of Florida. The vessel will be self-contained, and the crew will live aboard the vessel for the entire cruise.

Procedures to be used for the proposed seismic survey and associated marine mammal monitoring will be similar to those during previous seismic surveys by L-DEO, e.g., in the equatorial Pacific Ocean (Carbotte et al. 1998, 2000). The proposed program will use conventional seismic methodology using towed airguns as the energy source, and a towed hydrophone streamer as the receiver system.

In addition to the airguns, a multibeam bathymetric sonar and a low-energy 3.5 kHz sub-bottom profiler will be used during the seismic profiling and continuously when underway. While on station for coring, a 12-kHz pinger will be used to monitor the depth of coring devices relative to the sea floor. Three coring systems are to be used: the multicorer, a gravity corer, and a piston corer. The multicorer recovers 8 samples, each 10 cm in diameter and <1 m in length. The gravity corer recovers a single sample 10 cm in diameter and 3 m in length, and the piston corer recovers a sample 10 cm in diameter and up to 20 m in length. All systems are lowered to the sea floor on the deep sea winch and are designed to leave nothing in the ocean after recovery. Core samples are contained in PVC (gravity and piston corer) or polycarbonate plastic tubing (multicorer). There are a total of 30 planned coring sites throughout the study area in water depths ranging from 30 to 3000 m (98–9843 ft).

Vessel Specifications

The *Ewing* will be used as the source vessel for the airgun sounds. It will tow the 2 GI airguns and a streamer containing hydrophones along predetermined lines. The *Ewing* has four 1000 kW diesel generators that supply power to the ship. The ship is powered by four 800 hp electric motors that, in combination, drive a single 5-blade propeller in a Kort nozzle and a single-tunnel electric bow thruster rated at 500 hp. At the typical operation speed of 7.4–9.3 km/h (4–5 knots) during seismic acquisition, the shaft rotation speed is about 90 rpm. When not towing seismic survey gear, the *Ewing* cruises at 18.5–20.4 km/h (10–11 knots) and has a maximum speed of 25 km/h (13.5 knots). It has a normal operating range of about 31,484 km (17,000 n.mi.).

The *Ewing* will also serve as the platform from which vessel-based marine mammal observers will watch for mammals before and during airgun operations. The characteristics of the *Ewing* that make it suitable for visual monitoring are described in § XI, MITIGATION MEASURES.

Other details of the *Ewing* include the following:

Owner:	National Science Foundation
Operator:	Lamont-Doherty Earth Observatory of Columbia University
Flag:	United States of America
Date Built:	1983 (modified in 1990)
Gross Tonnage:	1978
Fathometers:	3.5 and 12 kHz hull mounted transducers; Furuno FGG80 Echosounder; Furuno FCU66 Echosounder Recorder
Bottom Mapping Equipment:	Atlas Hydrosweep DS-2, 15.5 kHz (details below)
Compressors for Air Guns:	LMF DC, capable of 1000 scfm at 2000 psi (scfm = standard cubic feet per minute)
Accommodation Capacity:	21 crew plus 3 technicians and 26 scientists

Airgun Description

Two GI airguns will be used from the *Ewing* during the proposed program. The 2 GI guns will be spaced ~7 m (23 ft) from midships on opposite sides of the midline (i.e., 14 m or 45.9 ft apart) and will be towed ~44.3 m (145 ft) behind the stern. The GI gun specifications are shown below.

GI Guns Specifications

Energy source	Two GI airguns of 105 in^3 each
Source output (downward)	0-pk is 7.2 bar-m (237 dB re 1 µPa-m); pk-pk is 14.0 bar-m (243 dB)
Towing depth of energy source	3 m (10 ft)
Air discharge volume	~210 in^3
Dominant frequency components	0–188 Hz
Gun positions used	Two side by side guns 7.8 m apart
Gun volumes at each position (in^3)	105, 105

The nominal downward-directed source levels indicated in the Table above do not represent actual sound levels that can be measured at any location in the water. Rather, they represent the level that would be found 1 m from a hypothetical point source emitting the same total amount of sound as is emitted by the combined airguns in the airgun array. The actual received level at any location in the water near the airguns will not exceed the source level of the strongest individual source. In this case, that will be about 231 dB re 1µPa-m peak, or 237 dB re 1µPa-m peak-to-peak. Actual levels experienced by any organism more than 1 m from either GI gun will be significantly lower.

A further consideration is that the rms (root mean square) received levels that are used as impact criteria for marine mammals are not directly comparable to the peak or peak to peak values normally used to characterize source levels of airgun arrays. The measurement units used to describe airgun sources, peak or peak-to-peak decibels, are always higher than the "root mean square" (rms) decibels referred to in biological literature. A measured received level of 160 decibels rms in the far field would typically correspond to a peak measurement of about 170 to 172 dB, and to a peak-to-peak measurement of about 176 to 178 decibels, *as measured for the same pulse received at the same location* (Greene 1997;

McCauley et al. 1998, 2000a). The precise difference between rms and peak or peak-to-peak values depends on the frequency content and duration of the pulse, among other factors. However, the rms level is always lower than the peak or peak-to-peak level for an airgun-type source.

The depth at which the sources are towed has a major impact on the maximum near-field output, because the energy output is constrained by ambient pressure. The normal tow depth of the sources to be used in this project is 3 m, where the ambient pressure is 3 decibars. This also limits output, as the 3 decibars of confining pressure cannot fully constrain the source output, with the result that there is loss of energy at the sea surface.

Additional discussion of the characteristics of airgun pulses is included in Appendix A (subpart c).

For the 2 GI airguns, the sound pressure field has been modeled by L-DEO in relation to distance and direction from the airguns, and in relation to depth. Predicted received sound levels are depicted in Figure 2. Table 1 shows the maximum distances from the airguns where sound levels of 190, 180, 170 and 160 dB re 1 μPa (rms) are predicted to be received.

Empirical data concerning the 180, 170 and 160 dB distances have been acquired based on measurements during the acoustic verification study conducted by L-DEO in the northern Gulf of Mexico from 27 May to 3 June 2003 (Tolstoy et al. 2004). Although the results are limited, the data showed that radii around the airguns where the received level would be 180 dB re 1 μPa (rms), the safety criterion applicable to cetaceans (NMFS 2000), varies with water depth. Similar depth-related variation is likely in the 190 dB distances applicable to pinnipeds. The proposed study area will occur in water ~30–3000 m (<98–9843 ft).

- The empirical data indicate that, for ***deep water*** (>1000 m or 3281 ft), the L-DEO model tends to overestimate the received sound levels at a given distance (Tolstoy et al. 2004). However, to be precautionary pending acquisition of additional empirical data, it is proposed that safety radii during airgun operations in deep water will be the values predicted by L-DEO's model (Table 1).
- The 180- and 190-dB radii were not measured for the 2 GI guns operating in ***shallow water*** (<100 m or 328 ft). However, the measured 180 dB radius for the 6-airgun array operating in shallow water was 6.8x that predicted by L-DEO's model for operation of the 6-airgun array in deep water. The conservative correction factor is applied to the model estimates to predict the radii for the 2 GI guns in shallow water (Table 1).
- Empirical measurements were not conducted for ***intermediate depths*** (100–1000 m or 328–3281 ft). On the expectation that results will be intermediate between those from shallow and deep water, a 1.5x correction factor is applied to the estimates provided by the model for deep water situations (Table 1). This is the same factor that was applied to the model estimates during L-DEO cruises in 2003.

Description of Operations

The GOA cruise will consist of four different stages of seismic surveys interspersed with coring operations in four general areas. The different stages are outlined below in the order that they are currently planned to take place. Transit time between areas and between lines is not included in the estimates of survey time below, because the seismic source will generally not be operating during transits.

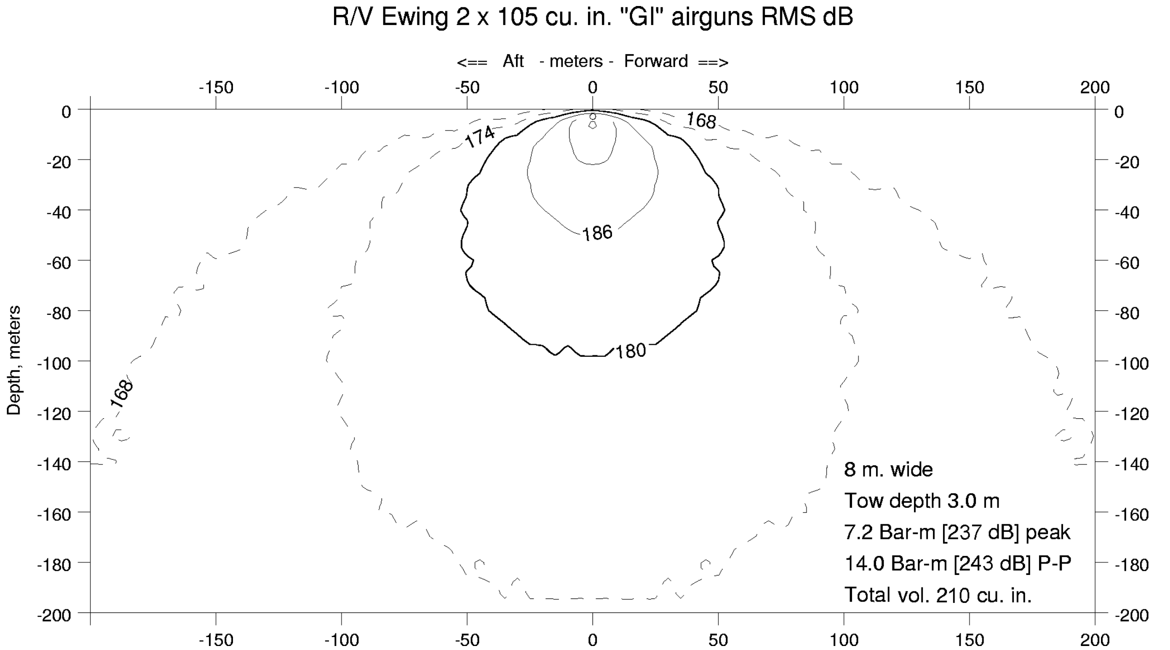

FIGURE 2. Modeled received sound levels from the two 105 in^3 GI airguns that will be used during the L-DEO survey in the GOA during 2004. The model does not allow for bottom interactions, so is most directly applicable to deep-water situations.

TABLE 1. Estimated distances to which sound levels ≥190, 180, 170 and 160 dB re 1 µPa (rms) might be received from two 105 in^3 GI guns that will be used during the seismic survey in the GOA during 2004. Distance estimates are given for operations in deep, intermediate, and shallow water. The 180- and 190-dB distances are the safety radii to be used during the survey.

Water depth	Estimated Distances at Received Levels (m)			
	190 dB	180 dB	170 dB	160 dB
>1000 m	17	54	175	510
100–1000 m	26	81	263	765
<100 m	250	400	750	1500

Stage 1 Prince of Wales Island.—During the Prince of Wales Island stage, four short seismic surveys will be completed in conjunction with four coring sites that will be sampled (Fig. 3; Table 2). Each of the four surveys, including seismic lines and coring, will take 9–14 hr and cover 17.7–45.3 n.mi. (32.9–83.8 km). A total of 13 lines will be shot around the four coring stations. Stage 1 will take ~50 hr of survey time over ~3 days to complete.

***Stage 2 Baranof Island*.—**During the Baranof Island stage, five short seismic surveys will be completed in conjunction with six coring sites that will be sampled (Fig. 3; Table 2). Each of the five surveys, including seismic lines and coring, will take ~6–17 hr and cover 4.1–54.5 n.mi. (7.6–101.0 km). Stage 2 will take ~45 hr of survey time over ~4.5 days to complete.

***Stage 3 Juneau (Southeast Alaska Inland Waters)*.—**During Stage 3, three short seismic surveys will be completed in conjunction with four coring sites that will be sampled (Fig. 3; Table 2). Each survey, including seismic lines and coring, will take ~8–21 hr and will cover 15.1–104.1 n.mi. (27.7–192.9 km). Stage 3 will take ~38 hr of survey time over 2.5 days to complete.

***Stage 4 Glacier Bay, Yakutat Bay, Icy Bay, Prince William Sound, and Gulf of Alaska*.—**During Stage 4, 14 seismic surveys will be conducted in conjunction with 16 coring sites that will be sampled (Figs. 3–5; Table 2). Surveys during Stage 4, including seismic lines and coring, will range in length from 5.3 to 111.2 n.mi. (9.8–205.9 km). Stage 4 will take ~172 h or survey time over ~13 days to complete.

***Contingency Sites*.—**In the event that one or more of the planned sites are unavailable due to poor weather conditions, ice conditions, unsuitable geology (shallow sediments), or other reasons, contingency sites (alternative seismic survey and coring locations) will be substituted. Contingency sites (Fig. 6) will only be considered in lieu of the planned sites, and their use will not substantially change the total length or duration of the proposed seismic surveys. Seismic survey lines have not been selected or plotted (in Fig. 6) for some contingency core sites. However, it is anticipated that each contingency core site would require ~40 km (22 n.mi.) of seismic surveying to locate optimal coring locations. It is highly unlikely that all contingency sites will be used. To the extent that contingency sites are used, a similar number of "primary" sites will be dropped from the project.

Bathymetric Sonar, Sub-bottom Profiler, and Pinger

Along with the airgun operations, three additional acoustical systems will be operated during much or all of the cruise. The ocean floor will be mapped with a multibeam bathymetric sonar, and a 3.5 kHz sub-bottom profiler will also be used. These two systems are commonly operated simultaneously with airguns. During coring operations, a 12 kHz pinger will be used to monitor the depth of coring devices relative to the sea floor.

TABLE 2. Planned total seismic survey lengths and number of coring stations by project stage (=region), shown in the order they are expected to occur, and the approximate number of days required to complete each stage.

Stage	Number of Survey Lines	Total Length of Survey Lines	Number of Coring Stations	Estimated Number of Days
1. Prince of Wales Island	13	229 km	4	4
2. Baranof Island	12	109 km	6	5
3. Juneau	8	249 km	4	4
4. Gulf of Alaska	101	1192 km	16	16

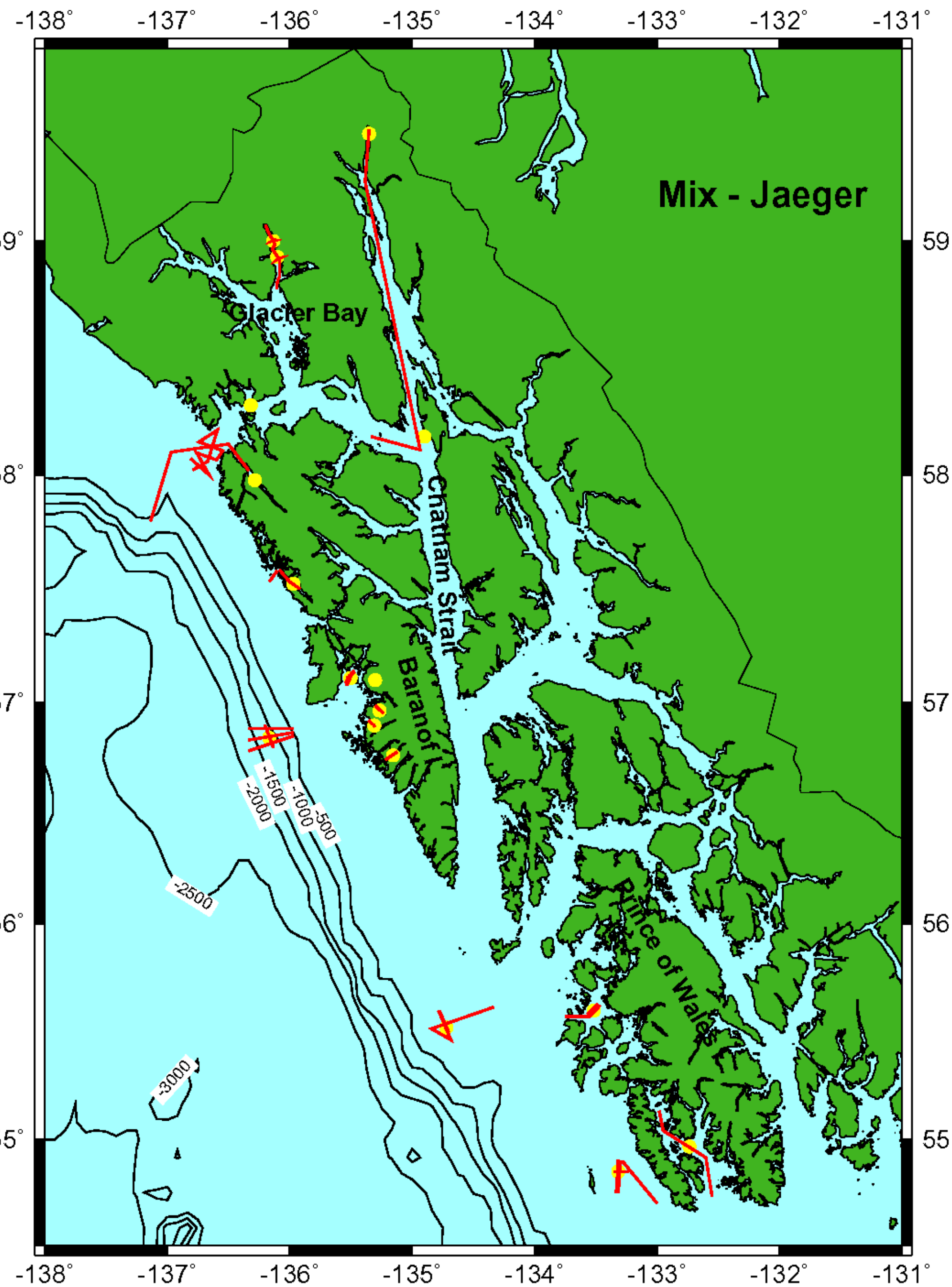

FIGURE 3. Survey lines near Prince of Wales (Stage 1) and Baranof (Stage 2) islands, and in inland waters in Southeast Alaska (Stage 3). Yellow dots represent planned coring locations.

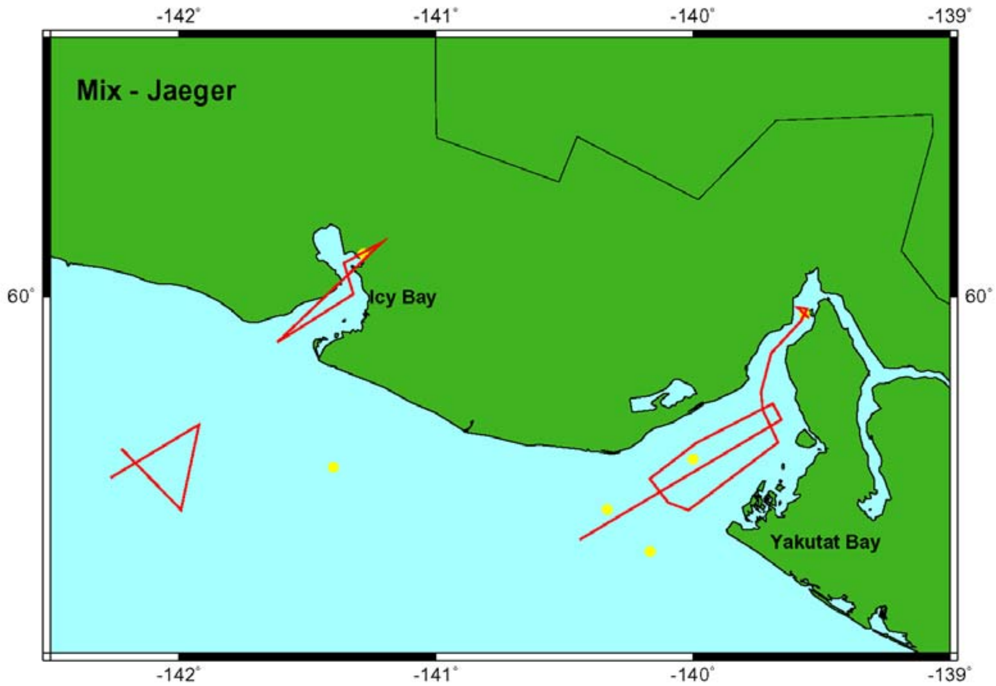

FIGURE 4. Proposed survey lines for Stage 4 in and near Icy and Yakutat bays. Yellow dots represent planned coring locations.

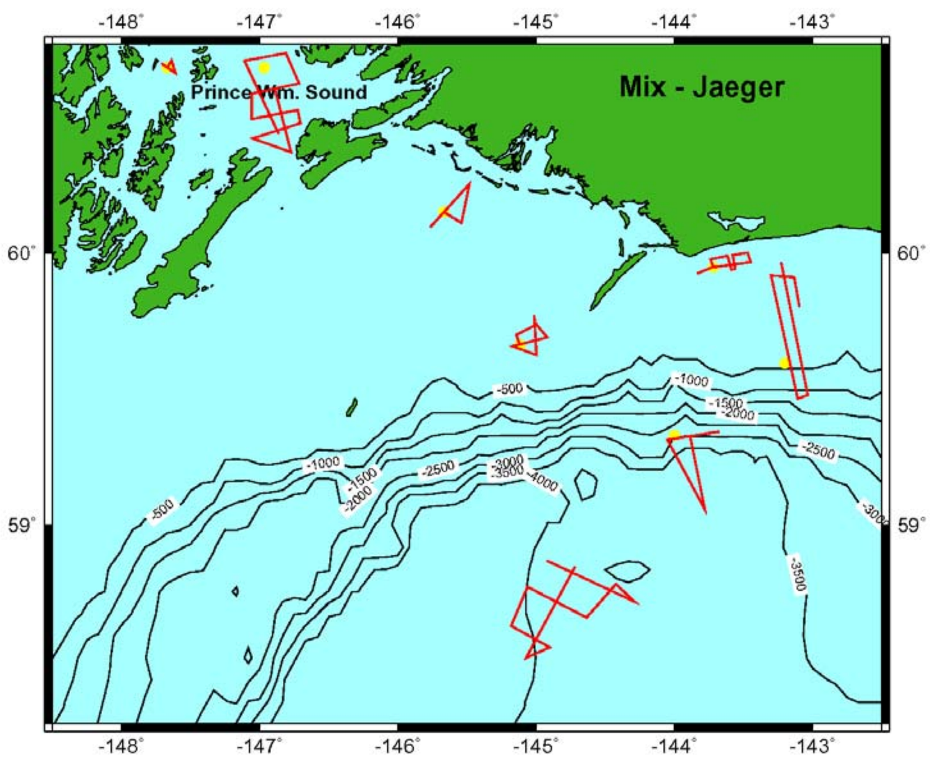

FIGURE 5. Proposed survey lines for Stage 4 in and near Prince William Sound and in the Gulf of Alaska. Yellow dots represent planned coring locations.

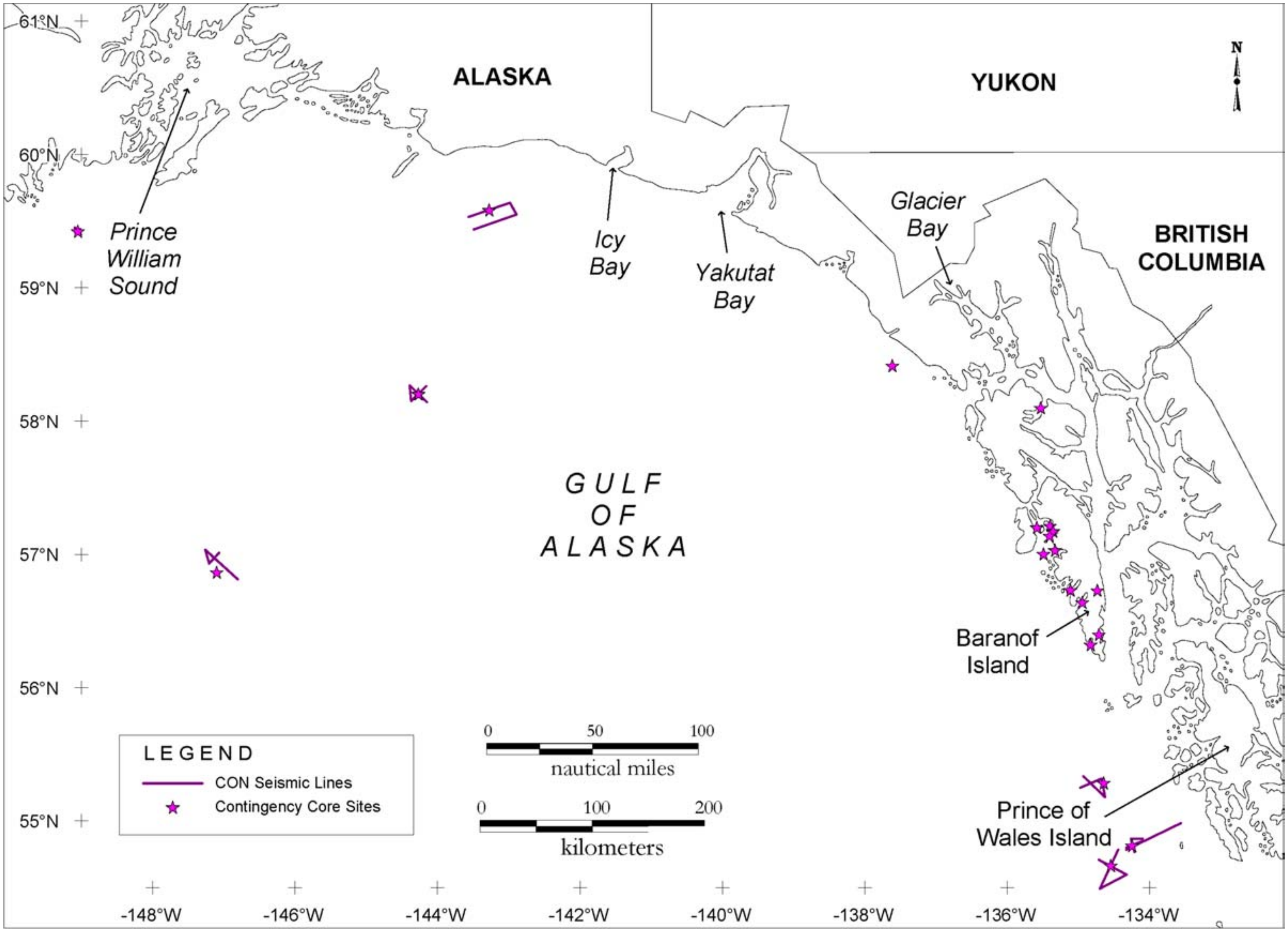

FIGURE 6. Contingency survey lines and coring sites. Seismic lines are not included for all contingency coring sites. It is anticipated that ~40 km or 22 n.mi. of seismic surveying will be required to determine the optimal coring location for each contingency coring site.

Bathymetric Sonar

Atlas Hydrosweep*.—**This 15.5 kHz sonar is mounted in the hull of the *Ewing*, and it operates in three modes, depending on the water depth. There is one shallow water mode and there are two deep-water modes: an Omni mode and a Rotational Directional Transmission mode (RDT mode). ***(1) When water depth is <400 m, the source output is 210 dB re 1 μPa·m rms and a single 1-millisecond pulse or "ping" per second is transmitted, with a beam width of 2.67 degrees fore-aft and 90 degrees athwartship. The beam width is measured to the –3 dB point, as is usually quoted for sonars. ***(2)*** The Omni mode is identical to the shallow-water mode except that the source output is 220 dB rms. The Omni mode is normally used only during start up. ***(3)*** The RDT mode is normally used during deep-water operation and has a 237 dB rms source output. In the RDT mode, each "ping" consists of five successive transmissions, each ensonifying a beam that extends 2.67 degrees fore-aft and ~30 degrees in the cross-track direction. The five successive transmissions (segments) sweep from port to starboard with minor overlap, spanning an overall cross-track angular extent of about 140 degrees, with tiny (<<1 millisec) gaps between the pulses for successive 30-degree segments. The total duration of the "ping", including all five successive segments, varies with water depth, but is 1 millisec in water depths <500 m and 10 millisec in the deepest water. For each segment, ping duration is $1/5^{th}$ of these values or $2/5^{th}$ for a receiver in the overlap area ensonified by two beam segments. The "ping" interval during RDT operations depends on water depth and varies from once per second in <500 m (1640.5 ft) water depth to once per 15 seconds in the deepest water. During the proposed project, the Atlas Hydrosweep will generally be used in waters >800 m deep.

***EM1002 Portable Sonar*.—** The EM1002 is a compact high-resolution multibeam echo sounder that operates at a frequency of 92 to 98 kHz in water depths from 10 to 800 m (33–2625 ft). The EM1002 will be used instead of the Atlas Hydrosweep in waters <800 m deep. The EM1002 will be pole mounted on the *Ewing*, either over the side or through a well. The system operates with one of three different pulselengths: 0.2, 0.7 and 2 ms. Pulselength increases with increased water depth. Overall angular coverage of the transmitted beam is 3 degrees along the fore-aft axis and 150 degrees (7.4 times the water depth) along the cross-track axis when operating in the shallowest mode. Maximum ping rate is 10 per second (in shallow water) with the ping rate decreasing with increasing water depth. Maximum output using long pulses in 800 meters water depth is 226 dB re 1 μPa at one meter, although operations in shallower depths, including most of the work in these surveys, will use significantly lower output levels.

Sub-bottom Profiler

***EDO sub-bottom profiler*.—**The sub-bottom profiler is normally operated to provide information about the sedimentary features and the bottom topography that is simultaneously being mapped by the bathymetric sonar. The energy from the sub-bottom profiler is directed downward by a 3.5 kHz transducer mounted in the hull of the *Ewing*. The output varies with water depth from 50 watts in shallow water to 800 watts in deep water. Pulse interval is 1 second but a common mode of operation is to broadcast five pulses at 1-s intervals followed by a 5-s pause.

***ODEC Bathy 2000P "chirp" sonar*.—**This sonar may be used instead of the EDO sub-bottom profiler. This sonar transmits a 50 ms pulse during which the frequency is swept from 4 to 7 kHz. The transmission rate is variable from 1 to 10 seconds, and the maximum output power is 2 kW. This sonar uses a transducer array very similar to that used by the 3.5 kHz sub-bottom profiler described below.

3.5 kHz Sub-bottom Profiler Specifications

Maximum source output (downward)	204 dB re 1 µPa at 800 watts
Normal source output (downward)	200 dB re 1 µPa at 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 1ms
Nominal beam width	30 degrees
Pulse duration	1, 2, or 4 ms

12 kHz Pinger

The 12 kHz Pinger will be used only during coring operations, to monitor the depth of the coring apparatus relative to the sea floor. The pinger is a battery-powered acoustic beacon that is attached to a wire just above the corehead. The pinger produces an omnidirectional 12 kHz signal with a source output of 193 dB re 1µPa at one meter. The pinger produces a 2 ms pulse every second.

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 cruise is presently scheduled to take place for ~34 days, in a time frame between late July and October 2004. The specific dates depend on ship availability and other factors. The earliest date when the *Ewing* may be ready to depart from port is on or about 26 July, but a departure date as late as September is possible. The vessel will transit directly from port to Prince of Wales Island, where the seismic survey will commence (Figs. 1 & 3). Seismic surveys will occur intermittently for ~13 days over the course of the cruise. Seismic surveys will alternate with core sampling at ~30 locations. The streamer will be recovered at the end of each seismic survey, but may remain deployed between seismic lines when the airguns may not be firing. The general schedule and port of embarkation may vary (within the late summer/early autumn period) because of ship availability and other factors. The specific schedule and sequence of operations may vary because of weather conditions and uncertainties associated with repositioning, streamer operations and adjustments, airgun deployment, or the need to repeat some lines if data quality is substandard.

The seismic survey is planned to occur within the GOA, in an area located between 54º and 61ºN and 132º and 148ºW (Fig. 1). Operations will be conducted in the territorial waters and Exclusive Economic Zone (EEZ) of the U.S.A.

III. Species and Numbers of Marine Mammals in Area

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

A total of 18 cetacean species, 3 species of pinnipeds, and the sea otter are known to or may occur in Southeast (SE) Alaska (Table 3; Rice 1998; Angliss and Lodge 2002). Several of the species are listed as

TABLE 3. The habitat, abundance, and conservation status of marine mammals inhabiting the proposed study area in Southeast Alaska and the Gulf of Alaska. Abundance estimates are also given for the Northeastern Pacific Ocean (NPO) or the U.S. West Coast (USWC).

Species	Habitat	Abundance (Alaska)	Abundance (NPO, USWC, or other)	ESA[1]	IUCN[2]	CITES[3]
Odontocetes						
Sperm whale (*Physeter macrocephalus*)	Usually pelagic and deep seas	N.A	24,000 [4]	Endangered*	VU	I
Cuvier's beaked whale (*Ziphius cavirostris*)	Pelagic	N.A.	20,000 [5] 1884 [6]	Not listed	DD	II
Baird's beaked whale (*Berardius bairdii*)	Pelagic	N.A.	6000 [7] 228 [6]	Not listed	LR-cd	I
Stejneger's beaked whale (*Mesoplodon stejnegeri*)	Likely pelagic	N.A	N.A	Not listed	DD	II
Beluga whale (*Delphinapterus leucas*)	Coastal and ice edges	435 [23]	N.A.	Not listed	VU	II
Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)	Offshore and inshore	26,880 [8]	59,274 [6]	Not listed	LR-lc	II
Risso's dolphin (*Grampus griseus*)	Offshore and inshore, >400m	N.A.	16,066 [6]	Not listed	DD	II
Killer whale (*Orcinus orca*)	Widely distributed	1069 [9]	8500 [10]	Not listed	LR-cd	II
Short-finned pilot whale (*Globicephala macrorhynchus*)	Inshore and offshore	N.A.	160,200 [5] 304 [6]	Not listed	LR-cd	II
Harbor Porpoise (*Phocoena phocoena*)	Coastal and inland waters	10,508 [11] 21,451 [12]	28,967 [10]	Not listed	VU	II
Dall's Porpoise (*Phocoenoides dalli*)	Shelf and pelagic	417,000 [13]	98,617 [6]	Not listed	LR-cd	II
Mysticetes						
North Pacific right whale (*Eubalaena japonica)*	Coastal and continental shelf	N.A.	<100 [10].	Endangered*	EN	I
Gray whale (*Eschrichtius robustus*) (eastern Pacific population)	Coastal, lagoons	N.A.	26,000 [14]	Not listed	LR-cd	I
Humpback whale (*Megaptera novaeangliae*)	Mainly near-shore waters and banks	404 [15]	>6000 [10]	Endangered*	VU	I

Species	**Habitat**	**Abundance (Alaska)**	**Abundance (NPO, USWC, or other)**	**ESA[1]**	**IUCN[2]**	**CITES[3]**
Minke whale (*Balaenoptera acutorostrata*)	Continental shelf, coastal waters	936 [16]	1015 [6]	Not listed	LR-cd	I
Sei whale (*Balaenoptera borealis*)	Primarily offshore, pelagic	N.A.	7260-12,620 [10,17] 56 [6]	Endangered*	EN	I
Fin whale (*Balaenoptera physalus*)	Continental slope, mostly pelagic	N.A.	8520-10,970 [10,18] 3279 [6]	Endangered*	EN	I
Blue whale (*Balaenoptera musculus*)	Pelagic and coastal	N.A.	1400-1900 [19] 3000 [20]	Endangered*	EN	I
Pinnipeds						
Northern fur seal (*Callorhinus ursinus*)	Pelagic, Breeds coastally	N.A.	941,756 [21]	Not listed	VU	N.A.
Steller sea lion (*Eumetopias jubatus*)	Coastal	16,674 [13]	31,028 [21]	Threatened† Endangered‡	EN	N.A.
Harbor seal (*Phoca vitulina richardsi*)	Coastal	37,450 [11] 29,175 [12]	N.A.	Not listed	N.A.	N.A.
Mustelids						
Sea otter (*Enhydra lutris*)	Coastal	12,632 [11] 16,552 [22]	N.A.	Not listed	EN	II

N.A. means data not available.
[1] Endangered Species Act
[2] IUCN Red List of Threatened Species (2003). Codes for IUCN classifications: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; LR = Lower Risk (-cd = Conservation Dependent; -nt = Near Threatened; -lc = Least Concern); DD = Data Deficient.
[3] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2004).
[4] Abundance estimate for eastern temperate North Pacific (Whitehead 2002).
[5] Abundance in the Eastern Tropical Pacific (Wade and Gerrodette 1993).
[6] Abundance off California/Oregon/Washington (Barlow 2003).
[7] Abundance in Western North Pacific (Reeves and Leatherwood 1994).
[8] Abundance estimate for GOA (Buckland et al. 1993a).
[9] Includes 723 Resident and 346 Transient (Angliss and Lodge 2002).
[10] Carretta et al. (2002).
[11] Abundance estimate for SE Alaska stock (Angliss and Lodge 2002).
[12] Abundance estimate for GOA stock (Angliss and Lodge 2002).
[13] Abundance estimate for GOA (Angliss and Lodge 2002).
[14] Abundance estimate for eastern Pacific (Hobbs and Rugh 1999).
[15] SE Alaska feeding aggregation (Straley et al. 1995).
[16] Abundance estimate for central Bearing Sea (Angliss and Lodge 2002).
[17] Abundance in NPO (Tillman 1977).

[18] Abundance in NPO (Ohsumi and Wada 1974).
[19] Abundance in NPO (Klinowska 1991).
[20] Abundance for California/Oregon/Washington (Calambokidis and Barlow 2004).
[21] Abundance for NPO (NOAA 2004).
[22] Abundance estimate Southcentral Alaska (Angliss and Lodge 2002).
[23] Abundance estimate Cook Inlet stock (Hobbs et al. 2000).
* Listed as a strategic stock under the U.S. Marine Mammal Protection Act.
† Eastern stock; listed as a strategic stock under the U.S. Marine Mammal Protection Act.
‡ Western stock; listed as a strategic stock under the U.S. Marine Mammal Protection Act.

"Endangered" under the ESA, including the humpback, sei, fin, blue, North Pacific right, and sperm whale. Also, the eastern stock of the Steller sea lion is listed under the ESA as "Threatened", and the western stock is listed as "Endangered". There is little information on the distribution of marine mammals inhabiting the waters offshore of SE Alaska or the eastern GOA, although a few reports are available (e.g., Buckland et al. 1993a; Hobbs and Lerczak 1993; Straley et al. 1995; Calambokidis et al. 1997; Angliss and Lodge 2002).

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

IV. Status, Distribution and Seasonal Distribution of Affected Species or Stocks of Marine Mammals

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

Sections III and IV are integrated here to minimize repetition.

A total of 18 cetacean species, 3 species of pinnipeds, and the sea otter are known to or may occur in SE Alaska (Table 3; Rice 1998; Angliss and Lodge 2002). The marine mammals that occur in the proposed survey area belong to four taxonomic groups: odontocetes (toothed cetaceans, such as dolphins), mysticetes (baleen whales), pinnipeds (seals and sea lions), and fissipeds (the sea otter). Cetaceans and pinnipeds are the subject of the IHA Application to NMFS. Of the 18 cetacean species in the area, several are common (see below). Of the three species of pinnipeds that could potentially occur in SE Alaska, only the Steller sea lion and harbor seal are likely to be present. The northern fur seal inhabits the Bering Sea during the summer and is generally found in SE Alaska in low numbers during the winter, and during the northward migration in spring. Sea otters (*Enhydra lutris*) generally inhabit coastal waters within the 40-m (131-ft) depth contour (Riedman and Estes 1990) and may be encountered in coastal areas of the study area. [The sea otter is the one marine mammal species mentioned in this document that, in the U.S.A., is managed by the U.S. Fish and Wildlife Service (USFWS); all others are managed by NMFS. Informal consultation from the USFWS is being sought for otters.]

Odontocetes

Sperm Whale (*Physeter macrocephalus*)

Sperm whales are the largest of the toothed whales, with an extensive worldwide distribution (Rice 1989). They range as far north and south as the edges of the polar pack ice, although they are most abundant in tropical and temperate waters where temperatures are >15ºC or 59ºF (Rice 1989). They generally occur in deep water, over and beyond the continental slope.

Sperm whales occur singly (older males) or in groups of up to 50 individuals. Christal et al. (1998) noted that typical social unit sizes ranged from 3 to 24 individuals. Sperm whale distribution is thought to be linked to social structure. Adult females and juveniles generally occur in tropical and subtropical waters, whereas males are commonly alone or in same-sex aggregations, often occurring in higher latitudes outside of the breeding season (Best 1979; Watkins and Moore 1982; Arnbom and Whitehead 1989; Whitehead and Waters 1990). Mature sperm whales begin to migrate to warmer waters to breed when they are in their late twenties (Best 1979), returning to colder waters to feed after the breeding season. They typically move between mixed schools, and only spend a short period of time with those groups (Whitehead 1993). Sperm whales are seasonal breeders, but the mating season is prolonged. In the Northern Hemisphere, conception may occur from January to August (Rice 1989), although the peak breeding season is from April to June (Best et al. 1984). Females bear a calf every 3–6 years (Rice 1989).

Sperm whales generally are distributed over large areas that have high secondary productivity and steep underwater topography (Jacquet and Whitehead 1996). They routinely dive to depths of hundreds of meters and may occasionally dive to depths of 3000 m or 9843 ft (Rice 1989). They are capable of remaining submerged for longer than two hours, but most dives probably last a half-hour or less (Rice 1989).

Sperm whales produce acoustic clicks when underwater, probably for locating prey and for communication (Backus and Schevill 1966; Møhl et al. 2003). In the Galapagos Islands, sperm whales started to click regularly when they were 150–300 m (492–984 ft) deep (Papastavrou et al. 1989), which may indicate that the sperm whales were echolocating for food at those depths (Backus and Schevill 1966; Weilgart and Whitehead 1988; Smith and Whitehead 1993). On the breeding grounds, mature males produce "slow clicks" (Whitehead 1993) in the frequency range 0.1–30 kHz (review by Thomson and Richardson 1995).

Most of the information regarding sperm whale distribution in the GOA and SE Alaska comes from anecdotal observations from fishermen and reports from fisheries observers aboard commercial fishing vessels (e.g., Dahlheim 1988). Fishery observers in 1997 and 1998 identified interactions between longline vessels and sperm whales in the GOA (Hill et al. 1999). They noted that most interactions occurred in the GOA to the east of Kodiak Island, even though there was substantial longline effort in waters to the west of Kodiak. Sperm whales were regularly sighted in waters off SE Alaska by fishery observers in 1997 and 1998 (Hill et al. 1999), and there are numerous reports of sperm whales in SE Alaska from the National Marine Mammal Laboratory's Platforms of Opportunity database (NMML unpublished data *in* Hill et al. 1999). Analysis of 64 photographs taken by fishery observers and fishermen has resulted in identification of 26 individual sperm whales that were associated with longline fishing vessels in 1997 and 1998 (Hill et al. 1999).

Commercial whaling severely reduced the abundance of sperm whales. Whitehead (2002) estimated that the worldwide stock was 32% of its original level in 1999, ten years after the end of large-scale hunting.

The sperm whale is the one species of odontocete discussed here that is listed under the ESA, and the one species of odontocete that is listed in CITES Appendix I (Table 3). Although the species is formally listed as ***Endangered*** under the ESA, it is a relatively common species on a worldwide basis, and is not biologically endangered.

Baird's Beaked Whale (*Berardius bairdii*)

Baird's beaked whales have a fairly extensive range across the North Pacific north of 35ºN, with concentrations apparently occurring in the Sea of Okhotsk and Bering Sea (Rice 1998; Kasuya 2002). Baird's beaked whales may be divided into three distinct stocks: a Sea of Japan stock, an Okhotsk Sea stock, and a Bering Sea/eastern North Pacific stock (Balcomb 1989; Reyes 1991).

Little is known about the abundance of Baird's beaked whales in the GOA and SE Alaska. Angliss and Lodge (2002) report that reliable estimates of abundance are unavailable, and therefore no minimum population estimation or population trend can be calculated. However, an estimated 6000 animals are thought to occur in the western North Pacific (Reeves and Leatherwood 1994; Kasuya 2002). Baird's beaked whales sometimes are seen close to shore, but their primary habitat is over or near the continental slope and oceanic seamounts in waters 1000–3000 m (3281–9843 ft) deep (Jefferson et al. 1993). Baird's beaked whales live in pods of 5 to 20 whales, although larger groups are sometimes seen. There appears to be a calving peak in March and April (Jefferson et al. 1993).

Cuvier's Beaked Whale (*Ziphius cavirostris*)

This cosmopolitan species is probably the most widespread of the beaked whales, although it is not found in polar waters (Heyning 1989). It appears to be absent from areas north of 60ºN and south of 50ºS (Würsig et al. 2000). Cuvier's beaked whales range north to the northern GOA, including SE Alaska (Rice 1998); however, no reliable estimates are available for the Alaska population (Angliss and Lodge 2002).

Cuvier's beaked whales are rarely found close to mainland shores, except in submarine canyons or in areas where the continental shelf is narrow and coastal waters are deep (Carwardine 1995). Mostly pelagic, this species appears to be confined to waters warmer than 10°C and deeper than 1000 m or 3281 ft (Houston 1991; Robineau and di Natale 1995). Cuvier's beaked whales typically dive for 20–40 min. Their inconspicuous blows, deep-diving behavior, and tendency to avoid vessels may help explain the rarity of sightings. Adult males usually travel alone, but Cuvier's beaked whales can be seen in groups of up to 25 individuals. Calves appear to be born year-round (Würsig et al. 2000).

Cuvier's beaked whale is mostly known from strandings (Leatherwood et al. 1976; NOAA and USN 2001). There are more recorded strandings for Cuvier's beaked whale than for any other beaked whale (Heyning 1989). Causes of most specific strandings are unknown, but they likely include old age, illness, disease, pollution, exposure to certain strong noises, and perhaps geomagnetic disturbance. Mass strandings of Cuvier's beaked whales are rare (although individual strandings are quite common), with only seven documented cases of more than four individuals stranding between 1963 and 1995 (Frantzis 1998). Several additional mass strandings have been documented subsequently in association with sources of strong noise (see § VII, later).

Stejneger's Beaked Whale (*Mesoplodon stejnegeri*)

The Stejneger's beaked whale is endemic to the cold waters of the North Pacific, Sea of Japan, and Bering Sea (Angliss and Lodge 2002). The Stejneger's beaked whale is the only mesoplodont species known to occur in Alaskan waters, occurring from SE Alaska through the Aleutian Chain, and the central

Bering Sea. There are currently no reliable estimates of the abundance of the Alaskan stock of Stejneger's beaked whales (Angliss and Lodge 2002). Small groups of Stejneger's beaked whales travel together and may dive and surface in unison (Carwardine 1995).

Beluga Whale (*Delpinapterus leucas*)

Beluga whales are distributed in seasonally ice-covered seas throughout the northern hemisphere (Gurevich 1980). In Alaska, beluga whales comprise five distinct stocks: Beaufort Sea, eastern Chukchi Sea, eastern Bering Sea, Bristol Bay, and Cook Inlet (O'Corry-Crowe et al. 1997). It is assumed that all of these beluga whale populations, other than the Cook Inlet stock, overwinter in the Bering Sea and are segregated only during the summer (Shelden 1994). Cook Inlet belugas are isolated from other stocks throughout the year, and are considered to be the most genetically isolated of the five Alaskan sub-populations (O'Corry-Crowe et al. 1997). Cook Inlet belugas may also show some morphological differences and are reported to be larger than individuals of other Alaskan populations (Murray and Fay 1979; Huntington 2000).

Estimates of the size of the Cook Inlet beluga population over the last several decades have ranged from 300 to 1300 whales. From 1994 to 1998, the Cook Inlet beluga population apparently declined from an estimated 653 to 347 whales (Hobbs et al. 2000). It is likely that an uncontrolled and excessive Native hunt to supply the Anchorage, Alaska market for traditional foods caused the most recent decline. The harvest is now limited to 2 whales per year, and the population may have stabilized. However, there is concern about a relatively high number of beluga strandings noted in Cook Inlet during 2003.

Pod structure in beluga groups appears to be along matrilineal lines, with males forming separate aggregations. Small groups are often observed traveling or resting together. The relationships between whales within or between groups are not known, although hunters have reported that belugas form family groups with whales of different ages traveling together (Huntington 2000).

Recently, a group of belugas has been seen in Yakutat–Disenchantment Bay, within 1 km of the tidewater Hubbard Glacier terminus (Hubbard et al. 1999). Belugas were also documented in Yakutat Bay in May 1976, and Alaska Natives from Yakutat Bay have observed belugas near streams on the northwest side of the bay, primarily in August and September, when coho salmon are present (Hubbard et al. 1999). Aerial surveys for other marine mammal species near Yakutat Bay have only sporadically reported belugas. Researchers believe that the belugas occasionally seen there are visitors from the Cook Inlet population, rather than permanent residents of Yakutat Bay (Hubbard et al. 1999).

Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*)

The Pacific white-sided dolphin is found throughout the temperate North Pacific, north of the coasts of Japan and Baja California Sur (Rice 1998). The species is common on both the high seas and along the continental margins, and animals are known to enter the inshore passes of SE Alaska, British Columbia, and Washington (Leatherwood et al. 1984; Dahlheim and Towell 1994; Ferrero and Walker 1996). Some seasonal shifts are known to occur, in rough synchrony with movements of prey (Leatherwood et al. 1984). Two stocks are identified in North America: the North Pacific and the California/Oregon/Washington stock (Angliss and Lodge 2002). Pacific white-sided dolphins in SE Alaska are of the North Pacific stock.

Pacific white-sided dolphins form large herds, averaging 90 individuals, but groups of more than 3000 individuals are known (Van Waerebeek and Würsig 2002). Pacific white-sided dolphins are acrobatic and frequently approach vessels to "bow ride" (Van Waerebeek and Würsig 2002).

Buckland et al. (1993a) estimated a total of 931,000 Pacific white-sided dolphins, rangewide, from surveys conducted in the North Pacific. While there have been no comprehensive surveys for Pacific white-sided dolphins in Alaska, the portion of the Buckland et al. (1993a) estimate derived from GOA waters (26,880) is used as an estimate of the population size in the GOA (Angliss and Lodge 2002). Dahlheim and Towell (1994) encountered 85–1331 Pacific white-sided dolphins during their surveys through inland waters of SE Alaska in 1991–1993. During small cetacean surveys in the GOA in 1997, a single group of 164 Pacific white-sided dolphins was seen off Dixon Entrance (R. Hobbs pers. comm. *in* Angliss and Lodge 2002).

Risso's Dolphin (*Grampus griseus*)

Risso's dolphin is primarily a tropical and mid-temperate species that is distributed worldwide. Risso's dolphins are pelagic, mostly occurring in steep, shelf edge habitats in waters 400 to 1000 m (1312 to 3281 ft) deep (Baumgartner 1997; Davis et al. 1998). They occur between 60ºN and 60ºS, where surface water temperatures range from ~7.5 to 35ºC (Kruse et al. 1999). In California, increasing numbers of Risso's dolphins, and a shoreward shift in their distribution, have been observed during periods of warm water (Kruse et al. 1999). Barlow (2003) estimated the abundance of Risso's dolphin off California/Oregon/Washington at 16,066, from surveys conducted in 1996 and 2001. Surveys for Risso's dolphins have not been conducted in the GOA or SE Alaska.

Risso's dolphins occur individually or in groups normally ranging from two to <250 individuals, although groups as large as 4000 have been sighted (Baird 2002). The majority of groups consist of <50 individuals (Kruse et al. 1999). They use sounds that range from 0.1 to 8 kHz and ultrasounds up to 65 kHz (review by Thomson and Richardson 1995).

Killer Whale (*Orcinus orca*)

Killer whales are cosmopolitan, occurring from equatorial regions to the polar pack-ice and are fairly abundant globally. They are most common in high latitudes, especially in cooler areas where productivity is high. The greatest abundance is thought to occur within 800 km (432 n.mi.) of major continents (Mitchell 1975). Killer whales are known to inhabit almost all coastal waters of Alaska, extending from the Chukchi and Bering Seas, along the Aleutian Islands, the GOA, and SE Alaska.

Killer whales are segregated socially, genetically, and ecologically into three distinct groups: residents, transients, and offshore animals. Resident groups feed exclusively on fish, whereas transients feed exclusively on marine mammals. Offshore killer whales are less known, and their feeding habits are not strictly defined. Killer whale movements generally appear to follow the distribution of prey.

Killer whales are large and conspicuous, often traveling in close-knit matrilineal groups of a few to tens of individuals (Dahlheim and Heyning 1999). Sightings range from the surf zone to the open sea, though usually within 800 km (432 n.mi.) of shore. Killer whales appear to prefer coastal areas, but are also known to occur in deep water (Dahlheim and Heyning 1999; Springer et al. 2003).

Killer whales are capable of hearing high-frequency sounds, which is related to their use of high-frequency sound for echolocation (Richardson 1995). They produce whistles and calls in the frequency range of 0.5–25 kHz (review by Thomson and Richardson 1995), and their hearing ranges from below 500 Hz to 120 kHz (Hall and Johnson 1972; Bain et al. 1993).

Matkin et al. (1997) noted that three resident killer whale pods inhabit SE Alaskan waters, and 13 resident pods have been identified as regular to rare visitors in Prince William Sound (PWS). Two transient assemblages, the AT1 group and GOA transients, are seen in SE Alaska and PWS. Little is known about the offshore killer whales in the GOA, but few offshore killer whales are likely to be encountered during the proposed survey.

Recently, NMFS proposed to list the AT1 group of transient killer whales in PWS as depleted, pursuant to the MMPA (NOAA 2003). AT1 killer whales have been recognized in PWS and Resurrection and Aialike bays since at least 1978 (Leatherwood et al. 1984; Saulitas 1993). The AT1 group once had as many as 22 members, but was reduced to 9 members after the Exxon Valdez Oil Spill (EVOS). No new calves have been observed since the AT1 group was recognized in 1984.

Short-finned Pilot Whale (*Globicephala macrorhynchus*)

The short-finned pilot whale can be found in tropical and warm temperate waters (Leatherwood and Reeves 1983; Bernard and Reilly 1999), and is a vagrant visitor as far north as the Alaska Peninsula. The short-finned pilot whale is mainly pelagic and occurs in moderately-deep waters (Davis et al. 1998). It is usually found in waters with a depth of ~1000 m (3281 ft), where it feeds on squid. It is generally nomadic, but may be resident in certain locations, including California and Hawaii (Olson and Reilly 2002). Changes in the distribution of the short-finned pilot whale are likely influenced by the distribution of its prey. The species is very social and is usually seen in large groups of up to 60 animals. Pilot whale pods are composed of individuals with matrilineal associations (Olson and Reilly 2002). Pilot whales are also known to strand frequently. This species produces whistles with dominant frequencies of 2–14 kHz (review by Thomson and Richardson 1995).

Harbor Porpoise (*Phocoena phocoena*)

The harbor porpoise is a small odontocete that inhabits temporal, subarctic, and arctic waters. There is also an isolated, remnant population in the Black Sea. In the eastern North Pacific, harbor porpoises range from Point Barrow, Alaska, to Point Conception, California. Harbor porpoises have small, stocky bodies that help them limit heat loss in the cold northern waters. The harbor porpoise primarily inhabits coastal waters, although sightings have been made over deeper waters between land masses (Bjørge and Tolley 2002).

Harbor porpoises are normally found in small groups of up to 3 animals that often contain at least one mother-calf pair. Larger groups of 6 to 8 animals are not uncommon, and rarely, much larger aggregations are seen. Harbor porpoises surface quickly, rarely leaping out of the water.

Dahlheim et al. (2000) investigated the abundance of harbor porpoises in Alaska from Bristol Bay to SE Alaska from 1991 to 1993. In 1993, they surveyed 8573 km (4629 n.mi.) and encountered 105 groups (131 animals). They estimated that 3982 harbor porpoises occurred between Dixon Entrance and PWS in June. The density of harbor porpoises in their survey area was estimated at 40.2 groups/1000 km^2, with an average group size of 1.22.

Dall's Porpoise (*Phocoenoides dalli*)

Dall's porpoise is only found in the North Pacific and adjacent seas. It is widely distributed across the North Pacific Ocean over the continental shelf and slope waters, and over deep (>2500 m or 8203 ft) oceanic waters (Hall 1979). Its distribution extends from southern California and southern Japan to ~65°N (Buckland et al. 1993a). The only apparent gaps in distribution in Alaskan waters south of Bering Strait are for upper Cook Inlet and the Bering Sea shelf.

Dall's porpoises are most commonly found in small groups of 20 to 30 individuals; larger groups of several hundred to ~1000 are rarely seen. Very little is known about group structure, except that group composition is probably fluid (Jefferson 2002). They are fast-swimming and active porpoises, and readily approach vessels to ride the bow wave. They have also been seen to "snout ride" (Jefferson 2002) the wave pushed forward by the heads of large whales. Turnock and Quinn (1991) suggested that, because Dall's porpoise has a tendency to approach vessels, this has resulted in inflated abundance estimates, perhaps by as much as 5 times. This species is often seen traveling quickly along the surface, creating a V-shaped splash known as a rooster tail.

Dall's porpoises calve in the summer, but some calves probably are born outside that season as well. Gestation lasts ~10–12 months, and lactation lasts up to a year.

Mysticetes

North Pacific Right Whale (*Eubalaena japonica*)

The North Pacific right whale is ***Endangered*** under the ESA, and 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). Based on sighting data, Wada (1973) estimated a total population of 100 to 200 in the North Pacific. Rice (1974) stated that only a few individuals remained in the eastern North Pacific stock. A reliable estimate of abundance is not available, but is likely less than 100.

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 eastern North Pacific, south of 50ºN, only 29 reliable sightings were recorded from 1900 to 1994 (Scarff 1986, 1991; Carretta et al. 1994). There have been several recent sightings of right whales in the North Pacific in recent years. In 1996, a group of 3 to 4 right whales that may have included a juvenile animal was seen in western Bristol Bay (Goddard and Rugh 1998). During July 1997, a group of 4 to 5 right whales was seen in Bristol Bay, followed the next morning by another sighting of 4 to 5 right whales in approximately the same place (Tynan 1999 *in* Angliss and Lodge 2002). During July 1998, 1999 and 2000, six, five, and eight right whales were seen, respectively, in the southwestern Bering Sea (LeDuc et al. 2000 and W. Perryman *in* Angliss and Lodge 2002). During these photographic surveys, only 14 individuals were photographed, but at least two whales were photographed in more than one year; this is indicative of a very small population (Angliss and Lodge 2002).

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). The wintering areas for that population 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). Historical records indicate that whalers took right whales in Baja California, as far south as the Bay of San Sebastian Viscaino, and Cerros Island (Scammon 1968). Two right whales were observed east of Guadalupe Island in April 1856, and another two were observed south of Punta Abreojos in March 1965.

Considering the rarity of right whale sightings, and the generally restricted area in which sightings in Alaska have been made, it is highly unlikely that any right whales will be seen during the proposed surveys.

Gray Whale (*Eschrichtius robustus*)

The eastern gray whale population ranges from the Chukchi and Beaufort seas to the Gulf of California (Rice 1998). Gray whales are found primarily in shallow water, and usually remain closer to shore than any other large cetacean. Most of the eastern Pacific population makes a round-trip annual migration of more than 18,000 km (9719 n.mi.). From late May to early October, the majority of the population concentrates in the northern and western Bering Sea and in the Chukchi Sea. However, some individuals spend the summer months scattered along the coasts of SE Alaska, British Columbia, Washington, Oregon, and northern California (Rice and Wolman 1971; Darling 1984; Nerini 1984; Calambokidis et al. 2002). Calambokidis et al. (2002) report the results of a collaborative study to photo-identify a feeding aggregation of gray whales from California to SE Alaska in 1998. They completed one survey near Sitka in November 1998 and identified four unique gray whales, one of which had been identified in previous years off Washington. A few gray whales were seen during summer (July to August) surveys from the Kenai Peninsula to the central Aleutian Islands in 2001 (A. Zerbini pers. comm.).

It is difficult to determine precisely when the southbound migration begins; whales near Barrow were moving predominantly south in August (Maher 1960; Braham 1984). Gray whales leave the Bering Sea through Unimak Pass from late October through January (Braham 1984). From October to January, the main part of the population moves down the west coast of North America. Rugh et al. (2002) analyzed data collected from two sites in California to estimate the timing of the gray whale southward migration. They estimated that the median date for the migration past various sites was 1 December in the central Bering Sea (a nominal starting point), 12 December at Unimak Pass, AK, 18 December at Kodiak Island, AK, and 5 January for Washington. There have been no systematic surveys for gray whales migrating past sites in SE Alaska. However, based on Braham (1984) and Rugh et al. (2002), it can be assumed that the first southward migrants will occur in SE Alaska in late October or November, with the peak of the gray whale migration in SE Alaska sometime between mid-December and early January, after the proposed survey ends. By January and February, most of the whales are concentrated in the lagoons along the Pacific coast of the Baja Peninsula, Mexico. From late February to June, the population migrates northward to arctic and subarctic seas (Rice and Wolman 1971).

Gray whales have been counted as they migrate southward past Granite Canyon in central California each year since 1967. The highest population estimate of 26,635 was derived from counts during the 1997/98 southward migration (Angliss and Lodge 2002). However, surveys conducted from December 2001 to March 2002 resulted in an abundance estimate of 17,414 (Rugh 2004). The lower encounter rate in 2001–2002 may be a result of fewer whales migrating as far south as Granite Canyon, where the surveys took place, or an actual decline in abundance following high mortality in 1999 and 2000 (Rugh 2004). Gray whale numbers increased steadily until at least 1998, with an estimated annual rate of growth of 3.29% between 1967 and 1988 (Buckland et al. 1993b). Recent reductions in abundance estimates may be a function of this population reaching its carrying capacity (Rugh 2004). The gray whale was removed from the endangered species list in 1994.

Humpback Whale (*Megaptera novaeangliae*)

The humpback whale has a near-cosmopolitan distribution, occurring in all ocean basins from Disko Bay in northern Greenland to the pack-ice zone around Antarctica (Rice 1998). Although it is considered a mainly coastal species, it often traverses deep pelagic areas while migrating. Its migrations between high-latitude summering grounds and low-latitude wintering grounds are reasonably well known (Winn and Reichley 1985). The worldwide population of humpback whales is divided into northern and southern ocean populations (Mackintosh 1965). The population size of the North Pacific humpback whale stock is estimated at more than 6000 individuals (Calambokidis et al. 1997; Angliss and Lodge 2002), but under the ESA provisions, it is officially considered an ***Endangered*** species. The central

North Pacific stock was estimated as 4005 by Calambokidis et al. (1997). Three feeding areas have been identified for the central North Pacific stock: SE Alaska, PWS, and Kodiak Island. The SE Alaska feeding aggregation was estimated to be 404 individuals (Straley et al. 1995), and the PWS feeding aggregation was estimated to be <200 (Waite et al. 1999). Waite et al. (1999) identified 127 individuals in the Kodiak area from 1991 to 1994, and calculated a total abundance estimate of 651 for the Kodiak region.

The humpback whales of Glacier Bay National Park and Preserve (GBNPP) have been monitored each year since 1985 to document the number of individuals, residence times, spatial and temporal distribution, reproductive parameters, feeding behavior, and human/whale interactions (Doherty and Gabriele 2001). Site fidelity to the Glacier Bay area appears to be high; ~70% of the whales identified in the Glacier Bay area have been resighted in the Glacier Bay-Icy Strait area (Gabriele 1995). The number of whales using Glacier Bay and Icy Strait annually from 1985 to 2001 ranged from 41 to 104 (Doherty and Gabriele 2001). The number of whales using Glacier Bay typically peaks in July and August, with lower counts in May and September. Park Service personnel do not routinely survey some parts of the bay, including the East Arm, so it is likely that the presence of whales in that part of the bay is underreported. Humpbacks typically move between Glacier Bay/Icy Strait and other areas of SE Alaska (Baker 1986; Baker et al. 1990; Straley 1994, 1995).

Rice and Wolman (1981) encountered 190 humpbacks in 90 groups during their surveys in 1980, although only 14 sightings were made during census transects, precluding an abundance estimate. They encountered small aggregations at Yakutat Bay, Cape St. Elias to Middleton Island, the Barren Islands, and PWS. Zerbini et al. (2003) sighted 263 and 207 humpback whales during surveys from the Kenai Peninsula to the central Aleutian Islands in 2001 and 2002, respectively. They estimated the abundance of humpback whales in the northern GOA and Aleutian Islands at 2037 (95% CI 1491–2781). Waite (2003) reported that 117 humpbacks were seen in 41 groups during their surveys in the northern GOA in 2003.

Humpback whales are often sighted singly or in groups of two or three, but while in their breeding and feeding ranges, they may occur in groups of up to 15 (Leatherwood and Reeves 1983). Humpback whale feeding has been studied in great detail in GBNPP. Whales in GBNPP typically feed alone or in pairs, primarily on small schooling fishes such as capelin *Mallotus villosus*, juvenile walleye pollock *Theragra chalcogramma*, sand lance *Ammodytes hexapterus*, and Pacific herring *Clupea herengus pallasi* (Wing and Krieger 1983; Krieger and Wing 1984). Whales in GBNPP tend to feed below the surface. Lunge feeding, bubblenet feeding, and other surface feeding modes were commonly seen in the 1970s (Jurasz and Palmer 1979) but are now rarely seen (Baker 1985; Gabriele 1995). The results of diet studies conducted during commercial whaling operations identified a wide range of prey species for humpbacks in the North Pacific (Frost and Lowry 1981).

There appears to be considerable within and between year variability in humpback whale prey availability in SE Alaska (Vequist and Baker 1987). The distribution and abundance of humpback whale prey species varies both spatially and temporally and is probably affected by many physical and biological factors. It is likely that humpback whale abundance and occupancy time in SE Alaska is driven by the variability in prey availability.

Sexual maturity is reached at about 5 years (Clapham 2002). Females usually give birth to one calf every 2 years, although annual calving is also known to occur (Clapham and Mayo 1990; Glockner and Ferrari 1990). Gestation lasts ~11 months, and most calves are born during mid-winter (at low latitudes Clapham 2002).

Humpback whale males sing long, complex songs on their wintering grounds (Payne and McVay 1971). The songs are shared by all singing whales while on the breeding grounds. The songs may serve to attract reproductive females or may be a form of competitive behavior with other whales. Humpback songs have been recorded on feeding grounds in Stellwagen Bank in the North Atlantic (Mattila et al. 1987) and in SE Alaska (McSweeney et al. 1989). Songs appear to be rare in summer, but increase in frequency in fall, and are heard in pelagic waters as whales make their migration to wintering grounds (Mattila et al. 1987). The songs heard on the summering grounds are generally condensed versions of songs heard during the winters surrounding the summer feeding season. The function of songs on the summer feeding grounds is unknown.

Humpback whales have also been recorded uttering stylized rhythmic vocalizations identified as "feeding calls" (Jurasz and Jurasz 1979) and "cries" while feeding cooperatively in SE Alaska (Cerchio and Dahlheim 2001). The cries may play a role in prey manipulation (Baker 1985), creating a broad band of frequencies to which their prey may be sensitive. Humpback whales produce sounds in the frequency range of 20 Hz–8.2 kHz, although songs have dominant frequencies of 120–4000 Hz (review by Thomson and Richardson 1995).

Minke Whale (*Balaenoptera acutorostrata*)

Minke whales are small baleen whales that inhabit all oceans of the world from the high latitudes to near the equator (Leatherwood et al. 1982). Two minke whale stocks are recognized in U.S. waters, the Alaskan stock and the California/Oregon/Washington (COW) stock (Angliss and Lodge 2002). There are no population estimates for the Pacific population as a whole or the Alaskan stock. However, an estimate of 936 minke whales was made for the central Bering Sea during July–August 1999 (Moore et al. 2000), but that is not specifically relevant to the present study area.

Minke whales are relatively common in the Bering and Chukchi seas and in the inshore waters of the GOA (Mizroch 1992), but they are not considered abundant in any other part of the eastern Pacific (Bruggeman et al. 1990). In the Northern Hemisphere, minke whales are usually seen in coastal areas, but can be seen in pelagic waters during northward migrations in spring and summer, and southward migration in autumn (Stewart and Leatherwood 1985).

Low numbers of minke whales are seen regularly around Glacier Bay in SE Alaska (Gabriele and Lewis 2000). Sightings were concentrated in Sitakaday Narrows and in central Icy Strait. One minke was sighted north of Strawberry Island, and there are anecdotal reports of minke whales in the upper West Arm of GBNPP (Gabriele and Lewis 2000). The number of individual minke whales seen in Glacier Bay varied from 5 to 8 in 1996–1999 (Gabriele and Lewis 2000). Zerbini et al. (2003) sighted 31 and 20 minke whales during surveys from the Kenai Peninsula to the central Aleutians in 2001 and 2002, respectively. They estimated the abundance of minke whales in the northern GOA and Aleutian Islands to be 595 (95% CI 443–746). Waite (2003) reported that 4 minke whales in 3 groups were seen during surveys in the northern GOA in 2003.

Minke whales are relatively solitary, but may occur in aggregations of up to 100 animals when food resources are concentrated. 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). Detection of minke whales with listening devices is unreliable. A large variety of sounds, ranging in frequency from 60 Hz to 12 kHz, has been attributed to minke whales (Stewart and Leatherwood 1985; Edds-Walton 2000; Mellinger et al. 2000; Gedamke et al. 2001).

Females attain sexual maturity at ~7 years and males are sexually mature at 6 years (Stewart and Leatherwood 1985). Females give birth every year with gestation lasting ~10 months and calving typically occurring from November to March (Sergeant 1963).

Sei Whale (*Balaenoptera borealis*)

The sei whale has a nearly-cosmopolitan distribution, with a marked preference for temperate oceanic waters (Gambell 1985a). In the eastern Pacific, sei whales range in the summer from the Bering Sea and the northern GOA to the coast of southern California. Winter sightings have been made between southern Baja California and the Islas Revilla Gigedo (Rice 1998). Sei whale populations were depleted by whaling, and their current status is generally uncertain (Horwood 1987). The sei whale is listed as ***Endangered*** under the ESA.

In the open ocean, sei whales generally migrate from temperate zones occupied in winter to higher latitudes in the summer, where most feeding takes place (Gambell 1985a). Sei whales are mainly pelagic, and usually occur in small groups of up to six individuals. They tend to make shallow dives and surface relatively frequently. They apparently produce sounds in the range of 1.5–3.5 kHz, though few data on their calls are available (review by Thomson and Richardson 1995).

Fin Whale (*Balaenoptera physalus*)

Fin whales are widely distributed in all the world's oceans (Gambell 1985b), but typically occur in temperate and polar regions. They appear to have complex seasonal movements, and are likely seasonal migrants (Gambell 1985b). Fin whales mate and calve in temperate waters during the winter, but migrate to northern latitudes during the summer to feed (Mackintosh 1965 *in* Gambell 1985b). The North Pacific population summers from the Chukchi Sea to California, and winters from California southwards (Gambell 1985b).

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. Fin whales are typically observed alone or in pairs, but on feeding grounds, up to 20 individuals can occur together.

Shore-based whaling stations operated at Akutan in the Aleutian Islands and Port Hobron, on the west side of Kodiak Island, Alaska from 1912 to 1939 and 1926 to 1937, respectively. Reeves et al. (1985) compiled information from unpublished records of the American Pacific Whaling Company, and a variety of other sources, concerning the catch from these stations. They report that most fin whales were taken in the Bering Sea, but from Port Hobron, most catches occurred east of Kodiak Island, and catches were higher during summer (June–August) than early or late in the season.

Rice and Wolman (1981) encountered 19 fin whales during surveys in the GOA, including 10 animals aggregated near Middleton Island on 1 July 1980. Recent information about the seasonal distribution of fin whales in the North Pacific has been obtained from the reception of fin whale calls by bottom-mounted, offshore hydrophone arrays along the U.S. Pacific coast, in the central North Pacific, and in the western Aleutian Islands (Moore et al. 1998; Watkins et al. 2000a,b). There was a peak in the number of calls received near the Alaska Peninsula in the western GOA (Site 7; Moore et al. 1998) in May–August, with few calls through the rest of the year. Calls were received relatively uniformly from July through September, with small peaks in November, February and May at the northern most site along the USWC (Site 5; Moore et al. 1998). The patterns of fin whale call reception generally corresponded to seasonal productivity in the areas monitored by Moore et al. (1998).

The diving behavior of fin whales in the western North Atlantic was reviewed by Stone et al. (1992) with the objective of evaluating the likelihood of detection by aerial and shipboard surveys. Fin whales in their study area blew about 50 times per hour, and the average dive time was about 3 min. As fin whales do not usually remain submerged for long periods, have tall blows, have a conspicuous surfacing profile, and often occur in groups of several animals, they are less likely to be overlooked than most other species.

The distinctive 20-Hz pulses of fin whales, with source levels as high as 180 dB re 1 μPa, can be heard reliably to distances of several tens of kilometers (Watkins 1981; Watkins et al. 1987; Edds 1988; Cummings and Thompson 1994) or even further (Cummings and Thompson 1971; Payne and Webb 1971). Watkins (1981) believed that most fin whale responses to singers are at distances <15 km (8 n.mi.). Fin whales primarily emit their 20-Hz signals during their reproductive season from autumn to early spring. Watkins et al. (1987) believed that the repetitive signals are an acoustic display associated with reproduction, and Croll et al. (2002) report that it is the male fin whales that make strong calls. Fin whales also produce sounds at frequencies up to 150 Hz, including 34–75-Hz tones, a 129–150-Hz tone preceding 20-Hz sounds, and generally downsweeping pulses in the range 118–14 Hz (Watkins 1981; Cummings et al. 1986; Edds 1988). Watkins (1981) heard those sounds mostly during interactions of two or more whales, and speculated that the sounds were used to communicate with nearby whales. Fin whales >15–20 km (8–10.8 n.mi.) from one another apparently do not emit the higher-frequency sounds (Watkins 1981).

Probably at least in part because of their initially high abundance, wide distribution, and diverse feeding habits, fin whales seem not to have been as badly depleted as the other large whales in the North Pacific. However, the species is listed as ***Endangered*** under the ESA, and it is a CITES Appendix I species (Table 3).

Blue Whale (*Balaenoptera musculus*)

The blue whale is widely distributed throughout most of the world's oceans, occurring in coastal, shelf, and oceanic waters. The worldwide population has been estimated at 15,000 blue whales, with 10,000 in the Southern Hemisphere (Gambell 1976), 3500 in the North Pacific, and up to 1400 in the North Atlantic (NMFS 1998). Little is known about the movements and wintering grounds of the stocks (Mizroch et al. 1984). 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; Watkins et al. 2000a).

Generally, blue whales are seasonal migrants between high latitudes in the summer, where they feed, and low latitudes in winter, where they mate and give birth (Lockyer and Brown 1981). However, some individuals may stay in low or high latitudes throughout the year (Reilly and Thayer 1990; Watkins et al. 2000b). Little is known about the movements and wintering grounds of the stocks (Mizroch et al. 1984). However, broad-scale acoustic monitoring indicates that blue whales of the Northeast Pacific stock may range from the Eastern Tropical Pacific along the coast of North America to Canada, and offshore at least 500 km or 270 n.mi. (Stafford et al. 1999, 2001).

Blue whales were hunted from shore-based whaling stations in Akutan on the Aleutian Islands and Port Hobron on the west of Kodiak Island from 1912 to 1939 and 1926 to 1937, respectively. Reeves et al. (1985) report that blue whales were caught primarily south of the Aleutian Islands from Akutan and to the east of Kodiak Island from Port Hobron. Soviet whaling fleets took large numbers of blue whales in the GOA, primarily from the northern and eastern parts of the Gulf, offshore of SE Alaska to east of Kodiak Island. From 1963 to 1965, Soviet whalers reportedly took 739 blue whales from the GOA, including 491 in 1963 alone (Doroshenko 2000).

Blue whales have been detected in the North Pacific by identifying stereotypic calls with offshore hydrophones (e.g., Stafford et al. 1998; Watkins et al. 2000a,b; Moore et al. 2002). Moore et al. (2002) reported that blue whale calls are received in the North Pacific year-round, indicating that this area is suitable habitat for blue whales year-round. However, the number of whales producing the calls remains unknown.

The distribution of the species, at least during times of the year when feeding is a major activity, is in areas that provide large seasonal concentrations of euphausiids, which are the blue whale's main prey (Yochem and Leatherwood 1985). One population feeds in the Northeast Pacific from June to November and migrates south in winter/spring (Calambokidis et al. 1990; Mate et al. 1999). During summer, blue whale call locations from the Northwest Pacific were closely associated with cold water and sharp sea surface temperature gradients or fronts, probably corresponding to zooplankton concentrations. From fall through spring, call locations were concentrated primarily near seamounts (Moore et al. 2002).

Blue whales usually occur alone or in small groups (Leatherwood and Reeves 1983; Palacios 1999). Blue whales attain sexual maturity at 5–15 years of age (Sears 2002). The lengths at sexual maturity for blue whales in the Northern Hemisphere are 21–23 m for females and 20–21 m for males, (Yochem and Leatherwood 1985). Blue whales calve and mate in the late fall and winter (Yochem and Leatherwood 1985). Females give birth in the winter to a single calf every 2–3 years (Sears 2002). The gestation period is usually estimated to be 10–12 months (Sears 2002).

Blue whales have a tall and conspicuous blow, and may lift their flukes clear of the surface before a deep dive. Dives can last from 10–30 min and are usually separated by a series of 10–20 shallow dives. Swimming speed has been estimated as 2–6.5 km/hr while feeding, and 5–33 km/hr while traveling (Yochem and Leatherwood 1985). The best-known sounds of blue whales consist of low-frequency “moans” and “long pulses”, which range from 12.5–200 Hz and can have source levels up to 188 dB re 1 µPa (Cummings and Thompson 1971).

All populations of blue whales have been exploited commercially, and many have been severely depleted as a result. The blue whale is listed as ***Endangered*** under the ESA and by IUCN, and is listed in CITES Appendix I (Table 3).

Pinnipeds

Steller Sea Lion (*Eumetopias jubatus*)

Steller sea lions occur in the coastal and immediate offshore waters of the North Pacific. In the western Pacific, they are distributed from the Bering Strait along the Aleutian Islands, the Kuril Islands, and the Okhotsk Sea to Hokkaido, Japan. In the eastern Pacific, they occur along the coast of North America south to the Channel Islands off Southern California (Rice 1998). Two stocks of Steller sea lions are recognized in Alaskan waters, based on differences in population dynamics (York et al. 1996) and mitochondrial DNA sequence distribution (Bickham et al. 1996). Cape Suckling (144º W longitude) forms the boundary between these two stocks, known as the Eastern and Western populations (Loughlin 1997). Steller sea lions are present in SE Alaska and the GOA year round. Aerial and ground based surveys suggest that the minimum population size of the Eastern stock of Steller sea lions, including animals in British Columbia, Washington, Oregon, and California, is 31,028 animals (Angliss and Lodge 2002). The minimum population estimate for the Western stock, not including animals from the Commander or Kuril Islands, is 35,595 (Angliss and Lodge 2002).

Critical habitat for Steller sea lions has been identified (50 CFR 226.202; see Fig. 7). This includes 14 sites (3 rookeries and 11 haulouts) in SE Alaska and 13 sites (2 rookeries and 11 haulouts) in the eastern GOA. Areas of critical habitat are more extensive for the ***Endangered*** Western stock than for the ***Threatened*** Eastern stock. Critical habitat includes land 3000 ft (0.9 km) inshore from the baseline or basepoint of each major rookery and major haulout in Alaska. It also includes waters 3000 ft (0.9 km) seaward in state- and federally-managed waters from every major rookery and haulout east of 144ºW, and 20 n.mi. (37 km) seaward from every major rookery and haulout west of 144ºW (50 CFR 226.202). In addition, "no approach" zones have been identified wherein no vessel may approach within 3 n.mi. (5.6 km) of listed rookeries. None of the "no approach" zones occur in the eastern GOA or SE Alaska where the proposed surveys will take place.

The Steller sea lion was declared a ***Threatened*** species throughout its range in 1990, and the Western stock was listed as ***Endangered*** in 1997 (Loughlin et al. 1992; 62 FR 30772). These determinations were a result of the precipitous decline in the Alaskan population from 140,000 in 1956 to 60–68,000 in 1985 (Merrick et al. 1987). Worldwide, the population dropped from 240,000–300,000 to 116,000 (Loughlin et al. 1992) during a 30-year period. The decline in numbers has been greatest for the Western stock, with some breeding rookeries in the Aleutians declining as much as 87% from 1960 to 1989 (Loughlin et al. 1992). The causes of the decline in the Western stock are not known. Several hypotheses, including food stress, direct human interaction, indirect effects from human activities, natural climactic variation, and long-term shifts due to past human activities have been proposed (see summary in NRC 2003; Springer et al. 2003).

There has not been a concomitant decline in the Eastern stock; the number of Steller sea lions in SE Alaska increased as much as 70% from 1960 to 1989 (Loughlin et al. 1992). The Eastern stock is still listed as threatened (Angliss and Lodge 2002) although Kruse et al. (2001) report that abundance of the Eastern stock may be the highest ever recorded, and that re-evaluation of the threatened listing is warranted.

Breeding adults occupy rookeries from late May to early July (NMFS 1992). Males become sexually mature at 3–7 years and physically mature around 10 years of age. Physically mature males may gain and hold a territory for up to 7 years (NMFS 1992). Females become sexually mature at 3–6 years and may produce young into their early 20s. Most females breed annually. Females frequently return to the same pupping site within the rookery in successive years, although the site may or may not be in the same territory within the rookery.

Pregnancy rates of mature females in the GOA in April–May 1985 was 60%, which is slightly lower than the 67% pregnancy rate recorded there in 1975–1978 (NMFS 1992). A decline in juvenile survival appears to be an important cause of the decline in the Western stock of Steller sea lions. Declines in the number of juvenile sea lions have been reported at many Alaskan rookeries and haulouts since the 1980s (Merrick et al. 1987; Loughlin et al. 1992). The ultimate causes of the decline in survivorship are not yet understood.

Steller sea lions haul out on beaches and rocky shorelines of remote islands, often in areas exposed to wind and waves (NMFS 1992). Haulouts are areas used by sea lions at times other than the breeding season. During the breeding season, adults use some haulouts as rookeries, where males establish territories, pups are born, and breeding occurs. Rookeries are generally found on gently sloping beaches that are protected from waves (NMFS 1992). There are three known rookeries in SE Alaska (Fig. 7): Hazy Island and White Sisters Island near Sitka, and Forrester Island near Dixon Entrance (Calkins et al. 1999). There are two known rookery sites near PWS, Seal Rocks and Wooded Island. Recently, up to 49

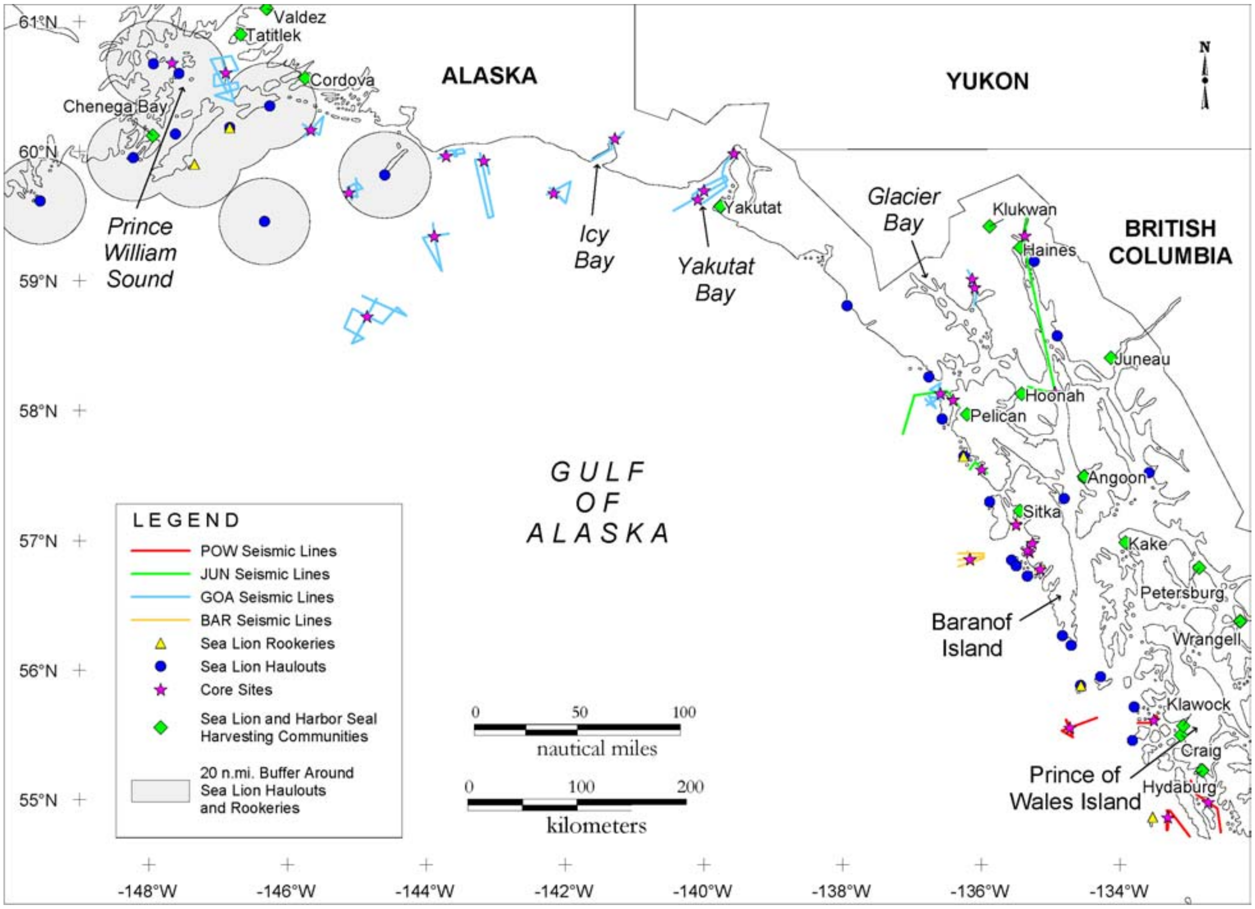

FIGURE 7. Steller sea lion rookeries and haulouts (all rookeries and major haulouts have critical habitat associated with them), and Steller sea lion and harbor seal harvesting communities near the planned seismic surveys in Southeast Alaska, the northern Gulf of Alaska, and Prince William Sound, Alaska.

pups have been seen in June on Graves Rocks along GBNPP's outer coast and this may be a new rookery (Raum-Suryan and Pitcher 2000; Raum-Suryan 2001). During the non-breeding season, sea lions may disperse great distances from the rookeries. Juvenile sea lions branded as pups on Forrester Island have been observed at South Marble Island in GBNPP (Mathews 1996), and some juveniles from the Western stock have been observed at South Marble Island and Graves Rocks in GBNPP (Raum-Suryan 2001).

Steller sea lions are an important subsistence resource for Alaska Natives from SE Alaska to the Aleutian Islands. Within and near the areas where L-DEO plans to operate, subsistence hunting occurs at low levels in 17 communities in SE Alaska, and at four communities along the northern GOA and PWS (Fig. 7). However, the modern harvest of sea lions in SE Alaska and PWS is small. In 2002, seven sea lions were taken in SE Alaska, and five were taken in the North Pacific Rim, including PWS (Wolfe et al. 2003). However, Imler and Sarber (1947) report that sea lions were harvested regularly in PWS in the 1940s. The sea lion harvest in SE Alaska peaks in October and March and is lowest in May through September. A list of Steller sea lion and harbor seal harvesting communities and the estimated harvest from those communities are shown in Table 4.

Northern Fur Seal (*Callorhinus ursinus*)

Northern fur seals are endemic to the North Pacific Ocean and occur from southern California to the Bering Sea and west to the Okhotsk Sea and Honshu Island, Japan. Two stocks are recognized in U.S. waters, the Eastern Pacific and the San Miguel Island stocks. The Eastern Pacific stock ranges from the Pribilof Islands and Bogoslof Island in the Bering Sea (summer range) to the Channel Islands in Southern California during winter. During the breeding season (June–September), ~70% of the world's population of northern fur seals occurs on the Pribilof Islands. The worldwide population of fur seals has declined from a peak of ~2.1 million in the 1950s to ~ 941,756 in 2000 (Angliss and Lodge 2002).

When not on rookery islands, northern fur seals are primarily pelagic but occasionally haul out on rocky shorelines. Adult females may migrate as far south as the Hawaiian Islands (NMML unpubl. data), but males are thought to remain in the North Pacific. Pups travel through Aleutian passes and spend the first two years at sea before returning to their islands of origin.

Northern fur seals were subject to large scale harvests on the Pribilof Islands to supply a lucrative fur trade, beginning with the discovery of the Pribilof Islands by Russian sealers in 1786. Prior to the 1940s, a few northern fur seals were harvested by Alaska Native hunters in the Sitka area, presumably as they passed during their spring migration to the Pribilof Islands. Currently northern fur seals are only harvested by Aleuts living on the Pribilof Islands.

Harbor Seal (*Phoca vitulina richardsi*)

Harbor seals range from Baja California, north along the western coasts of the United States, British Columbia, and SE Alaska, west through the GOA, PWS, and the Aleutian Islands, and north in the Bering Sea to Cape Newenham and the Pribilof Islands. Angliss and Lodge (2002) identified three stocks in Alaska: Southeast Alaska, GOA, and Bering Sea. They noted that recent genetic evidence indicated a need to reassess these boundaries. Angliss and Lodge (2002) estimate that there are 37,450 individuals in the Southeast Alaska stock, from the Alaska–Canada border to Cape Suckling. Small et al. (2003) report that harbor seal numbers increased significantly in the Ketchikan and Kodiak areas from 1983 to 2001, but were stable (no significant trends) in Sitka and Bristol Bay. However, harbor seal abundance has declined in some parts of Alaska (Frost et al. 1999; Pitcher 1990).

Harbor seals inhabit estuarine and coastal waters, hauling out on rocks, reefs, beaches, and glacial ice flows. They are generally non-migratory, but move locally with the tides, weather, season, food availability, and reproduction (Scheffer and Slipp 1944; Fisher 1952; Bigg 1969, 1981). Juvenile harbor seals can travel significant distances (525 km or 283 n.mi.) to forage or disperse, whereas adults were generally found within 190 km or 103 n.mi. of the tagging location (Lowry et al. 2001) in PWS. The smaller home range used by adults is suggestive of a strong site fidelity (Pitcher and Calkins 1979; Pitcher and McAllister 1981; Lowry et al. 2001). Female harbor seals give birth to a single pup while hauled out on shore or on glacial ice flows. In SE Alaska, pups are generally born in mid-June. The mother and pup remain together until weaning occurs at 3 to 6 weeks (Bishop 1967; Bigg 1969). Little is known about breeding behavior in harbor seals. When molting, which occurs primarily in late August, seals spend the majority of the time hauled out on shore, glacial ice, or other substrates.

Harbor seals are an important subsistence resource for Alaska Natives in SE Alaska and the northern GOA. In 2002, ~1007 harbor seals were taken in SE Alaska communities, including both harvested and "struck and lost" animals (Table 4). In addition, about 287 were taken in the northern GOA and PWS (Wolfe et al. 2003). The harbor seal harvest in SE Alaska is highest in October–December, with a smaller peak in March. Harbor seal harvest is lowest in May–August.

TABLE 4. The estimated 2002 harvest of harbor seals and Steller sea lions by Alaska Native communities near the study area in Southeast Alaska, the northern Gulf of Alaska, and Prince William Sound.

Village	Estimated total take [1] Harbor seal	Estimated total take [1] Steller sea lion	Peak of harbor seal harvest [2]
Southeast Alaska			
Angoon	74.9	0.0	November
Craig	44.6	0.0	December
Haines	45.8	0.0	November
Hoonah	102.4	0.0	October
Hydaberg	14.4	0.0	February – April
Juneau	18.7	0.0	November
Kake	108.7	0.0	September – December
Ketchikan	124.6	0.0	October and December
Klawock	24.0	1.0	March
Kukwan	0.0	0.0	
Pelican	1.8	0.0	October
Petersburg	63.0	0.0	December
Saxman	28.5	0.0	April and December
Sitka	189.0	6.0	November
Wrangell	29.0	0.0	April
Yakutat	137.5	0.0	March
Northern GOA and PWS			
Chenega Bay	10.5	0.0	August
Cordova	108.5	3.5	February
Tatilek	14.9	0.0	February and March [3]
Valdez	50.0	0.0	December

[1] Includes estimates of both harvested and struck-and-lost animals. Totals are estimated from incomplete household surveys and were multiplied by a correction factor for missed households, which results in fractional estimates rather than whole number counts.
[2] Maximum number harvested in 2002 reported by Wolfe et al. (2003).
[3] Peak harvest in 2000 (Wolfe 2001).

California Sea Lion (*Zalophus californianus*)

The California sea lion is found from southern Mexico to southwestern Canada, and occasionally to SE Alaska and PWS. The breeding areas of the California sea lion are on islands located in southern California, western Baja California, and the Gulf of California. Three stocks are recognized: (1) The U.S. stock begins at the U.S./Mexico border and extends north to Canada. (2) The Western Baja California stock extends from the U.S/Mexican border to the southern tip of Baja California. (3) The Gulf of California stock is in the Gulf of California from the southern tip of the peninsula and along the mainland coast, extending to southern Mexico (Lowry et al. 1992). The proposed survey area is outside of the California sea lion's normal range, and any California sea lions that might be seen would be considered extralimital.

The California sea lion population is growing at an annual rate of 5–6.2%. Recent population estimates range from 204,000 to 214,000 (Boveng 1988; Lowry et al. 1992; Lowry 1999). Sea lions are killed incidentally in set and drift-gillnet fisheries (Hanan et al. 1993; Barlow et al. 1994; Julian 1997; Julian and Beeson 1998; Cameron and Forney 1999). California sea lions are not listed as endangered or threatened under the ESA or as "depleted" under the MMPA.

Marine Fissipeds

Sea Otter (*Enhydra lutris*)

Before commercial exploitation, the worldwide population of sea otters was estimated to be between 150,000 (Kenyon 1969) and 300,000 (Johnson 1982). Sea otters occupied coastal areas from Hokkaido, Japan, around the North Pacific Rim to central Baja California, Mexico (Rotterman and Simon-Jackson 1988). Commercial exploitation reduced the total sea otter population to as low as 2000 animals in 13 locations (Kenyon 1969). In 1911, sea otters received protection under the North Pacific Fur Seal Convention, and sea otter populations recovered quickly (Kenyon 1969). Sea otters were reintroduced into SE Alaska from 1965 to 1969 when 412 otters were transplanted from Amchitka Island and PWS. There are currently an estimated 70,658 sea otters in three stocks in Alaskan waters: the southwestern stock with 41,474, the southcentral stock with 16,552, and the southeastern stock with 12,632 (Angliss and Lodge 2002). Doroff et al. (2003) reported that sea otters in the Aleutian archipelago declined by 75% between 1965 and 2000 (see also Estes et al. 1998; Springer et al. 2003). However, both the southeast and southcentral stocks of sea otters appear to be growing (Irons et al. 1988; Pitcher 1989; Agler 1995; Bodkin and Udevitz 1999). Several thousand sea otters were killed by the *Exxon Valdez* oil spill in 1989, and the detrimental effects of the spill may have persisted into the 1990s (Estes and Bodkin 2002).

Sea otters generally occur in shallow (<35 m or 115 ft), nearshore waters in areas with sandy or rocky bottoms where they feed on a wide variety of sessile and slow moving benthic invertebrates (Rotterman and Simon-Jackson 1988). Sea otters in Alaska are generally not migratory and do not disperse over long distances. Individual sea otters are capable of long-distance movements of >100 km or >54 n.mi. (Garshelis and Garshelis 1984), although movements are likely limited by geographic barriers, high energy requirements of animals, and social behavior.

Sea otters are harvested by Alaska Native hunters from SE Alaska to the Aleutian Islands. Sea otters harvested by Alaska Natives must be tagged by the USFWS. The USFWS keeps records of the number of tags issued, by each community. In SE Alaska and the GOA, a total of 7511 sea otters were harvested by 18 communities from 1988 to 2003. In 2003, a total of 536 sea otters were harvested in those communities (USFWS unpublished data). Although sea otters are harvested year-round in SE Alaska, there is decreased harvest effort during May–August.

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 MMPA for incidental take by harassment during its planned seismic survey in the GOA during late summer/early autumn 2004.

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 a bathymetric sonar, a sub-bottom profiler sonar, a pinger, 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 sonars. 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 in the general vicinity of the tracklines of the source vessel. No take by serious injury is anticipated, given the nature of the planned operations and the mitigation measures that are planned (see § XI, "MITIGATION MEASURES"). No lethal takes are expected.

VI. NUMBERS OF MARINE MAMMALS THAT MAY BE TAKEN

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

VII. ANTICIPATED IMPACT ON SPECIES OR STOCKS

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

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

- First we summarize the potential impacts on marine mammals of airgun operations, as called for in Section VII. A more comprehensive review of the relevant background information appears in Appendix A. That Appendix is little changed from corresponding parts of § VII in related IHA Applications previously submitted to NMFS concerning L-DEO projects in the following areas: northern Gulf of Mexico (2003 and planned 2004 projects), Hess Deep in the Eastern Tropical Pacific, Norway, Mid-Atlantic Ocean, Bermuda, Southeast Caribbean, and southern Gulf of Mexico (Yucatan Peninsula).
- Then we discuss the potential impacts of operations by L-DEO's bathymetric sonar, a sub-bottom profiler, and pinger.
- Finally, we estimate the numbers of marine mammals that might be affected by the proposed activity in the GOA in late summer/early autumn 2004. This section includes a description of the rationale for L-DEO's estimates of the potential numbers of harassment "takes" during the planned survey, as called for in Section VI.

(a) Summary of Potential Effects of Airgun Sounds

The effects of sounds from airguns might 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 effects (Richardson et al. 1995). Given the small size of the airgun array planned for the present project, its effects are anticipated to be considerably less than would be the case with a large array of airguns. It is very unlikely that there would be any cases of temporary or especially permanent hearing impairment, or non-auditory physical effects. Also, behavioral disturbance is expected to be limited to relatively short distances.

Tolerance

Numerous studies have shown that pulsed sounds from airguns are often readily detectable in the water at distances of many kilometers. For a summary of the characteristics of airgun pulses, see Appendix A (c). However, it should be noted that most of the measurements of airgun sounds that have been reported concerned sounds from larger arrays of airguns, whose sounds would be detectable farther away than those planned for use in the present project.

Numerous studies have shown that marine mammals at distances more than a few kilometers from operating seismic vessels often show no apparent response—see Appendix A (e). 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 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 and small odontocetes seem to be more tolerant of exposure to airgun pulses than are baleen whales. Given the relatively small and low-energy airgun source planned for use in this project, marine mammals are expected to tolerate being closer to this source than would be the case for a larger airgun source typical of most seismic surveys.

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 that. Some whales are known to continue calling in the presence of seismic pulses. Their calls can be heard between the seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999). Although there has been one report that sperm whales cease calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994), a more recent study reports that sperm whales off northern Norway continued calling in the presence of seismic pulses (Madsen et al. 2002). Given the small source planned for use here, there is even less potential for masking of baleen or sperm whale calls during the present study than in most seismic surveys. Masking effects of seismic pulses are expected to be negligible in the case of the smaller odontocete cetaceans, given the intermittent nature of seismic pulses and the relatively low source level of the airguns to be used here. Also, the sounds important to small odontocetes are predominantly at much higher frequencies than are airgun sounds. Masking effects, in general, are discussed further in Appendix A (d).

Disturbance Reactions

Disturbance includes a variety of effects, including subtle changes in behavior, more conspicuous changes in activities, and displacement. Based on NMFS (2001, p. 9293), 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. 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 the species as a whole. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on the animals 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 were present within a particular distance of industrial activities, or exposed to a particular level of industrial sound. That likely overestimates the numbers of marine mammals that are 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 on behavioral observations during studies of several species. However, information is lacking for many species. Detailed studies have been done on humpback, gray, and bowhead whales, and on ringed seals. Less detailed data are available for some other species of baleen whales, sperm whales, and small toothed whales. Most of those studies have concerned reactions to much larger airgun sources than planned for use in the present project. Thus, effects are expected to be limited to considerably smaller distances and shorter periods of exposure in the present project than in most of the previous work concerning marine mammal reactions to airguns.

Baleen Whales.— Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to pulses from large arrays of airguns at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, as reviewed in Appendix A (e), 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 case of the 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 determined that received levels of pulses in the 160–170 dB re 1 µPa rms[1] range seem to cause obvious avoidance behavior in a substantial fraction of the animals exposed. In many areas, seismic pulses from large arrays of airguns diminish to those levels at distances ranging from 4.5–14.5 km (2.4–7.8 n.mi.) from the source. A substantial proportion of the baleen whales within those distances may show avoidance or other strong disturbance reactions to the airgun array. Subtle behavioral changes sometimes become evident at somewhat lower received levels, and recent studies reviewed in Appendix A (e) 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. Reaction distances would be smaller during the present project, as a small 2 GI gun source will be used.

Humpback whales summering 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 on an approximate rms basis. Malme et al. (1985) concluded that there was no clear evidence of avoidance, despite the possibility of subtle effects, at

---

[1] The rms (root mean square) pressure is an average over the pulse duration. It is the measure commonly used in studies of marine mammal reactions to airgun sounds, and in NMFS guidelines concerning levels above which “taking” might occur. The rms level of a seismic pulse is typically about 10–12 dB less than its peak level (Greene 1997; McCauley et al. 1998, 2000a).

received levels up to 172 re 1 µPa (rms). More detailed information on responses of humpback whales to seismic pulses during studies in Australia can be found in Appendix A (a).

Data on short-term reactions (or lack of reactions) of cetaceans to impulsive noises do not necessarily provide information about long-term effects. It is not known whether impulsive noises affect reproductive rate or distribution and habitat use in subsequent days or years. However, gray whales continued to migrate annually along the west coast of North America despite intermittent seismic exploration and much ship traffic in that area for decades (Appendix A *in* Malme et al. 1984). Bowhead whales continued to travel to the eastern Beaufort Sea each summer despite seismic exploration in their summer and autumn range for many years (Richardson et al. 1987). Populations of both gray whales and bowhead whales grew substantially during this time. In any event, the brief exposures to sound pulses from the present small airgun source are highly unlikely to result in prolonged effects.

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 Appendix A have been reported for toothed whales. However, systematic work on sperm whales is underway.

Seismic operators sometimes see dolphins and other small toothed whales near operating airgun arrays, but in general there seems to be a tendency for most delphinids to show some limited avoidance of seismic vessels operating large airgun systems. However, 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. Nonetheless, there have been indications that small toothed whales sometimes move away, or maintain a somewhat greater distance from the vessel, when a large array of airguns is operating than when it is silent (e.g., Goold 1996a; Calambokidis and Osmek 1998; Stone 2003). Similarly, captive bottlenose dolphins and beluga whales exhibit changes in behavior when exposed to strong pulsed sounds similar in duration to those typically used in seismic surveys (Finneran et al. 2000, 2002). However, the animals tolerated high received levels of sound (pk–pk level >200 dB re 1 µPa) before exhibiting aversive behaviors. With the presently-planned small airgun system, such levels would only be found within a few meters of the airguns.

There are no specific data on the behavioral reactions of beaked whales to seismic surveys. A few beaked whale sightings have been reported from seismic vessels (Stone 2003). However, most beaked whales tend to avoid approaching vessels even without the added noise from airguns (e.g., Kasuya 1986; Würsig et al. 1998). There are increasing indications that some beaked whales tend to strand when naval exercises, including sonar operations, are ongoing nearby—see Appendix A (g). The strandings are apparently, at least in part a disturbance response, although auditory or other injuries may also be a factor. Whether beaked whales would ever react similarly to seismic surveys is unknown (see "Strandings and Mortality", below).

Sperm whales have been reported to show avoidance reactions to standard vessels not emitting airgun sounds, and it is to be expected that they would tend to avoid an operating seismic survey vessel. There were some limited early observations suggesting that sperm whales in the Southern Ocean and Gulf of Mexico might be fairly sensitive to airgun sounds from distant seismic surveys. However, more extensive data from recent studies in the North Atlantic suggest that sperm whales in those areas show little evidence of avoidance or behavioral disruption in the presence of operating seismic vessels (McCall Howard 1999; Madsen et al. 2002; Stone 2003). An experimental study of sperm whale reactions to seismic surveys in the Gulf of Mexico has been done recently (Jochens and Biggs 2003).

Odontocete reactions to large arrays of airguns are variable and, at least for small odontocetes, seem to be confined to a smaller radius than has been observed for mysticetes. Thus, behavioral reactions of odontocetes to the small airgun source to be used here are expected to be very localized.

Pinnipeds.—Pinnipeds are not likely to show a strong avoidance reaction to the small airgun source that will be used. Visual monitoring from seismic vessels, usually employing much larger sources, has shown only slight (if any) avoidance of airguns by pinnipeds, and only slight (if any) changes in behavior—see Appendix A (e). Those studies show that pinnipeds frequently do not avoid the area within a few hundred meters of operating airgun arrays, even for arrays much larger than the one to be used here (e.g., Harris et al. 2001). However, initial telemetry work suggests that avoidance and other behavioral reactions to small airgun sources may at times be stronger than evident to date from visual studies of pinniped reactions to airguns (Thompson et al. 1998). Even if reactions of the species occurring in the present study area are as strong as those evident in the telemetry study, reactions are expected to be confined to relatively small distances and durations, with no long-term effects on pinniped individuals or populations.

Hearing Impairment and Other Physical Effects

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds, but there has been no specific documentation of this for marine mammals exposed to airgun pulses. Current NMFS policy regarding exposure of marine mammals to high-level sounds is that cetaceans and pinnipeds should not be exposed to impulsive sounds ≥180 and 190 dB re 1 μPa (rms), respectively (NMFS 2000). Those criteria have been used in defining the safety (=shut-down) radii planned for the proposed seismic survey. However, those criteria were established before there were any data on the minimum received levels of sounds necessary to cause temporary auditory impairment in marine mammals. As discussed in Appendix A (f) and summarized here,

- the 180-dB criterion for cetaceans is probably quite precautionary, i.e., lower than necessary to avoid temporary threshold shift (TTS), let alone permanent auditory injury, at least for delphinids.
- the minimum sound level necessary to cause permanent hearing impairment 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.

NMFS is presently developing new noise exposure criteria for marine mammals that take account of the now-available data on TTS in marine (and terrestrial) mammals.

Because of the small size of the airgun source in this project (two 105 in^3 GI guns), along with the planned monitoring and mitigation measures, there is little likelihood that any marine mammals will be exposed to sounds sufficiently strong to cause even the mildest (and reversible) form of hearing impairment. Several aspects of the planned monitoring and mitigation measures for this project are designed to detect marine mammals occurring near the 2 GI airguns (and multibeam bathymetric sonar), 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 are likely to show some avoidance of the area with high received levels of airgun sound (see above). 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 theoretically might occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, resonance effects, 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 pulsed sounds. However, as discussed below, there is no evidence that any of these effects occur even for marine mammals in close proximity to large arrays of airguns. It is especially unlikely that any effects of these types would occur during the present project given the small size of the source, the brief duration of exposure of any given mammal, and the planned monitoring and mitigation measures (see below). The following subsections discuss in somewhat more detail the possibilities of TTS, permanent threshold shift (PTS), and non-auditory physical effects.

Temporary Threshold Shift (TTS).—TTS is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter 1985). While experiencing TTS, the hearing threshold rises and a sound must be stronger in order to be heard. 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 recovers rapidly after exposure to the noise ends. Only a 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.

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). Given the available data, the received level of a single seismic pulse might need to be on the order of 210 dB re 1 μPa rms (~221–226 dB pk–pk) in order to produce brief, mild TTS. Exposure to several seismic pulses at received levels near 200–205 dB (rms) might result in slight TTS in a small odontocete, assuming the TTS threshold is (to a first approximation) a function of the total received pulse energy. Seismic pulses with received levels of 200–205 dB or more are usually restricted to a radius of no more than 100 m (328 ft) around a seismic vessel operating a large array of airguns. Such levels would be limited to distances within a few meters of the small airgun source to be used in this project.

For baleen whales, there are no data, direct or indirect, on levels or properties of sound that are required to induce TTS. However, no cases of TTS are expected given the small size of the source, and the strong likelihood that baleen whales would avoid the approaching airguns (or vessel) before being exposed to levels high enough for there to be any possibility of TTS.

In pinnipeds, TTS thresholds associated with exposure to brief pulses (single or multiple) have not been measured. However, prolonged exposures show that some pinnipeds may incur TTS at somewhat lower received levels than do small odontocetes exposed for similar durations (Kastak et al. 1999; Ketten et al. 2001; *cf.* Au et al. 2000).

A marine mammal within a radius of ≤100 m (≤328 ft) around a typical large array of operating airguns might be exposed to a few seismic pulses with levels of ≥205 dB, and possibly more pulses if the mammal moved with the seismic vessel. (As noted above, most cetacean species tend to avoid operating airguns, although not all individuals do so.) However, several of the considerations that are relevant in assessing the impact of typical seismic surveys with arrays of airguns are not directly applicable here:

- The planned airgun source is much smaller, with correspondingly smaller radii within which received sound levels could exceed any particular level of concern.
- "Ramping up" (soft start) is standard operational protocol during startup of large airgun arrays in many jurisdictions. Ramping up involves starting the airguns in sequence, usually commencing

with a single gun and gradually adding additional guns. This is not possible for the small 2-gun source, planned for use in the present project.

- With a large airgun array, it is unlikely that cetaceans would be exposed to airgun pulses at a sufficiently high level for a sufficiently long period to cause more than mild TTS, given the relative movement of the vessel and the marine mammal. In this project, the airgun source is much less strong, so the radius of influence and duration of exposure to strong pulses is much smaller, especially in deep and intermediate-depth water.
- With a large array of airguns, TTS would be most likely in any odontocetes that bow-ride or otherwise linger near the airguns. In the present project, the anticipated 180 dB distances in deep and intermediate-depth water are 54 and 81 m, respectively (Table 2), and the bow of the *Ewing* will be 87 m ahead of the airguns.

NMFS (1995, 2000) concluded that cetaceans and pinnipeds should not be exposed to pulsed underwater noise at received levels exceeding, respectively, 180 and 190 dB re 1 µPa (rms). The 180 and 190 dB distances for the GI airguns operated by L-DEO vary with water depth. They are estimated to be no more than 54 m and 17 m, respectively, in deep water, but are predicted to increase to 367 m and 116 m respectively in shallow water (Table 2). Furthermore, those sound levels are ***not*** considered to be the levels above which TTS might occur. Rather, they are 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, TTS data that are now available imply that, at least for dolphins, TTS is unlikely to occur unless the dolphins are exposed to airgun pulses much stronger than 180 dB re 1 µPa rms.

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

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 TTS, there has been further speculation about the possibility that some individuals occurring very close to airguns might incur PTS. Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage in terrestrial mammals. 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 20 dB or more above that inducing mild TTS if the animal were exposed to the strong sound for an extended period, or to a strong sound with very rapid rise time—see Appendix A (f).

It is highly unlikely that marine mammals could receive sounds strong enough (and over a sufficient duration) to cause permanent hearing impairment during a project employing two 105 in^3 GI guns. In the present project, marine mammals are unlikely to be exposed to received levels of seismic pulses strong enough to cause TTS, as they would probably need to be within a few meters of the airguns for that to occur. Given the higher level of sound necessary to cause PTS, it is even less likely that PTS could occur. In fact, even the levels immediately adjacent to the airguns may not be sufficient to induce PTS, especially because a mammal would not be exposed to more than one strong pulse unless it swam immediately alongside an airgun for a period longer than the inter-pulse interval. Baleen whales generally avoid the immediate area around operating seismic vessels. The planned monitoring and mitigation measures, including visual monitoring and shut downs of the airguns when mammals are seen within the "safety radii", will minimize the already-minimal probability of exposure of marine mammals to sounds strong enough to induce PTS.

***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 effects, and other types of organ or tissue damage. There is no proof that any of those effects occur in marine mammals exposed to sound from airgun arrays (even large ones). However, there have been no direct studies of the potential for airgun pulses to elicit any of those effects. If any such effects do occur, they probably would be limited to unusual situations when animals might be exposed at close range for unusually long periods.

It is doubtful that any single marine mammal would be exposed to strong seismic sounds for sufficiently long that significant physiological stress would develop. That is especially so in the case of the present project where the airguns are small, the ship is moving at 4–5 knots, and for the most part each survey does not encompass a large area.

Gas-filled structures in marine animals have an inherent fundamental resonance frequency. If stimulated at that frequency, the ensuing resonance could cause damage to the animal. A recent workshop (Gentry [ed.] 2002) was held to discuss whether the stranding of beaked whales in the Bahamas in 2000 (Balcomb and Claridge 2001; NOAA and USN 2001) might have been related to air cavity resonance or bubble formation in tissues caused by exposure to noise pulses from naval sonar. A panel of experts concluded that resonance in air-filled structures was not likely to have caused the stranding. Opinions were less conclusive about the possible role of gas (nitrogen) bubble formation/growth in the Bahamas stranding of beaked whales.

Until recently, it was assumed that diving marine mammals are not subject to the bends or air embolism. However, a short paper concerning beaked whales stranded in the Canary Islands in 2002 suggests that cetaceans might be subject to decompression injury in some situations (Jepson et al. 2003). If so, that might occur if they ascend unusually quickly when exposed to aversive sounds. Whether or not that can occur during exposure to mid-frequency sonar, there is no evidence that that type of effect occurs in response to airgun sounds. It is especially unlikely in the case of this project involving only two small GI guns. Also, beaked whales are infrequent in the present project area (see § IV).

In general, little is known about the potential for seismic survey sounds to cause auditory impairment or other physical effects in marine mammals. Available data suggest that such effects, if they occur at all, would be limited to short distances and probably to projects involving large arrays of airguns. However, the available data do not allow for 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 auditory impairment or other physical effects. Also, the planned monitoring and mitigation measures include shut downs of the airguns, which will reduce any such effects that might otherwise occur.

Strandings and Mortality

Marine mammals close to underwater detonations of high explosive can be killed or severely injured, and the auditory organs are especially susceptible to injury (Ketten et al. 1993; Ketten 1995). Airgun pulses are less energetic and have slower rise times, and there is no proof 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, 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. Appendix A (g) provides additional details.

Seismic pulses and mid-frequency sonar pulses are quite different. Sounds produced by airgun arrays are broadband with most of the energy below 1 kHz. Typical military mid-frequency sonars operate at frequencies of 2–10 kHz, generally with a relatively narrow bandwidth at any one time. 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 pulses can, in special circumstances, lead to physical damage and mortality (NOAA and USN 2001; Jepson et al. 2003), even if only indirectly, suggests that caution is warranted when dealing with exposure of marine mammals to any high-intensity pulsed sound.

In May 1996, 12 Cuvier's beaked whales stranded along the coasts of Kyparissiakos Gulf in the Mediterranean Sea. That stranding was subsequently linked to the use of low- and medium-frequency active sonar by a North Atlantic Treaty Organization (NATO) research vessel in the region (Frantzis 1998). In March 2000, a population of Cuvier's beaked whales being studied in the Bahamas disappeared after a U.S. Navy task force using mid-frequency tactical sonars passed through the area; some beaked whales stranded (Balcomb and Claridge 2001; NOAA and USN 2001).

In September 2002, a total of 14 beaked whales of various species stranded coincident with naval exercises in the Canary Islands (Martel n.d.; Jepson et al. 2003; Fernández et al. 2003). Also in Sept. 2002, there was a stranding of two Cuvier's beaked whales in the Gulf of California, Mexico, when the L-DEO vessel *Maurice Ewing* was operating a 20-gun 8490-in^3 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, that plus the incidents involving beaked whale strandings near naval exercises suggests a need for caution in conducting seismic surveys in areas occupied by beaked whales.

The present project will involve a much smaller sound source than used in typical seismic surveys. That, along with the monitoring and mitigation measures that are planned, and the infrequent occurrence of beaked whales in the project area, will minimize any possibility for strandings and mortality.

(b) Possible Effects of Bathymetric Sonar Signals

A bathymetric sonar (Atlas Hydrosweep DS-2, 15.5-kHz, or Simrad EM1002, ~95 kHz) will be operated from the source vessel essentially continuously during the planned study. Details about this equipment were provided in § I. Sounds from the Atlas Hydrosweep are very short pulses, occurring for 1–10 ms once every 1 to 15 s, depending on water depth. Most of the energy in the sound pulses emitted by the Atlas Hydrosweep is at moderately high frequencies, centered at 15.5 kHz. The beam is narrow (2.67º) in fore-aft extent, and wide (140º) in the cross-track extent. Each ping consists of five successive 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 five segments, i.e., for 1/5th or at most 2/5th of the 1–10 ms.

The EM1002 is a compact high resolution multibeam echo sounder that operates at a frequency of 95 kHz (92 to 98 kHz) in water depths from 10 to 800 m (33–2625 ft). The high operational frequency of this unit is assumed to be beyond the effective audible range of all mysticetes and pinnipeds, but the hearing capabilities of many odontocetes extend to frequencies this high. The system operates with 3 different pulselengths, 0.2, 0.7 and 2 ms, with pulselength increasing with increased water depth. The transmitted beam is narrow (3º) fore-aft, and wide (150º) across-track. Maximum ping rate is 10 per second (in shallow water) with the ping rate decreasing with increasing water depth.

Navy sonars that have been linked to avoidance reactions and stranding of cetaceans (1) generally are more powerful than either the Hydrosweep or the EM1002 sonars, (2) have a longer pulse duration, and (3) are directed close to horizontally vs. downward for the Atlas Hydrosweep and EM1002. The area of possible influence of the bathymetric sonar is much smaller—a narrow band oriented in the cross-track direction below the source vessel. Marine mammals that encounter the bathymetric sonar at close range 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.

Masking

Marine mammal communications will not be masked appreciably by the bathymetric sonar signals given the low duty cycle of both sonars and the brief period when an individual mammal is likely to be within the sonar beam. Furthermore, the 15.5 kHz sounds from the Hydrosweep will not overlap with the predominant frequencies in baleen whale calls, further reducing any potential for masking in that group. The ~95 kHz pulses from the EM1002 sonar will be inaudible to baleen whales and pinnipeds.

Behavioral Responses

Behavioral reactions of free-ranging marine mammals to military and other sonars 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. Also, Navy personnel have described observations of dolphins bow-riding adjacent to bow-mounted mid-frequency sonars during sonar transmissions. However, all of those observations are of limited relevance to the present situation. Pulse durations from those sonars were much longer than those of the bathymetric sonars to be used during the proposed study, and a given mammal would have received many pulses from the naval sonars. 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.

Captive bottlenose dolphins and a white whale exhibited changes in behavior when exposed to 1 s pulsed sounds at frequencies similar to those that will be emitted by the bathymetric sonar to be 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). The relevance of those data to free-ranging odontocetes is uncertain, and in any case, the test sounds were quite different in either duration or bandwidth as compared with those from a bathymetric sonar.

We are not aware of any data on the reactions of pinnipeds to sonar sounds at frequencies similar to those of the Hydrosweep bathymetric sonar (15.5 kHz). Based on observed pinniped responses to other types of pulsed sounds, and the likely brevity of exposure to the bathymetric sonar sounds, pinniped reactions to the Hydrosweep sounds are expected to be limited to startle or otherwise brief responses of no lasting consequence to the animals. The ~95 kHz sounds from the EM1002 will be inaudible to pinnipeds and to baleen whales, so will have no disturbance effects on those groups.

As noted earlier, NMFS (2001) has concluded that momentary behavioral reactions "do not rise to the level of taking". Thus, brief exposure of cetaceans or pinnipeds to small numbers of signals from a multibeam bathymetric sonar system would not result in a "take" by harassment.

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 multibeam sonars proposed for use by L-DEO are quite different than sonars used for navy operations. Pulse duration of the bathymetric sonar is very short relative to the naval sonars. Also, at any given location, an individual marine mammal would be in the beam of the multibeam sonar 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 bathymetric sonar rather drastically relative to that from the sonars used by the Navy.

(c) Possible Effects of Sub-bottom Profiler Signals

A sub-bottom profiler will be operated from the source vessel at nearly all times during the planned study. Details about the equipment were provided in § I. Sounds from the EDO sub-bottom profiler are very short pulses, occurring for 1, 2, or 4 ms once every second, or 50 ms pulses every 1 to 10 s, depending on water depth. Most of the energy in the sound pulses emitted by this sub-bottom profiler is at mid frequencies, centered at 3.5 kHz. The beamwidth is ~30° and is directed downward. The ODEC Bathy 2000P "chirp" sonar transmits a 50 ms pulse during which the frequency is swept from 4 to 7 kHz. The transmission rate is variable from 1 to 10 seconds, and the maximum output power is 2 kW.

Sound levels have not been measured directly for the sub-bottom profilers to be used by the *Ewing*, but Burgess and Lawson (2000) measured sounds propagating more or less horizontally from a similar unit with similar source output (205 dB re 1 μPa·m). The 160 and 180 dB re 1 μPa rms radii, in the horizontal direction, were estimated to be, respectively, near 20 m (66 ft) and 8 m (26 ft) from the source, as measured in 13 m or 43 ft water depth. The corresponding distances for an animal in the beam below the transducer would be greater, on the order of 180 m (591 ft) and 18 m (59 ft), assuming spherical spreading.

The EDO sub-bottom profiler on the *Ewing* has a stated maximum source level of 204 dB re 1 μPa·m and a normal source level of 200 dB re 1 μPa·m (see § I). Thus the received level would be expected to decrease to 160 and 180 dB about 160 m (525 ft) and 16 m (52 ft) below the transducer, respectively, again assuming spherical spreading. Corresponding distances in the horizontal plane would be lower, given the directionality of this source (30° beamwidth) and the measurements of Burgess and Lawson (2000).

Masking

Marine mammal communications will not be masked appreciably by the sub-bottom profiler signals given its relatively low power output, the low duty cycle, directionality, and the brief period when an individual mammal is likely to be within its beam. Furthermore, in the case of most odontocetes, the sonar signals do not overlap with the predominant frequencies in the calls, which would avoid significant masking.

Behavioral Responses

Marine mammal behavioral reactions to other pulsed sound sources are discussed above, and responses to the sub-bottom profiler are likely to be similar to those for other pulsed sources if received at the same levels. However, the pulsed signals from the sub-bottom profiler are much weaker than those from the bathymetric sonar and the two GI guns. Therefore, behavioral responses are not expected unless marine mammals are very close to the source. Also, NMFS (2001) has concluded that momentary behavioral reactions "do not rise to the level of taking". Thus, brief exposure of cetaceans to small numbers of signals from the sub-bottom profiler would not result in a "take" by harassment.

Hearing Impairment and Other Physical Effects

Source levels of the sub-bottom profiler are much lower than those of the airguns and the bathymetric sonar, which are discussed above. Sound levels from a sub-bottom profiler similar to the EDO unit on the *Ewing* were estimated to decrease to 180 dB re 1 μPa (rms) at 8 m or 26 ft horizontally from the source (Burgess and Lawson 2000), and at ~18 m downward from the source. Furthermore, received levels of pulsed sounds that are necessary to cause temporary or especially permanent hearing impairment in marine mammals appear to be higher than 180 dB (see earlier). Thus, it is unlikely that the sub-bottom profiler 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 sub-bottom profiler 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 sub-bottom profiler. 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 the higher-power sources would further reduce or eliminate any minor effects of the sub-bottom profiler.

(d) Possible Effects of Sub-bottom Profiler Signals

A 12 kHz pinger will be operated during all coring work, to monitor the depth of the coring devices relative to the sea floor. Details about the equipment were provided in § I. Sounds from the pinger are very short pulses, occurring for 1 ms once every second. Most of the energy in the sound pulses emitted by this pinger is at mid frequencies, centered at 12 kHz. The signal is omnidirectional. The pinger produces sounds that are within the range of frequencies used by small odonotocetes (killer whales, Pacific white-sided dolphins, Dall's porpoise) that occur or may occur in the area of the planned surveys.

Masking

While the pinger produces sounds within the frequency range used by odontocetes that may be present in the survey area, marine mammal communications will not be masked appreciably by the pinger signals. This is a consequence of the relatively low power output, low duty cycle, and brief period when an individual mammal is likely to be within the area of potential effects. In the case of mysticetes, the pulses 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 pinger are likely to be similar to those for other pulsed sources if received at the same levels. However, the pulsed signals from the pinger are much weaker than those from the bathymetric sonars and from the two GI guns. Therefore, behavioral responses are not expected unless marine mammals are very close to the source.

NMFS (2001) has concluded that momentary behavioral reactions "do not rise to the level of taking". Thus, brief exposure of cetaceans to small numbers of signals from the pinger would not result in a "take" by harassment.

Hearing Impairment and Other Physical Effects

Source levels of the pinger are much lower than those of the airguns and bathymetric sonars, which are discussed above. Therefore, it is unlikely that the pinger produces pulse levels strong enough to cause temporary hearing impairment or (especially) physical injuries even in an animal that is (briefly) in a position near the source.

The pinger is operated while the ship is stationary during coring work. The stationary vessel would allow marine mammals to avoid the ship and the sounds from the pinger before the mammals would be close enough for there to be any possibility of effects from the pinger.

(e) Numbers of Marine Mammals that Might 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 and in Appendix A, 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 "take by harassment" and present estimates of the numbers of marine mammals that might be affected during the proposed seismic study in SE Alaska. These estimates are based on data obtained during marine mammal surveys in 1991–1993 in SE Alaska by Dahlheim and Towell (1994) and in 2003 in the GOA by Waite (2003), and on estimates of the size of the areas where effects could potentially occur.

This section provides two types of estimates: estimates of the number of potential "exposures" to sound levels ≥160 and/or ≥170 dB re 1 µPa (rms), and estimates of the number of different individual marine mammals that might potentially be exposed to such levels. The ≥160 dB criterion is applied for all species; the ≥170 dB criterion is applied for delphinids and pinnipeds (where possible).

The number of different individual mammals exposed to a given sound level is lower than the calculated number of exposures. When marine mammals are present near overlapping or intersecting survey lines, some of the same individuals are likely to be approached by the 2 GI airguns on more than one occasion. The distinction between "exposures" and "number of different individuals exposed" is less important in this project than in some other projects because this survey calls for only a small amount of repeat operations by 2 GI airguns through the same or adjacent waters. However, the estimated number of exposures is likely to be an overestimate because the density of marine mammals in the area in the absence of seismic surveys is assumed to apply throughout the seismic survey. In fact, any animals that react to airgun sounds by moving away from the source are not likely to be present and affected during the second and subsequent surveys of any given area.

The distinction between the number of *exposures* and the number of *different individuals exposed* has been recognized in estimating numbers of "takes" during some previous seismic surveys conducted under IHAs (e.g., Harris et al. 2001; Moulton and Lawson 2002; Smultea and Holst 2003; MacLean and Haley 2004). Estimates of the number of exposures are considered precautionary *overestimates* of the actual numbers of different individuals potentially exposed to seismic sounds, because in all likelihood, exposures include repeated exposures of some of the same individuals.

It should be noted that there are few systematic data on the numbers and distributions of marine mammals in SE Alaska and the GOA. Zerbini et al. (2003) surveyed the northern and western GOA from the Kenai Peninsula to the central Aleutian Islands in 2001 and 2002. Killer whales were the principal target of the surveys, but Zerbinie et al. also reported the abundance and distribution of fin, humpback, and minke whales. Waite et al. (2003) surveyed the northern and western GOA on a piggy-back project during a Resource Assessment and Conservation Engineering (RACE) acoustic trawl survey for pollock. Waite et al. reported on the presence of small odontocetes, beaked whales, and mysticetes. Also, Dahlheim et al. (2000) surveyed SE Alaska for harbor porpoise abundance. However, no comprehensive surveys have been undertaken for abundance or density of marine mammals in the large geographic area of the southeastern, central and western GOA, although many studies have noted the presence or abundance of marine mammals in small parts of the area (e.g., humpback whales and sea otters in Glacier Bay; harbor seals at index locations throughout SE Alaska and the GOA). Furthermore, the proposed survey encompasses a wide range of habitats, including the protected, inland waters of Glacier Bay and Lynn Canal, the waters of PWS and Yakutat Bay, and the deep water (up to 3000 m or 9843 ft) of the GOA. There is, therefore, uncertainty about the representativeness of the data and assumptions used below to estimate the potential "take by harassment". However, the approach used here seems to be the best available approach.

The following estimates are based on a consideration of the number of marine mammals that might be disturbed appreciably by 1779 line kilometers of seismic surveys with the 2 GI airguns in SE Alaska. The anticipated radii of influence of the bathymetric sonars and sub-bottom profiler are less than those for the 2 GI airguns. It is assumed that, during simultaneous operations of those additional sound sources and the 2 GI airguns, any marine mammals close enough to be affected by the sonar or profiler would already be affected by the GI airguns. No animals are expected to exhibit more than short-term and inconsequential responses to these sources given their characteristics (e.g., narrow downward-directed beam) and other considerations described in § I and VII. Such reactions are not considered to constitute "taking" (NMFS 2001). Therefore, no additional allowance is included for animals that might be affected by the sound sources other than the 2 GI airguns. For similar reasons, any effects of the bathymetric sonars, profilers, or pinger during times when one or more of them are operating but the 2 GI airguns are silent are not considered.

Basis for Estimating "Take by Harassment" for the SE Alaska Cruise

Some limited ship-based surveys have been conducted for marine mammals in the GOA (Waite 2003) and in SE Alaska (Dahlheim and Towell 1994). The most comprehensive and recent data available for cetacean species in and near the proposed seismic survey area are from the 2003 NMFS/AFSC ship surveys reported by Waite (2003). Additional data from SE Alaska are available for harbor porpoises for 1993 (Dahlheim et al. 2000) and Pacific white-sided dolphins for 1991–1993 (Dahlheim and Towell 1994).

Surveys have also been conducted for pinnipeds in Alaskan waters; however, those counts are typically to estimate the number of animals at haulout sites, not in the water. Counts of Steller sea lions are conducted on rookeries and haulouts throughout their range every year in June and July when the maximum numbers of sea lions are hauled out (e.g., Sease et al. 2001). Sea lions appear to spend more time in the water during the winter than they do during the breeding season. Sease and York (2003) counted approximately half the number of sea lions during winter surveys compared to the breeding-season surveys. They determined that the difference was primarily a function of sea lions dispersing to local haulout sites during the winter, rather than large-scale movements. There may also be differences in the proportion of time that different age or sex classes spend in the water or hauled out. Trites and Porter (2002) report that lactating females may spend as little as 24% of their time on shore. Mature females without dependent offspring, adult males, and weaned juveniles probably have different foraging strategies than lactating females, and spend different proportions of their time ashore. Assuming that the number of sea lions that are in the water at any one time after the breeding season is half of the maximum breeding-season counts (Sease and York 2003), then it is possible to estimate the number of sea lions that could potentially be exposed to seismic sounds. However, not all of the animals that are in the water would be near the seismic operation; most would be dispersed some distance from the haulout. Furthermore, the density of sea lions in the water presumably would decrease as distance from the haul-out increased.

The abundance of harbor seals in Alaska has been determined by aerial surveys conducted in 1991–1994 (e.g., Loughlin 1994). The last survey in SE Alaska was in 1993 (Loughlin 1994), and the last survey in PWS east to Kayak Island, was in 2001 (Withrow and Cesarone 2002). These counts resulted in estimates of 37,450 harbor seals in SE Alaska, and 6246 harbor seals in PWS to Kayak Island (Withrow and Cesarone 2002) for a total of 43,696 harbor seals from Dixon Entrance to PWS. These counts were conducted during the summer and early fall (August–September), when the maximum number of harbor seals are hauled out during the molt, and cover every known haulout. However, there are no data on the densities of harbor seals at sea. Harbor seals generally have a small home range (Lowry et al. 2001), and do not disperse long distances, particularly during the molt. Therefore, only harbor seals from haulout areas near the planned seismic surveys are likely to be exposed to seismic sounds.

Sea otters occur throughout the proposed survey area, generally in waters <40 m (131 ft) deep (Riedman and Estes 1990). Sea otters generally do not disperse over long distances, although movements of tens of kilometers are normal. Sea otters also spend a great deal of time at the surface, feeding and grooming. The sea otter population in SE Alaska was surveyed in 1994 (Agler et al. 1995), resulting in a population estimate of 11,697. The otter population in Glacier Bay has been increasing and now numbers ~500 in the lower reaches of GBNPP (Bodkin et al. 2001). The otter populations of Yakutat Bay and northern GOA were estimated to be 404 in 1995 and 531 in 1996, respectively (Doroff and Gorbics 1998). The sea otter population of PWS in 1999 was estimated to be 13,234 (USGS unpublished data *in* Angliss and Lodge 2002). These estimates result in a total estimate of 25,866 sea otters from Dixon Entrance to PWS. There are no data for the density of sea otters at sea in SE Alaska.

Very few (7.6 km or 4.1 n.mi.) of the proposed seismic lines are in waters ≤50 m (164 ft) deep; that is 0.4% of the total line kilometers to be surveyed. Furthermore, most of the surveys will not occur in protected, inland waters. No seismic surveys are planned for lower Glacier Bay, and it is unlikely that any otters will occur in Muir Inlet (Upper East Arm) where seismic surveys are planned. Therefore, relatively few sea otters will be exposed to strong sounds from the proposed seismic surveys. Additionally, sea otters spend a great deal of time at the surface feeding and grooming. While at the surface, the potential noise exposure of sea otters would be much reduced by the pressure release effect at the surface. Considering all the factors presented above, it is clear that only small numbers of otters would be exposed to strong seismic sounds. Furthermore, a study in California showed that sea otters show little or no reaction to exposure to sound pulses from airguns (Riedman 1983, 1984).

Table 5 gives the average and maximum densities for each cetacean species or species group reported to occur in SE Alaska, corrected for effort, based on the sightings and effort data from the above reports. The densities from these studies have been corrected, using correction factors from Dahlheim et al. (2000) and from Koski et al. (1998), for both detectability and availability bias. Detectability bias is associated with diminishing sightability with increasing lateral distance from the trackline [$f(0)$]. Availability bias refers to the fact that there is less-than-100% probability of sighting an animal that is present along the survey trackline, and it is measured by $g(0)$.

TABLE 5. Densities and CVs of cetaceans sighted during surveys in the Gulf of Alaska during 2003. Densities are estimated from sighting and effort data from Waite (2003), Dahlheim et al. (2000), and Dahlheim and Towell (1994), and are based on ship transect surveys. Densities are corrected for *f*(0) and *g*(0). Species listed as endangered or threatened are in italics.

Species	**Average Density in the GOA and SE Alaska (#/km^2)**		**Assumed Maximum Density (#/km^2)**	
	Density	**CV** [a]	**Density**	**CV**
Odontocetes				
Sperm whale	*0.0006*	*0.83*	*0.0009*	*0.83*
Cuvier's beaked whale	0.0037	0.94	0.0055	0.94
Baird's beaked whale	0.0009	0.94	0.0013	0.94
Stejneger's beaked whale	0.0000	–	0.0000	–
Beluga	0.0000	–	0.0000	–
Pacific white-sided dolphin	0.0338	0.29	0.0692	0.38
Risso's dolphin	0.0000	–	0.0000	–
Killer whale	0.0136	0.60	0.0204	0.60
Short-finned pilot whale	0.0000	–	0.0000	–
Phocoenidae				
Harbor porpoise [b]	0.0393	0.18	0.0485	0.19
Dall's porpoise [c]	1.0994	0.08	1.6491	0.08
Mysticetes				
North Pacific right whale	*0.0000*	–	*0.0000*	–
Gray whale	0.0000	–	0.0000	–
Humpback whale	*0.0221*	*0.34*	*0.0331*	*0.34*
Minke whale	0.0004	0.76	0.0006	0.76
Fin whale	*0.0304*	*0.29*	*0.0456*	*0.29*
Blue whale	*0.0000*	–	*0.0000*	–

[a] CV (Coefficient of Variation) is a measure of a number's variability. The larger the CV, the higher the variability. It is estimated by the equation $0.94 - 0.162\log_e n$ from Koski et al. (1998), but likely underestimates the true variability.
[b] Includes surveys in SE Alaska in 1993 (Dahlheim 2000).
[c] Includes surveys in SE Alaska in 1991, 1992 and 1993 (Dahlheim and Towell 1994).

There is some uncertainty about the representativeness of the data and the assumptions used in the calculations below. However, the approach used here is believed to be the best available approach. Also, to provide some allowance for these uncertainties, "maximum estimates" as well as "best estimates" of the numbers potentially affected have been derived. For most species, only one density estimate was available and it was based on data in Waite (2003). For these species, the "maximum density" was the best estimate of density multiplied by 1.5. Best and maximum estimates are based on the average and maximum estimates of densities calculated from the data reported in the studies described above. The estimated numbers of potential exposures and individuals exposed are presented separately below based on the 160 dB re 1 µPa (rms) criterion for all cetaceans and pinnipeds, and the 170 dB criterion for delphinids and pinnipeds (where possible). It is assumed that marine mammals exposed to GI airgun sounds this strong might change their behavior sufficiently to be considered "taken by harassment" (see § I and Table 1 for a discussion of the origin of these potential disturbance isopleths).

Potential Number of "Takes by Harassment" Based on "Exposures"

Best and Maximum Estimates of "Exposures" to ≥160 dB

The potential number of *occasions* when members of each species might be exposed to received levels ≥160 dB re 1 µPa (rms) was calculated for each of three water depth categories (<100 m, 100–1000 m, and >1000 m) by multiplying

- the expected species density, either "average" (i.e., best estimate) or "maximum", corrected as described above, times
- the anticipated total line-kilometers of operations with the 2 GI airguns in each water depth category (excluding turns but including 25% additional line kilometers to allow for repeating of lines due to equipment malfunction, bad weather, etc.), times
- the cross-track distances within which received sound levels are predicted to be ≥160 dB for each water depth category.

For the 2 GI airguns, that cross track distance is 2 × the predicted 160 dB radius of 1.50 km for water depths <100 m, 2 × 765 m for water depths of 100–1000 m, and 2 × 510 m for water depths >1000 m. The numbers of exposures in the three depth categories were then summed for each species. Applying the approach described above, ~3800 km^2 would be within the 160 dB isopleth. We allowed a 25% contingency for lines that might be surveyed more than once, so the number of exposures is calculated based on ~4750 km^2.

Based on this method, the "best" and "maximum" estimates of the number of marine mammal exposures to sounds ≥160 dB re 1 µPa (rms) from the 2 GI airguns were obtained using the average and "maximum" densities from Table 5. These estimates show that three endangered cetacean species may be exposed to such noise levels, but two other endangered cetacean species that theoretically might be encountered in the area are unlikely to be exposed. Our respective best and maximum estimates for these species are as follows: sperm whale, 3 and 4 exposures; humpback whale, 105 and 157 exposures; and fin whale, 144 and 216 exposures (Table 6). Blue and North Pacific right whales occasionally occur in the area, but none are expected to be exposed with the planned levels of seismic survey effort in the three depth strata.

Most of the best and maximum exposures to seismic sounds ≥160 dB would involve phocoenids (mostly Dall's porpoises). Best and maximum estimates of the number of exposures of cetaceans, in descending order, are Dall's porpoise (5218 and 7828 exposures), harbor porpoise (187 and 230), and Pacific white-sided dolphin (161 and 329). Estimates for other species are lower (Table 6). However, as noted earlier, the 160 dB criterion is probably not appropriate as a criterion for disturbance to dolphins. Most of them are unlikely to show appreciable behavioral disturbance unless exposed to stronger sounds.

TABLE 6. Estimates of the possible numbers of marine mammal exposures to the different sound levels, and the numbers of different individuals that might be exposed, during L-DEO's proposed seismic program in SE Alaska in late summer/autumn 2004. The proposed sound source consists of 2 GI airguns. Received levels of airgun sounds are expressed in dB re 1 µPa (rms, averaged over pulse duration). Not all marine mammals will change their behavior when exposed to these sound levels but, partially offsetting that, some may alter their behavior when levels are lower (see text). Delphinids, pinnipeds and sea otters are unlikely to react to levels below 170 dB. Species in italics are listed under the ESA as endangered or threatened. The column of numbers in boldface shows the numbers of "takes" for which authorization is requested.[a]

	Number of Exposures to Sound Levels ≥160 dB (≥170 dB)		Number of Individuals Exposed to Sound Levels ≥160 dB (≥170 dB)			
			Best Estimate			
Species	**Best Estimate**	**Maximum Estimate**	**Number**	**% of Regional Pop'n[b]**	**Maximum Estimate**	**Requested Take Authori-zation**
Physeteridae						
Sperm whale	*3*	*4*	*2*	*0.0*	*3*	***5***
Ziphiidae						
Cuvier's beaked whale	18	26	11	0.1	17	**26**
Baird's beaked whale	4	6	3	0.0	4	**6**
Stejneger's beaked whale	0	0	0	0.0	0	**5**
Monodontidae						
Beluga	0	0	0	0.0	0	**5**
Delphinidae						
Pacific white-sided dolphin	161 (62)	329 (127)	103 (44)	0.1	211 (90)	**329**
Risso's dolphin	0	0	0	0.0	0	**5**
Killer whale	65 (25)	97 (37)	42 (18)	0.2	62 (27)	**97**
Short-finned pilot whale	0	0	0	0.0	0	**10**
Phocoenidae						
Harbor porpoise	187	230	120	0.4	148	**230**
Dall's porpoise	5218	7828	3354	0.8	5031	**7828**
Balaenopteridae						
North Pacific right whale	*0*	*0*	0	*0.0*	*0*	***2***
Gray whale	0	0	0	0.0	0	**15**
Humpback whale	*105*	*157*	67	*1.1*	*101*	***157***
Minke whale	2	3	1	*0.0*	2	**8**
Fin whale	*144*	*216*	93	*0.8*	*139*	***216***
Blue whale	*0*	*0*	0	*0.0*	*0*	***5***

TABLE 6. continued

Pinnipeds					
Northern fur seal [c]		0		0	**5**
Harbor seal [c]		1498	4.0		**1498**
Steller sea lion	*712 (275)*	*458 (195)*	*1.0*		***458***
Fissipeds					
Sea Otter [d]		68	0.3	123	**123**

[a] Best estimate and maximum estimates of density are from Table 5.
[b] Regional population size estimates are from Table 2.
[c] Estimates for fur and harbor seals are not based on direct calculations from density data (see text for explanation).
[d] Estimates for the sea otter are based on the encounter rate per linear kilometer, not densities.

The far right column in Table 6, "*Requested Take Authorization*", shows ***the numbers for which "take authorization" is requested***. For the common species, these requested take authorization numbers are calculated as indicated above based on the *maximum* densities calculated from the data reported in the different studies mentioned above or based on 1.5 × the densities from Waite (2003). In some cases, the requested numbers are somewhat higher than the maximum estimated numbers of exposures found in column 2 of Table 6. Some of the marine mammal species that are known or suspected to occur at least occasionally in SE Alaska were not recorded during the few systematic surveys that were used to estimate densities. In these cases, the "*Requested Take Authorization*" figures include adjustments for small numbers that might be encountered even though they were not recorded during the surveys mentioned above. The "*Requested Take Authorization*" figures also include adjustments for potentially increased numbers (5–10) of certain species that were observed infrequently or not at all, but that might be encountered in groups during the proposed activity. For these species, the mean observed group size during the above or other surveys was generally used to derive numbers for the "*Requested Take Authorization*" column.

The 160 dB distances used in these calculations take account of the results of L-DEO's calibration cruise in the northern Gulf of Mexico during 2003 (Tolstoy et al. 2004). The 160 dB distances used for water depths <100 m are based on empirical measurements in shallow waters (~30 m) of the Gulf of Mexico. Those for depths >1000 m are based on model predictions, but the few empirical measurements from deep water show that actual 160 dB distances in deep water are likely less than predicted. The 160 dB distances used for intermediate water depths (100–1000 m), for which no empirical data are available, are based on 1.5 × the predicted distances in deep water, and may also be overestimates of the actual 160 dB distances in intermediate depths. Given these considerations, the overall predicted numbers of marine mammals that might be exposed to sounds ≥160 dB may be somewhat overestimated.

Best and Maximum Estimates of Delphinid Exposures 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 most baleen whales. As summarized in Appendix A (e), delphinids commonly occur within distances where received levels would be expected to exceed 160 dB (rms). There is no generally accepted alternative "take" criterion for dolphins exposed to airgun sounds. However, our estimates assume that only those dolphins 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.) As such, the best and maximum estimates of the numbers of exposures to ≥170 dB for the two most common delphinid species would be as follows: Pacific white-sided dolphin, 62 and 127; and killer whale, 25 and 37. No other delphinids are expected to be exposed to ≥170 dB, given the limited survey coverage and the rarity of other delphinids in the area (Table 6). These values are considered to be *more realistic estimates* of the numbers of occasions when delphinids may be affected. However, actual 170 dB radii are probably somewhat less than those used to estimate exposures in deep and perhaps intermediate depths, so these estimated numbers of exposures to ≥170 dB may be overestimates.

Number of Different Individuals (Cetaceans) That Might be Exposed to ≥160 and ≥170 dB

The preceding text estimates the number of occasions when cetaceans of various species might be *exposed* to sounds from the 2 GI airguns with received levels ≥160 or ≥170 dB re 1 μPa (rms), whereas the following section estimates the number of different *individuals* that might potentially be subjected to such received levels on one or more occasions. There is only a small amount of overlap of the seismic lines during this project; nonetheless, some of the mammals in the project area may be disturbed more than once, or they may move away from the sound source during the first pass by the vessel and subsequently would not be approached during a later pass. Thus, the total numbers of individuals likely to be disturbed one or more times are *lower* than those calculated above based on the number of exposures.

The number of *different individuals* likely to be exposed to airgun sounds with received levels ≥160 or 170 dB re 1 μPa (rms) on one or more occasions can be estimated by considering the total marine area that would be within the 160 or 170 dB radii around the operating GI airguns on at least one occasion. This 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 or 170 dB buffer around each seismic line (depending on the water depth), and then calculating the total area within the buffers. For each species, this area was multiplied by the marine mammal density, thus estimating the minimum number of marine mammals that would be exposed to ≥160 or ≥170 dB on one or more occasions. These estimates are presented in Table 6 as the "*Number of Individuals Exposed to Sound Levels ≥160 dB (≥170 dB)*".

Applying the approach described above, ~3050 km^2 would be within the 160 dB isopleth on one or more occasions. After adjustment for overlap, the affected area is ~64% of the area used to calculate the number of exposures (3050 / 4750 × 100%). This percentage was used to calculate the estimates of the total number of different *individuals* likely to be exposed to sounds ≥160 or ≥170 dB. The estimates of *exposures* were multiplied by 0.64.

This approach does not allow for turnover in the mammal populations in the study area during the course of the study, and thus it might somewhat underestimate actual numbers of individuals exposed to ≥160 and ≥170 dB. However, during this project, operations at each site will be relatively brief (no more than a few days). Also, any tendency for underestimation that might occur is at least partly offset by the likely overestimation of 160 and 170 dB radii during the 86% of operations that will be conducted in water depths >100 m.

Estimated Numbers of Individuals Exposed to ≥160 dB

Estimates of the number of different individuals of each species that might be exposed to ≥160 dB, adjusted for overlap, are provided in Table 6 based on the reported average and maximum densities. As an example, the estimated number of different individual humpback whales that might be exposed to ≥160 dB would be 67 to 101, derived by multiplying the estimated 105 or 157 exposures by 0.64 (Table 6). Estimated numbers of individuals for the other endangered marine mammals that might be exposed to these sound levels are 2–3 sperm whales and 93–139 fin whales. For the most common cetacean species, the corresponding estimated numbers of individuals exposed to ≥160 dB are 3354–5031 Dall's porpoises, 120–148 harbor porpoises, 103–211 Pacific white-sided dolphins, and 42–62 killer whales. However, as previously discussed, the 160 dB criterion is probably inappropriate for white-sided dolphins, killer whales, and other delphinids.

Estimated Numbers of Delphinids Exposed to ≥170 dB

Applying the method described above to the common delphinids, the estimated numbers of individuals exposed to sounds from the 2 GI airguns with levels ≥170 dB are 73–150 Pacific white-sided dolphins and 30–44 killer whales (Table 6). These values are based on the predicted 170 dB radii around the 2 GI airguns proposed to be used. These are believed to be more realistic estimates of the numbers of delphinids that might be affected by the proposed activities.

Potential Number of Pinnipeds and Fissipeds that Might be Affected

Sea Otters

Very few (7.6 km or 4.1 n.mi.) of the proposed seismic lines are in water ≤50 m (164 ft) deep (where sea otters generally occur); that is 0.4% of the total line kilometers to be surveyed. Boat based sea otter surveys in the Aleutian Islands from 1992 to 1994 encountered sea otters at rates between 2.56 and 16.20 sea otters/km (Doroff et al. 2003). Applying an intermediate encounter rate of 9 otters/km (assuming that the Aleutian areas included both high and low density areas) to the seismic lines in water ≤50 m (164 ft) deep (7.6 km) results in a best estimate of 68 sea otters that could potentially be encountered during airgun operations and a maximum estimate of 123 sea otters. These estimates are likely to overestimate the number of otters affected. Also, there is little evidence that sea otters are disturbed by sounds from either a small airgun source or from a large array of airguns (Riedman 1983, 1984).

Harbor Seals

As discussed above, only harbor seals from haulout areas near the planned seismic surveys are likely to be affected by seismic sounds. The planned seismic lines in SE Alaska (including Yakutat Bay and Icy Bay) and PWS are close (within ~10 km or 5.4 n.mi.) to 80 of the 983 haulout sites (8.1%) identified in SE Alaska and PWS [see Figs. 2-12 in Loughlin (1994) and Figs. 11-14 in Withrow and Cesarone (2002)].

Because harbor seals do not move great distances between haulout areas during the molt, we can expect that the small-source seismic surveys would potentially encounter only a small portion of the total population. The number of haulouts that are near the planned seismic lines totals 8% of the known haul-out areas in SE Alaska and PWS. Thus, at most 8% of the total population of harbor seals in SE Alaska and PWS might be exposed to airgun sounds. Assuming that 50% of harbor seals are hauled out and would not be exposed to underwater sounds, the percentage is reduced to 4%. However, this is likely still a substantial overestimate of the number potentially affected, as not all seals in the water would be within the disturbance zone from the seismic source. Nonetheless, based on the 4% figure, we assume that as many as 1498 harbor seals could be exposed to airguns sounds, and some fraction of these might be disturbed. Given the limited responsiveness of pinnipeds to airgun sounds during previous monitoring studies (see Appendix A), it is likely that the number of harbor seals that would be disturbed would be much less than 1498.

Steller Sea Lions

To simplify the method for estimating the number of sea lions that may be affected by seismic noise, we calculated the density of sea lions in a specific area around the rookeries or haulouts. Fishery exclusion zones (20 n.mi.) occur around specific rookeries in the Aleutian Islands, designed to limit the impact of commercial fisheries on Steller sea lions [FR 98(1):204, FR 68(89)24615]. If we assume that sea lions from the various rookeries and haulouts will be within 20 n.mi. of those sites, we can roughly estimate the average density of sea lions in the water near the rookeries or haulouts. This is a conservative estimate, as some sea lions will travel farther than 20 n.mi., and the estimated density would, therefore, be biased upwards. Also, this method assumes a uniform density throughout the buffer area, which is unlikely to occur. Sea lions will be less abundant farther from rookeries and haulouts. To simplify the density estimation, we assume that sea lions would be uniformly distributed throughout the buffer. However, because the *Ewing* will avoid encroaching upon critical habitat adjacent to rookeries and haulouts, it is unlikely that seismic activities would occur in the areas of highest density. In SE Alaska, none of the proposed seismic lines are located within critical habitats of rookeries and haulout sites. Informal consultation with NMFS regarding the proposed project and critical habitat of Steller sea lions is being sought; no problems are anticipated with conducting the proposed project near critical habitat.

A total of 16,674 sea lions (12,417 non-pups, 4257 pups) occur in SE Alaska from Dixon Entrance to Cape Fairweather (Angliss and Lodge 2002). An additional 2560 (2353 non-pups, 207 pups) occur in the eastern GOA from Sitkagi Bluffs to Rabbit (Sease et al. 2001) for a total of 19,234 Steller sea lions between Dixon Entrance and PWS. The 20 n.mi. buffers around rookeries and haulouts in SE Alaska and PWS (excluding land) is 61,320 km^2. Assuming that half the sea lions present in SE Alaska and PWS are in the water and within the 20 n.mi. buffers around haulouts and rookeries at any given time, the density within the buffer area is ~0.15 sea lions/km^2. As previously noted, it is very likely that this overestimates the density of sea lions that would be encountered during operations by the *Ewing* at locations within 20 n.mi. of the haulouts and rookeries. In any case, this density estimate was multiplied by the total area expected to be ensonified to ≥160 dB and ≥170 dB during the survey to give estimates of the number of exposures and individual animals that may be exposed. Based on the 170 dB criterion, an estimated 195 Steller sea lions may be exposed to ≥170 dB.

Other Pinniped Species

For other pinniped species, our best estimate of the number of individuals that might be affected by the seismic survey is zero. Nonetheless, the "*Requested Take Authorization*" for the northern fur seal is listed as 5 individuals, to allow for the possibility that a few individuals might be encountered.

Conclusions

The proposed survey in SE Alaska will involve towing 2 GI airguns that introduce pulsed sounds into the ocean, along with simultaneous operation of a bathymetric sonar, a sub-bottom profiler, and a pinger. A towed hydrophone streamer will be deployed to receive and record the returning signals. Routine vessel operations, other than the proposed operations by the 2 GI airguns, are conventionally assumed not to affect marine mammals sufficiently to constitute "taking". For similar reasons, no "taking" is expected when the vessel is obtaining cores of bottom sediment. No "taking" of marine mammals is expected in association with operations of the sonar given the considerations discussed in § I and § VII, i.e., sonar sounds are beamed downward, the beam is narrow, the pulses are extremely short, etc.

Cetaceans

Strong avoidance reactions by several species of mysticetes to seismic vessels have been observed at ranges up to 6–8 km (3.2–4.3 n.mi.) and occasionally as far as 20–30 km (10.8–16.2 n.mi.) from the source vessel. However, reactions at the longer distances appear to be atypical of most species and situations, particularly when feeding whales are involved. Many of the mysticetes that will be encountered in SE Alaska at the time of the proposed seismic survey will be feeding. In addition, the estimated numbers presented in Table 6 are considered overestimates of actual numbers. The estimated 160 and 170 dB radii used here are probably overestimates of the actual 160 and 170 dB radii at water depths ≥100 m based on the few calibration data obtained in deep water (Tolstoy et al. 2004).

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 delphinids approaching active seismic vessels. However, delphinids as well as some other types of odontocetes sometimes show avoidance responses and/or other changes in behavior when near operating seismic vessels.

Taking into account the small size and relatively low sound output of the 2 GI guns to be used, and the mitigation measures that are planned, effects on cetaceans are generally expected to be limited to avoidance of a small area around the seismic operation and short-term changes in behavior, falling within the MMPA definition of "Level B harassment". Furthermore, the estimated numbers of animals potentially exposed to sound levels sufficient to cause appreciable disturbance are very low percentages of the population sizes in the Northeast Pacific Ocean, as described below.

Based on the 160 dB criterion, the *best estimates* of the numbers of *individual* cetaceans that may be exposed to sounds ≥160 dB re 1 µPa (rms) represent 0 to 1.1% of the populations of each species in the Northeast Pacific (Table 6). The assumed population sizes used to calculate these percentages are presented in Table 3. For species listed as ***Endangered*** under the ESA, this includes no North Pacific right whales or blue whales; <0.01% of the Northeast Pacific population of sperm whales; 1.1% of the humpback whale population; and 0.8% of the fin whale population (Table 6). In the cases of belugas, beaked whales, and sperm whales, these potential reactions are expected to involve no more than very small numbers (0 to 11) of individual cetaceans. Humpback and fin whales are the ***Endangered*** species that are most likely to be exposed, and their Northeast Pacific populations are ~6000 (Carretta et al. 2002) and 10,970 (Ohsumi and Wada 1974), respectively.

It is highly unlikely that any North Pacific right whales will be exposed to seismic sounds ≥160 dB re 1 µPa (rms). This conclusion is based on the rarity of this species in SE Alaska and in the Northeast Pacific (<100, Carretta et al. 2002; Table 3), and on the fact that the remnant population of this species apparently migrates to areas farther west for the summer. However, we request authorization to expose up to two North Pacific right whales to ≥160 dB, given the possibility (however unlikely) of encountering one or more of this endangered species. If a right whale is sighted by the vessel-based observers, the 2 GI airguns will be shut down regardless of the distance of the whale from the 2 GI airguns.

Substantial numbers of phocoenids and delphinids may be exposed to airgun sounds during the proposed seismic studies, but the population sizes of species likely to occur in the operating area are large, and the numbers potentially affected are small relative to the population sizes (Table 6). The best estimates of the numbers of *individual* Dall's and harbor porpoises that might be exposed to ≥160 dB represent 0.8% and 0.4% of their Northeast Pacific populations. The best estimates of the numbers of *individual* delphinids that might be exposed to sounds ≥170 dB re 1 µPa (rms) represents <<0.01% of the ~600,000 dolphins estimated to occur in the Northeast Pacific, and 0 to 0.2% of the populations of each species occurring there (Table 6).

Varying estimates of the numbers of marine mammals that might be exposed to sounds from the 2 GI airguns during the 2004 seismic surveys in SE Alaska have been presented, depending on the specific exposure criteria (≥160 vs. ≥170 dB), calculation procedures (exposures vs. individuals), and density criteria used (best vs. maximum). The requested "take authorization" for each species is based on the estimated *maximum number of exposures* to ≥160 dB re 1 µPa (rms), i.e., the highest of the various estimates. That figure *likely overestimates* the actual number of animals that will be exposed to these sounds; the reasons for this are outlined above. Even so, the estimates for the proposed surveys are quite low percentages of the population sizes. Also, these relatively short-term exposures are not expected to result in any long-term negative consequences for the individuals or their populations.

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

Pinnipeds and Fissipeds

Two pinniped species, the Steller sea lion and the harbor seal, as well as the sea otter, are likely to be encountered in the study area. In addition, it is possible (although unlikely) that a small number of northern fur seals may be encountered. An estimated 1498 harbor seals and 195 Steller sea lions (or 1% of the Northeast Pacific population) may be exposed to airgun sounds during the seismic survey. It is unknown how many of these would actually be disturbed—probably only a small percentage. It is most likely that no northern fur seals will be affected. An estimated 68 sea otters (0.3% of the local population) may be encountered during airgun operations. Again, the number that might be disturbed briefly is unknown but likely to be less than 68. As for cetaceans, the short-term exposures to airgun sounds are not expected to result in any long-term negative consequences for the individuals or their populations.

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.

Subsistence hunting and fishing continue to feature prominently in the household economies and social welfare of some Alaskan residents, particularly among those living in small, rural villages (Wolfe and Walker 1987). Subsistence remains the basis for Alaska Native culture and community. In rural

Alaska, subsistence activities are often central to many aspects of human existence from patterns of family life to artistic expression and community religious and celebratory activities.

Marine mammals are legally hunted in Alaskan waters by coastal Alaska Natives. In SE Alaska, the only marine mammals that are hunted are Steller sea lions, harbor seals, and sea otters. Wolfe et al. (2003) estimated that ~1294 harbor seals were harvested by Alaska Natives from SE Alaska and the North Pacific Rim (Cordova to Nanwalek) in 2002. This accounted for over 70% of the estimated total statewide harbor seal harvest in 2002. Wolfe et al. also estimated that a total of 13 Steller sea lions were harvested by Alaska Natives in SE Alaska and the North Pacific Rim in 2002, accounting for ~7% of the total estimated statewide harvest of Steller sea lions. Wolfe et al. report that overall harbor seal hunting was extremely poor in 2002; takes during the first seven months were the lowest recorded since surveys began in 1992. An unknown but presumably small number of harbor seals and Steller sea lions are also harvested by subsistence hunters from Canada.

The USFWS monitors the harvest of sea otters in Alaska using a mandatory Marking, Tagging and Reporting Program that has been implemented since 1988. The USFWS estimated that, from 1996 to 2000, the average annual harvest from the SE Alaska stock was 301 animals (Angliss and Lodge 2002).

Since 1992, the seasonal distribution of harbor seal takes by Alaska Natives has shown two distinct hunting peaks, one during spring, and the other during fall and early winter (Wolfe et al. 2003). The peak harbor seal harvest season for villages in SE Alaska and the northern GOA varies (Table 4), but in general the months of highest harvest are September through December, with a smaller peak in March. Harvests are traditionally low from May through August, when harbor seals are raising pups and molting in SE Alaska. The Steller sea lion harvest in SE Alaska and the northern GOA is low throughout the year. In 2002, the only harvests in SE Alaska occurred during March and November, and in the northern GOA and PWS, harvests occurred in July, November, and December (Wolfe et al. 2003).

The subsistence harvest of sea otters occurs year–round in coastal communities throughout SE Alaska and the northern GOA. However, there is a general reduction in harvest during the summer months (D. Willoya, The Alaska Sea Otter and Steller Sea Lion Commission, pers. comm.). Hunters are required to obtain tags for sea otter pelts from designated USFWS taggers located in all harvesting villages. The geographical distribution of the harvest is difficult to determine because reports are generated by marking location; harvest location is generally not recorded (USFWS unpublished data). Harvests can take place from a large geographic area surrounding each sea otter harvesting village (D. Willowa, pers. comm.).

Beluga whales do not occur regularly within the project area (see § IV). Any occasional subsistence hunting of belugas that might occur in that area would be opportunistic hunting of extralimital animals.

Gray whales are not hunted within the project area. Some of the gray whales that migrate through SE Alaskan waters in spring and late autumn are hunted in Russian waters during summer, and a very limited subsistence hunt has occurred in recent years off Washington. Any small-scale disturbance effects that might occur in SE Alaska as a result of L-DEO's project would have no effect on the hunts for gray whales in those distant locations.

The proposed project could potentially impact the availability of marine mammals for harvest in a very small area immediately around the *Ewing*, and for a very short time period during seismic activities. However, considering the limited time and locations for the planned seismic surveys, the proposed project is not expected to have any significant impacts to the availability of Steller sea lions, harbor seals, or sea otters for subsistence harvest. Nonetheless, L-DEO will coordinate its activities with local communities, so that seismic operations will be conducted outside of subsistence hunting times and areas if possible.

On average, subsistence fisheries provide about 230 pounds of food per person per year in rural Alaska (Wolfe 2000). Of the estimated 43.7 million pounds of wild foods harvested in rural Alaska communities annually, subsistence fisheries contribute ~60% from finfish and 2% from shellfish. In the rural communities along the GOA, salmon species are the most targeted subsistence fish.

Seismic surveys can, at times, cause changes in the catchability of fish. L-DEO will minimize the potential to negatively impact the subsistence fish harvest by actively avoiding conducting seismic or coring operations in areas where subsistence fishers are actively fishing. Additionally, L-DEO will consult with each village near the planned project area to identify and avoid areas of potential conflict. These consultations will include all marine subsistence activities (mammals and fisheries).

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 utilize. The main impact issue associated with the proposed activity will be temporarily elevated noise levels and the associated direct effects on marine mammals, as discussed in § VI/VII, above.

The actual area that will be affected by coring operations will be a very small fraction of the marine mammal habitat and the habitat of their food species in the area; thus, any effects are expected to be insignificant. Coring operations would result in no more than a negligible and highly localized short-term disturbance to sediments and benthic organisms. The area that might be disturbed is a very small fraction of the overall area.

One of the reasons for the adoption of airguns as the standard energy source for marine seismic surveys was that they (unlike the explosives used in the distant past) do not result in any appreciable fish kill. Various experimental studies showed that airgun discharges cause little or no fish kill, and that any injurious effects were generally limited to the water within a meter or so of an airgun. However, it has recently been found that injurious effects on captive fish, especially on fish hearing, may occur to somewhat greater distances than previously thought (McCauley et al. 2000a,b, 2002; 2003). Even so, any injurious effects on fish would be limited to short distances. Also, many of the fish that might otherwise be within the injury-radius are likely to be displaced from this region prior to the approach of the airguns through avoidance reactions to the passing seismic vessel or to the airgun sounds as received at distances beyond the injury radius.

Short, sharp sounds can cause overt or subtle changes in fish behavior. Chapman and Hawkins (1969) tested the reactions of whiting (hake) in the field to an airgun. When the airgun was discharged, the fish dove from 25 to 55 m (80–180 ft) depth and formed a compact layer. By the end of an hour of exposure to the sound pulses, the fish had habituated; they rose in the water despite the continued presence of the sound pulses. However, they began to descend again when the airgun resumed firing after it had stopped. The whiting dove when received sound levels were higher than 178 dB re 1 µPa (peak pressure[2]) (Pearson et al. 1992).

Pearson et al. (1992) conducted a controlled experiment to determine effects of strong noise pulses on several species of rockfish off the California coast. They used an airgun with a source level of 223 dB re 1 µPa. They noted

- startle responses at received levels of 200–205 dB re 1 µPa (peak pressure) and above for two sensitive species, but not for two other species exposed to levels up to 207 dB;
- alarm responses at 177–180 dB (peak) for the two sensitive species, and at 186 to 199 dB for other species;
- an overall threshold for the above behavioral response at about 180 dB (peak pressure);
- an extrapolated threshold of about 161 dB (peak) for subtle changes in the behavior of rockfish; and
- a return to pre-exposure behaviors within the 20–60 min exposure period.

In other airgun experiments, catch per unit effort (CPUE) of demersal fish declined when airgun pulses were emitted (Dalen and Raknes 1985; Dalen and Knutsen 1986; Skalski et al. 1992). Reductions in the catch may have resulted from a change in behavior of the fish. The fish schools descended to near the bottom when the airgun was firing, and the fish may have changed their swimming and schooling behavior. Fish behavior returned to normal minutes after the sounds ceased. In the Barents Sea abundance of cod and haddock measured acoustically was reduced by 44% within 9.2 km (5.0 n.mi.) of an area where airguns operated (Engås et al. 1993). Actual catches declined by 50% throughout the trial area and 70% within the shooting area. This reduction in catch decreased with increasing distance to 30–33 km (16.2–17.8 n.mi.) where catches were unchanged.

Other recent work concerning behavioral reactions of fish to seismic surveys, and concerning effects of seismic surveys on fishing success, is reviewed in Turnpenny and Nedwell (1994), Santulli et al. (1999), Hirst and Rodhouse (2000), Thomson et al. (2001), Wardle et al. (2001), and Engås and Løkkeborg (2002).

In summary, fish often react to sounds, especially strong and/or intermittent sounds of low frequency. Sound pulses at received levels of 160 dB re 1 µPa (peak) may cause subtle changes in behavior. Pulses at levels of 180 dB (peak) may cause noticeable changes in behavior (Chapman and Hawkins 1969; Pearson et al. 1992; Skalski et al. 1992). It also appears that fish often habituate to repeated strong sounds rather rapidly, on time scales of minutes to an hour. However, the habituation does not endure, and resumption of the disturbing activity may again elicit disturbance responses from the same fish.

Fish near the airguns are likely to dive or exhibit some other kind of behavioral response. This might have short-term impacts on the ability of cetaceans to feed near the survey area. However, only a small fraction of the available habitat would be ensonified at any given time, and fish species would return to their pre-disturbance behavior once the seismic activity ceased. Thus, the proposed surveys would have little impact on the abilities of marine mammals to feed in the area where seismic work is

[2] For airgun pulses, root-mean-square (rms) pressures, averaged over the pulse duration, are on the order of 10–13 dB less than peak pressure (Greene 1997; McCauley et al. 1998, 2000b).

planned. Some of the fish that do not avoid the approaching airguns (probably a small number) may be subject to auditory or other injuries.

Zooplankters that are very close to the source may react to the shock wave. These animals have an exoskeleton and no air sacs. Little or no mortality is expected. Many crustaceans can make sounds and some crustacea and other invertebrates have some type of sound receptor. However, the reactions of zooplankters to sound are not known. Some mysticetes feed on concentrations of zooplankton. A reaction by zooplankton to a seismic impulse would only be relevant to whales if it caused a concentration of zooplankton to scatter. Pressure changes of sufficient magnitude to cause this type of reaction would probably occur only very close to the source. Impacts on zooplankton behavior are predicted to be negligible, and this would translate into negligible impacts on feeding mysticetes.

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

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

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

The effects of the planned activity on marine mammal habitats and food resources are expected to be negligible, as described above. A small minority of the marine mammals that are present near the proposed activity may be temporarily displaced as much as a few kilometers by the planned activity.

Several cetacean species may be feeding in the area at the time of the survey, including humpback, gray, and fin whales. Feeding aggregations of humpback whales are known to occur in the GOA. In GBNPP, the number of feeding humpback whales are thought to peak in July and August, with lower counts in May and September. Feeding aggregations of gray whales could occur in the GOA during late October. North Pacific right whales apparently feed off southern and western Alaska from May to September. However, considering the rarity of right whale sightings, and the generally restricted area in which sightings in Alaska have been made, it is highly unlikely that any right whales will be seen during the proposed surveys.

Several species of pinnipeds are also known to feed and/or breed within the study area at the time of the proposed survey. Northern fur seals breed in the area from June to September, whereas the breeding season for harbor seals and Steller sea lions occurs before the proposed survey is expected to commence.

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, since operations at the various sites will be limited in duration. In addition, the vessel will attempt to avoid Steller sea lion rookeries and haulout sites if possible.

XI. Mitigation Measures

For the proposed seismic survey in the GOA in late summer/early autumn 2004, L-DEO will deploy 2 GI airguns as an energy source, with a total discharge volume of 210 in^3. The energy from the airguns will be directed mostly downward. The small size of the airguns to be used during the proposed study is an inherent and important mitigation measure that will reduce the potential for effects relative to those that might occur with large airgun arrays.

Received sound levels have been estimated by L-DEO in relation to distance from the 2 GI airguns. The radii around the 2 GI airguns where received levels would be 180 and 190 dB re 1 μPa (rms), depend on water depth, and are shown in Table 1 (in § I). The 180 and 190 dB levels are shut-down criteria applicable to cetaceans and pinnipeds, respectively, as specified by NMFS (2000).

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

Several cetacean species (including humpback and fin whales) are known to feed in the area at the time of the proposed survey. However, the number of individual animals expected to be closely approached during the proposed activity will be small in relation to regional population sizes. With the proposed monitoring and shut-down provisions (see below), any effects on individuals are expected to be limited to behavioral disturbance. This is expected to have negligible impacts on the species and stocks.

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

Marine Mammal Monitoring

Vessel-based observers will monitor marine mammals near the seismic source vessel during all daytime airgun operations and during any nighttime start ups of the airguns. These observations will provide the real-time data needed to implement some of the key mitigation measures. When marine mammals are observed within, or about to enter, designated safety zones (see below) where there is a possibility of significant effects on hearing or other physical effects, airgun operations will be shut down immediately.

- During daylight, vessel-based observers will watch for marine mammals near the seismic vessel during all periods with shooting and for a minimum of 30 min prior to the planned start of airgun operations after an extended shut down.
- L-DEO proposes to conduct nighttime as well as daytime operations. Observers dedicated to marine mammal observations will not be on duty during ongoing seismic operations at night. At night, bridge personnel will watch for marine mammals (insofar as practical at night) and will call for the airguns to be shut down if marine mammals are observed in or about to enter the safety radii. If the airguns are started up at night, two marine mammal observers will monitor marine mammals near the source vessel for 30 min prior to start up of the airguns using night vision devices.

Proposed Safety Radii

Received sound levels have been modeled by L-DEO for the 2 GI guns, in relation to distance and direction from the airguns (Fig. 2). The model does not allow for bottom interactions, and is most directly applicable to deep water. Based on the model, the distances from the 2 GI guns where sound levels of 190, 180, 170, and 160 dB re 1 µPa (rms) are predicted to be received are shown in the >1000 m line of Table 2 (§ I).

Empirical data concerning the 180, 170 and 160 dB distances have been acquired based on measurements during the acoustic verification study conducted by L-DEO in the northern Gulf of Mexico from 27 May to 3 June 2003 (Tolstoy et al. 2004). Although the results are limited, the data showed that radii around the airguns where the received level would be 180 dB re 1 µPa (rms), the safety criterion applicable to cetaceans (NMFS 2000), vary with water depth. Similar depth-related variation is likely in the 190 dB distances applicable to pinnipeds.

The proposed study area will occur in water ~30–3000 m (<98–9843 ft). In ***deep*** (>1000 m or 3281 ft) water, the safety radii during airgun operations will be the values predicted by L-DEO's model (Table 2). Therefore, the assumed 180- and 190-dB radii are 54 m (177 ft) and 17 m (56 ft), respectively. For operations in ***shallow*** (<100 m or 328 ft) water, conservative correction factors were applied to the predicted radii for the 2 GI gun array. The 180- and 190-dB radii in shallow water are assumed to be 400 m (1312 ft) and 250 m (820 ft), respectively. In ***intermediate*** depths (100–1000 m or 328–3281 ft), a 1.5x correction factor was applied to the estimates provided by the model for deep water situations. The assumed 180- and 190-dB radii in intermediate-depth water are 81 m (266 ft) and 26 m (85 ft), respectively. For more a more detailed explanation on how these safety radii were derived, please refer to the section on "Airgun Description" in § I.

The 2 GI guns will be immediately shut down when cetaceans or pinnipeds are detected within or about to enter the appropriate 180- or 190-dB radius, respectively. The 180 and 190 dB shut-down criteria are consistent with guidelines listed for cetaceans and pinnipeds, respectively, by NMFS (2000) and other guidance by NMFS. L-DEO is aware that NMFS is likely to release new noise-exposure guidelines soon. L-DEO will be prepared to revise its procedures for estimating numbers of mammals "taken", safety radii, etc., as may be required by the new guidelines.

Mitigation During Operations

In addition to marine mammal monitoring, mitigation measures that will be adopted will include (1) speed or course alteration, provided that doing so will not compromise operational safety requirements, (2) shut-down procedures, and (3) avoid encroaching upon critical habitat around Steller sea lion rookeries and haulouts. Special mitigation measures will be implemented for the North Pacific right whale (*Eubalaena japonica*). This species is of special concern due to its low population size (see "Shut-down Procedures", below).

Although a "power-down" procedure is often applied by L-DEO during seismic surveys with larger arrays of airguns, powering down to a single gun will not occur during the proposed project. Powering down from two guns to one gun would make only a small difference in the 180 or 190 dB radius—probably not enough to allow continued one-gun operations if a mammal came within the safety radius for two guns. Likewise, although ramp-up procedures are usually followed by L-DEO prior to airgun operations, ramp ups are not considered to be useful during the proposed project because of the small discharge volume of the 2 GI guns (210 in^3).

At night, vessel lights and/or NVDs[3] could be useful in sighting some marine mammals *at the surface* within a short distance from the ship (within the safety radii for the 2 GI guns in deep and intermediate waters). Thus, start up of the airguns may be possible at night in deep and intermediate waters, in situations when the entire safety radius is visible with vessel lights and NVDs. However, lights and NVDs will probably not be very effective as a basis for monitoring the larger safety radii around the 2 GI guns operating in shallow water. In shallow water, nighttime start ups of the airguns are not expected to be possible.

Speed or Course Alteration

If a marine mammal is detected outside the safety radius and, based on its position and the relative motion, is likely to enter the safety radius, the vessel's speed and/or direct course may, when practical and safe, be changed in a manner that also minimizes the effect to the planned science objectives. The marine mammal activities and movements relative to the seismic vessel will be closely monitored to ensure that the marine mammal does not approach within the safety radius. If the mammal appears likely to enter the safety radius, further mitigative actions will be taken, i.e., either further course alterations or shut down of the airguns. In the closely constrained waters of Lynn Canal, Muir Inlet, and Frederick Sound, it is unlikely that significant alterations to the vessel's speed or course could be made. In these circumstances, shut-down procedures would be implemented rather than speed or course changes.

Shut-down Procedures

If a marine mammal is detected outside the safety radius but is likely to enter the safety radius, and if the vessel's course and/or speed cannot be changed to avoid having the mammal enter the safety radius, the airguns will be shut down before the mammal is within the safety radius. Likewise, if a mammal is already within the safety radius when first detected, the airguns will be shut down immediately. The airguns will be shut down if a North Pacific right whale is sighted from the vessel, even if it is located outside the safety radius, because of the rarity and sensitive status of this species.

Airgun activity will not resume until the marine mammal has cleared the safety radius. The animal will be considered to have cleared the safety radius if it is visually observed to have left the safety radius, or if it has not been seen within the radius for 15 min (small odontocetes and pinnipeds) or 30 min (mysticetes and large odontocetes, including sperm, and beaked whales).

If the complete safety radius has not been visible for at least 30 min prior to the start of operations in either daylight or nighttime, airgun operations will not commence. However, if the airgun array has been operational before nightfall, it can remain operational throughout the night, even though the entire safety radius may not be visible. If the entire safety radius is visible at night, using vessel lights and NVDs (as may be the case in deep and intermediate waters), then start up of the airguns may occur at night.

---

[3] See Smultea and Holst (2003) and Holst (2004) for an evaluation of the effectiveness of night vision equipment for nighttime marine mammal observations.

XII. Plan of Cooperation

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

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

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

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

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

Not applicable. The proposed activity will take place in the GOA, 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 Incidental Harassment Authorization.

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

At least three observers dedicated to marine mammal observations will be stationed aboard L-DEO's seismic survey vessel for the study in the GOA. Observers will be appointed by L-DEO with NMFS concurrence.

It is proposed that one or two MMOs aboard the seismic vessel will search for and observe marine mammals whenever airgun operations are in progress during daylight hours. When feasible, observations will also be made during daytime periods without airgun operations.

Two observers will be on duty for 30 min prior to the start of airgun operations after an extended shut down. The 30-min observation period is only required prior to commencing seismic survey operations following a shut down of the airguns for more than 1 hr.

If the airguns must be started up at night, two MMOs will be on duty starting at least 30 min prior to the start of airgun operations. The airguns will not be started up at night or during the day in poor visibility unless the entire safety radius for the 2 GI airguns is visible. Other than the specified periods mentioned above, no observers will be required to be on duty during seismic operations at night. However, L-DEO bridge personnel (port and starboard seamen and one mate) will assist in marine mammal observations whenever possible, and especially during operations at night, when designated MMOs will not normally be on duty. At least one MMO will be on "standby" at night, in case bridge personnel see a marine mammal. Two image-intensifying night-vision devices (NVDs) will be available for use at night. These are ITT Industries Night Quest NQ220 "Night Vision Viewer" devices, equipped with a 3x magnification lens. The NQ220 is a Generation III binocular NVD.

If the airguns are shut down, observers will continue to maintain watch to determine when the animal is outside the safety radius. The airguns will not be started up again, until the observer has determined that the animal has cleared the safety zone. A mammal will be assumed to be clear of the safety zone if it is visually observed to have left that zone, or if it has not been seen within the zone for 15 min (small odontocetes and pinnipeds) or 30 min (mysticetes and large odontocetes). For this purpose, "large odontocetes" will include sperm, pygmy sperm, dwarf sperm, and beaked whales.

The MMOs will watch for marine mammals from the highest practical vantagepoint on the vessel, which is either the bridge or the flying bridge. On the bridge of the *Ewing*, the observer's eye level will be 11 m (36 ft) above sea level, allowing for good visibility within a 210º arc. If observers are stationed on the flying bridge, the eye level will be 14.4 m (47.2 ft) above sea level. During daytime, the MMOs will systematically scan the area around the vessel with reticle binoculars (e.g., 7 × 50 Fujinon). At night, night vision equipment will be available, if required. Laser rangefinding binoculars (Leica LRF 1200 laser rangefinder or equivalent) will be available to assist with distance estimation. These are useful in training observers to estimate distances visually, but are generally not useful in measuring distances to marine mammals directly. If a marine mammal is seen well outside the safety radius, the vessel may be maneuvered to avoid having the mammal come within the safety radius (see Section XI, "Mitigation", above). When mammals are detected within or about to enter the designated safety radii, the airguns will be shut down immediately. The observer(s) will continue to maintain watch to determine when the animal is outside the safety radius. Airgun operations will not resume until the animal is observed to be outside the safety radius or until the specified intervals (15 or 30 min) have passed without a re-sighting.

The vessel-based monitoring will provide data required to estimate the numbers of marine mammals exposed to various received sound levels, to document any apparent disturbance reactions, and thus to estimate the numbers of mammals potentially "taken" by harassment. It will also provide the information needed in order to shut down the airguns at times when mammals are present in or near the safety zone. When a mammal 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 seismic vessel (e.g., none, avoidance, approach, paralleling, etc.), and behavioral pace.

2. Time, location, heading, speed, activity of the vessel (shooting or not), sea state, visibility, cloud cover, 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 mammal observations and airgun shut downs will be recorded in a standardized format. Data will be entered into a custom database using a laptop computer when observers are off-duty. The accuracy of the data entry will be verified by computerized validity checks as the data are entered and by subsequent manual and computer checking of the database. These procedures will allow initial summaries of data to be prepared during and shortly after the field program, and will facilitate transfer of the data to statistical, graphical or other programs for further processing and archiving.

Observers will be on duty in shifts of duration no longer than 4 hours. A second observer will also be on watch part of the time, including the 30-min periods preceding startup of the airguns. Use of two simultaneous observers will increase the proportion of the marine mammals present near the source vessel that are detected. Bridge personnel additional to the dedicated MMOs will also assist in detecting marine mammals and implementing mitigation requirements, and before the start of the seismic survey will be given additional instruction in how to do so. (Most if not all bridge personnel will have had previous experience of this type during prior cruises aboard the *Ewing.*)

Results from the vessel-based observations will provide

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

Reporting

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

XIV. Coordinating Research to Reduce and Evaluate Incidental Take

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

L-DEO will coordinate the planned project with other parties that may or are planning to sponsor, conduct or participate in marine mammal, acoustical, and oceanographic studies in the same region during the corresponding part of 2004.

This EA has been adopted by the NSF primarily to address issues relating to the request that an IHA be issued by NMFS to authorize "taking by harassment" (disturbance) of small numbers of cetaceans and pinnipeds during L-DEO's planned project activities. In addition, L-DEO and NSF will coordinate with other applicable Federal and State agencies, and will comply with their requirements. Actions of this type that are underway in parallel with the request for issuance of an IHA include the following:

- Submission in early April 2004 of a request to the State of Alaska confirming that the project is in compliance with state and local Coastal Management Programs.
- Coordination on 25 March 2004 with the NMFS Alaska Region, Anchorage, AK, concerning compliance with requirements within areas designated as Critical Habitat for Steller sea lions.
- Coordination with the Alaska Department of Fish and Game's regional supervisors for the Commercial Fisheries Division (Andy McGregor for the SE region and Jeff Regnart for Central Region), concerning fisheries issues in state waters.
- Coordination with the Alaska Native Harbor Seal Commission, the Alaska Sea Otter and Steller Sea Lion Commission, and local communities within the project area with regard to potential concerns about interactions with fisheries and subsistence hunting.
- Coordination on 1 April 2004 with the USFWS, Marine Mammals Management, Anchorage, AK, regarding concerns about possible impacts on sea otters.
- Coordination with the NPS, regarding access to GBNPP. A "Scientific Research and Collecting Permit" was issued to the project by NPS in early April 2004.

XV. LITERATURE CITED

Agler, B.A., S.J. Kendall, P.E. Seiser, and J.R. Lindell. 1995. Estimates of marine bird and sea otter abundance in southeast Alaska during summer 1994. Migratory Bird Management, U.S. Fish and Wildife Service, Anchorage, Alaska. 90 p.

Akamatsu, T., Y. Hatakeyama and N. Takatsu. 1993. Effects of pulsed sounds on escape behavior of false killer whales. **Nippon Suisan Gakkaishi** 59(8):1297-1303.

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.

Angliss, R.P. and K.L. Lodge. 2002. Alaska marine mammal stock assessments, 2002. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-133. 224 p.

Anonymous. 1975. Phantom killer whales. **S. Afr. Ship. News Fish. Ind. Rev.** 30(7):50-53.

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.

Arnold, B.W. 1996. Visual monitoring of marine mammal activity during the Exxon 3-D seismic survey: Santa Ynez unit, offshore California 9 November to 12 December 1995. Rep. by Impact Sciences Inc., San Diego, CA, for Exxon Company, U.S.A., Thousand Oaks, CA. 20 p.

Au, W. W. L., A.N. Popper and R.R. Fay. 2000. Hearing by Whales and Dolphins. Springer-Verlag, New York, NY. 458 p.

Au, W., J. Darling and K. Andrews. 2001. High-frequency harmonics and source level of humpback whale songs. **J. Acoust. Soc. Am.** 110(5, Pt. 2):2770.

Au, W.W.L. 1993. The sonar of dolphins. Springer-Verlag, New York, NY. 277 p.

Backus, R.H. and W.E. Schevill. 1966. *Physeter* clicks. p. 510-528 *In:* K.S. Norris (ed.), Whales, Dolphins, and Porpoises. University of California Press, Berkeley.

Bain, D.E., B. Kriete and M.E. Dahlheim. 1993. Hearing abilities of killer whales (*Orcinus orca*). **J. Acoust. Soc. Am.** 94(3, Pt 2):1829.

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

Baker, C.S. 1985. Humpback whales of Glacier Bay and adjacent waters, summer 1985. U.S. National Park Service, Glacier Bay National Park and Preserve, Gustavus, AK.

Baker, C.S. 1986. Population characteristics of humpback whales in Glacier Bay and adjacent waters, summer 1986. U.S. National Park Service, Glacier Bay National Park and Preserve, Gustavus, AK.

Baker, C.S., S.T. Palumbi, R.H. Lambertsen, M.T. Weinrich, J.Calambokidis, and S.J. O'Brien. 1990. Influence of seasonal migration on geographic distribution of mitochondrial DNA haplotypes in humpback whales. **Nature** 344:238-240.

Balcomb, K.C. 1989. Baird's Beaked Whales *Berardius bairdii* Stejneger, 1883; Arnoux Beaked Whale *Berardius arnuxii* Duvernoy, 1851. p. 261-288 *In:* S.H. Ridgway and S.R. Harrison (eds.), Handbook of Marine Mammals. Vol. 4. River Dolphins and the Larger Toothed Whales. Academic Press, London.

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. 2003. Preliminary estimates of the abundance of cetaceans along the U.S. West Coast: 1991-2001. Administrative Report LJ-03-03, Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, CA. 31 p.

Barlow, J., R.W. Baird, J.E. Heyning, K. Wynne, A.M. Manville II, L.F. Lowry, D. Hanan, J. Sease, and V.N. Burkanov. 1994. A review of cetacean and pinniped mortality in coastal fisheries along the west coast of the USA and Canada and the east coast of the Russian Federation. **Rep. Int. Whal. Comm., Spec. Iss.** 15:405-425.

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.** 13:614-638.

Bernard, H.J. and B. Reilly. 1999. Pilot whales—*Globicephala Lesson*, 1828. p. 245-280 *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.

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.

Best, P.B., P.A.S. Canham and N. Macleod. 1984. Patterns of reproduction in sperm whales, *Physeter macrocephalus*. **Rep. Int. Whal. Comm., Spec. Iss.** 6:51-79.

Bickham, J.W., J.C. Patton and T.R. Loughlin. 1996. High variability for control-region sequences in a marine mammal: Implications for conservation and biogeography of Steller sea lions (*Eumetopias jubatus*). **J. Mammal.** 77(1):95-108.

Bigg, M. A. 1969. The harbour seal in British Columbia. **Fish. Res. Bd. Can. Bull.** 172. 33 p.

Bigg, M.A.. 1981. Harbor seal, *Phoca vitulina*, Linneaus, 1758 and *Phoca largha*, Pallas, 1811. p. 1-27 *In*: S.H. Ridgeway and R.J. Harrison (eds.), Handbook of Marine Mammals, Vol. 2: Seals. Academic Press, New York.

Bishop, R.H. 1967. Reproduction, age determination, and behavior of the harbor seal, *Phoca vitulina l.* in the Gulf of Alaska. M.S. thesis, Univ. Alaska, Fairbanks, AK. 121 p.

Bjørge, A. and K.A. Tolley. 2002. Harbor porpoise *Phocoena phocoena*. p. 549-551 *In:* W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of Marine Mammals. Academic Press, San Diego, CA. 1414 p.

Bodkin, J.L., K.A. Kloecker, G.G. Esslinger, D.H. Monson, and J.D. DeGroot. 2001. Sea otter studies in Glacier Bay National Park and Preserve: aerial surveys, foraging observations, and intertidal clam sampling 2000 annual report. U.S. Geological Survey, Alaska Biological Science Center, Anchorage, AK. 11 p.

Bodkin, J.L. and M.S. Udevitz. 1999. An aerial survey method to estimate sea otter abundance. *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. Rotterdam. 287 p.

Boveng, P. 1988. Status of the California sea lion population on the U.S. west coast. Admin. Rep. LJ-88-07. Southwest Fisheries Science Center, National Marine Fisheries Service, P.O. Box 271, La Jolla, CA 92038. 26 p.

Bowles, A.E., S.E. Eckert, L. Starke, E. Berg, and L. Wolski. 1999. Final Report: Effects of flight noise from jet aircraft and sonic booms on hearing, behavior, heart rate, and oxygen consumption of desert tortoises *(Gopherus agassizi*i). Hubbs-Sea World Research Institute and Parsons Engineering Science, for U.S. Air Force, Armstrong Laboratory, Brooks Air Force Base, TX, on Contract F33615-89-D-4003, Order 0132, 8 April 1999.

Braham, H.W. 1984. Distribution and migration of gray whales in Alaska. *In:* M.L. Jones, S.L. Swartz, S. Leatherwood (eds.), The gray whale *Eschrichtius robustus*. Academic Press, Orlando, FL.

Brueggeman, J.J., G.A. Gren, K.C. Balcomb, C.E. Bowlby, R.A. Grotefendt, K.T. Briggs, M.L. Bonnell, R.G. Ford, D.H. Varoujean, D. Heinemann, and D.G. Chapman. 1990. Oregon-Washington Marine Mammal and Seabird Survey: Information synthesis and hypothesis formulation. OCS Study MMS 89-0030. Rep. from Envirosphere Co., Bellevue, WA, and Ecological Consulting Inc., Portland, OR, for U.S. Minerals Manage. Serv., Pacific Region, Los Angeles, CA. 374 p.

Buckland, S.T., K.L. Cattanach and R.C. Hobbs. 1993a. 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.

Buckland, S.T., J.M. Breiwick, K.L. Cattanach, and J.L. Laake. 1993b. Estimated population size of the California gray whale. **Mar. Mamm. Sci.** 9(3):235-249.

Bullock, T.H., T.J. O'Shea and M.C. McClune. 1982. Auditory evoked potentials in the West Indian manatee (Sirenia: *Trichechus manatus*). **J. Comp. Physiol. A** 148(4):547-554.

Burgess, W.C. and C.R. Greene, Jr. 1999. Physical acoustics measurements. p. 3-1 to 3-63 *In*: W.J. Richardson (ed.), Marine mammal and acoustical monitoring of Western Geophysical's open-water seismic program in the Alaskan Beaufort Sea, 1998. LGL Rep. TA22303. Rep. from 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.

Burgess, W.C. and J.W. Lawson. 2000. Marine mammal and acoustic monitoring of Western Geophysical's shallow-hazards survey in the Alaskan Beaufort Sea, summer 2000. p. C-1 to C-28 *In*: W.J. Richardson (ed.), Marine mammal and acoustical monitoring of Western Geophysical's open-water seismic program in the Alaskan Beaufort Sea, 2000: 90-day report. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for Western Geophysical, Anchorage, AK, and U.S. Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 121 p.

Calambokidis, J. and J. Barlow. 2004. Abundance of blue and humpback whales in the eastern North Pacific estimated by capture-recapture and line-transect methods. **Mar. Mamm. Sci.** 20(1):63-85.

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. Draft Rep. from Cascadia Research, Olympia, WA, for U.S. Geol. Surv., Nat. Mar. Fish. Serv., and Minerals Manage. Serv.

Calambokidis, J., G.H. Steiger, J.C. Cubbage, K.C. Balcomb, C. Ewald, S. Kruse, R. Wells, and R. Sears. 1990. Sightings and movements of blue whales off central California 1986-88 from photo-identification of individuals. **Rept. Int. Whal. Comm., Spec. Iss.** 12:343-348.

Calambokidis, J., G.H. Steiger, J.M. Straley, T.J. Quinn, II, L.M. Herman, S. Cerchio, D.R. Salden, M.Yamaguchi, F. Sato, J. Urban R., 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 Center, P.O. Box 271, La Jolla, CA 92038. 72 p.

Calambokidis, J., J.D. Darling, V. Deecke, P. Gearin, M. Gosho, W. Megill, C.M. Tombach, D. Goley, C. Toropova, and B. Gisborne. 2002. Abundance, range and movements of a feeding aggregation of gray whales (*Eschrichtius robustus*) from California to southeastern Alaska in 1998. **J. Cetacean Res. Manage.** 4(3):267-276.

Caldwell, J. 2002. Does air-gun noise harm marine mammals? **The Leading Edge** 2002(1, Jan.):75-78.

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

Calkins, D.G., D.C. McAllister, K.W. Pitcher, and G.W. Pendleton. 1999. Steller sea lion status and trend in Southeast Alaska: 1979-1997. **Mar. Mamm. Sci**. 15(2):462-477.

Cameron, G. and K.A. Forney. 1999. Estimates of cetacean mortality in the California gillnet fisheries for 1997 and 1998. Paper SC/51/04 presented to the International Whaling Commission, May 1998 (unpublished). 14 p.

Carbotte, S.M., C.Z. Mutter, J. Mutter and G. Ponce-Correa. 1998. Influence of magma supply and spreading rate on crustal magma bodies and emplacement of the extrusive layer: insights from an intermediate-fast spreading ridge. **Geology** 26:455-458.

Carbotte, S.M., G. Ponce-Correa and A. Solomon. 2000. Evaluation of morphological indicators of magma supply and segmentation from a seismic reflection study of the EPR 15º30'-17ºN. **J. Geophys. Res.-Solid Earth** 105:2737-2759.

Carretta, J.V., J. M.M. Muto, J. Barlow, J. Baker, K.A. Forney, and M. Lowry. 2002. U.S. Pacific Marine Mammal Stock Assessments: 2002. NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-346. 286 p.

Carretta, J.V., M.S. Lynn and C.A. LeDuc. 1994. Right whale, *Eubalaena glacialis*, sighting off San Clemente Island, California. **Mar. Mamm. Sci.** 10(1):101-104.

Carwardine, M. 1995. Whales, Dolphins and Porpoises. Dorling Kindersley Publ., Inc., New York, NY. 256 p.

Cavanagh, R.C. 2000. Criteria and thresholds for adverse effects of underwater noise on marine animals. Rep by Science Applications Intern. Corp., McLean, VA, for Air Force Res. Lab., Wright-Patterson AFB, Ohio. AFRL-HE-WP-TR-2000-0092.

Cerchio, S. and M. Dahlheim. 2001. Variation in feeding vocalizations of humpback whales *Megaptera novaeangliae* from southeast Alaska. **Bioacoustics** 11:277-295.

Chapman, C.J. and A.D. Hawkins. 1969. The importance of sound in fish behaviour in relation to capture by trawls. p 717-729 *In:* A. Ben-Tuvia and W. Dickson (eds.), Proc. FAO conference on fish behaviour in relation to fishing techniques and tactics. 19-27 Oct. 1967. FAO Fisheries Report No. 62, Vol. 3, Rome.

Christal, J., H. Whitehead and E. Lettevall. 1998. Sperm whale social units: variation and change. **Can. J. Zool.** 76(8):1431-1440.

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. and C.A. Mayo. 1990. Reproduction of humpback whales, *Megaptera novaeangliae*, observed in the Gulf of Maine. **Rep. Int. Whal. Comm., Spec. Iss.** 12:171-175.

Croll, D.A., C.W. Clark, A. Acevedo, B. Tershy, S. Flores, J. Gedamke, and J. Urban. 2002. Bioacoustics: Only male fin whales sing loud songs. **Nature** 417(6891):809.

Cummings, W.C. and P.O. Thompson. 1971. Underwater sounds from the blue whale, *Balaenoptera musculus*. **J. Acoust. Soc. Am.** 50(4, Pt. 2):1193-1198.

Cummings, W.C. and P.O. Thompson. 1994. Characteristics and seasons of blue and finback whale sounds along the U.S. west coast as recorded at SOSUS stations. **J. Acoust. Soc. Am.** 95(5, Pt.2):2853.

Cummings, W.C., P.O. Thompson and S.J. Ha. 1986. Sounds from Bryde, *Balaenoptera edeni*, and finback, *B. physalus*, whales in the Gulf of California. **Fish. Bull.** 84(2):359-370.

Dahlheim, M.E 1987. Bio-acoustics of the gray whale (*Eschrichtius robustus*). Ph.D. Thesis, Univ. Brit. Columbia, Vancouver, B.C. 315 p.

Dahlheim, M.E. 1988. Killer whale (*Orcinus orca*) depredation on longline catches of sablefish (*Anoplopoma fimbria*) in Alaskan waters. U.S. Dep. Commerce, NWAFC Processed Rep. 88-14. 31 p.

Dahlheim, M.E. and J.E. Heyning. 1999. Killer whale *Orcinus orca* (Linnaeus, 1758). p. 281-322 *In:* S.H. Ridgway and R. Harrison (eds.), Handbook of Marine Mammals. Vol. 6. The Second Book of Dolphins and the Porpoises. Academic Press, San Diego, CA. 486 p.

Dahlheim, M.E. and R.G. Towell. 1994. Occurrence and distribution of Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) in southeastern Alaska, with notes on an attack by killer whales (*Orcinus orca*). **Mar. Mamm. Sci.** 10(4):458-464.

Dahlheim, M., A. York, R. Towell, J. Waite, and J. Breiwick. 2000. Harbor porpoise (*Phocoena phocoena*) abundance in Alaska: Bristol Bay to Southeast Alaska, 1991-1993. **Mar. Mamm. Sci.** 16(1):28-45.

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

Dalen, J. 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.

Darling, J.D. 1984. Gray whales off Vancouver Island, British Columbia. p. 2676-287 *In:* M.L. Jones, S.L. Swartz and S. Leatherwood (eds.), The Gray whale, *Eschrichtius robustus*. Academic Press, Orlando, Florida.

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.

Doherty, J. L. and C. M. Gabriele. 2001. Population characteristics of humpback whales in Glacier Bay and adjacent waters: 2001. Glacier Bay National Park and Preserve, Gustavus, AK.

Doroff, A.M. and C.S. Gorbics. 1998. Sea otter surveys of Yakutat Bay and adjacent Gulf of Alaska coastal areas – Cape Hinchinbrook to Cape Spencer 1995–1996. Minerals Manage. Ser., OCS Study MMS 97-0026.

Doroff, A.M., J.A. Estes, M. T. Tinker, D.M. Burn, and T.J. Evans. 2003. Sea otter population declines in the Aleutian Archipelago. **J. Mammal.** 84(1):55-64.

Doroshenko, N.V. 2000. Soviet whaling for blue, gray, bowhead and right whales in the North Pacific Ocean, 1961-1979. *In:* A.V. Yablokov and V.A. Zemsky (eds.), Soviet Whaling Data (1949-1979). Center for Russian Environmental Policy, Marine Mammal Council, Moscow, Russia.

Duncan, P.M. 1985. Seismic sources in a marine environment. p. 56-88 *In*: 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.

Edds, P.L. 1988. Characteristics of finback Balaenoptera physalus vocalizations in the St. Lawrence Estuary. **Bioacoustics** 1(2/3):131-149.

Edds-Walton, P.L. 2000. Vocalisations of minke whales *Balaenoptera acutorostrata* in the St. Lawrence estuary. **Bioacoustics** 11:31-50.

Engås, A. and S. Løkkeborg. 2002. Effects of seismic shooting and vessel-generated noise, on fish behaviour and catch rates. **Bioacoustics** 12(2/3):313-316.

Engås, A., S. Lokkeborg, A.V. Soldal, and E. Ona. 1993. Comparative trials for cod and haddock using commercial trawl and longline at two different stock levels. **J. Northw. Atl. Fish. Sci.** 19:83-90.

Estes, J.A. and J.L. Bodkin. 2002. Otters. p. 842-858 *In:* W.F. Perrin, B. Würsig and J.G. M. Thewissen (eds.), Encyclopedia of Marine Mammals. Academic Press. San Diego, CA. 1414 p.

Estes, J.A., M.T. Tinker, T.M. Williams, and D.F. Doak. 1998. Killer whale predation on sea otters linking oceanic and nearshore ecosystems. **Science** 282(5388):473-476.

Fernández, A., M. Arbelo, E. Degollada, M. André, A. Castro-Alonso, R. Jaber, V. Martín, P. Calabuig, P. Castro, P. Herraez, F. Rodríguez, and A. Espinosa de los Monteros. 2003. Pathological findings in beaked whales stranded massively in the Canary Islands (2002). p. 227-228 *In*: 17th Conf. Eur. Cetac. Soc., Las Palmas, March 2003/Conf. Guide & Abstr. European Cetacean Society.

Ferrero, R.C. and W.A. Walker. 1996. Age, growth and reproductive patterns of the Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) taken in high seas driftnets in the central North Pacific Ocean. **Can. J. Zool.** 74(9):1673-1687.

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., R. Dear, D.A. Carder, and S.H. Ridgway. 2003. Auditory and behavioral responses of California sea lions (*Zalophus californianus*) to single underwater impulses from an arc-gap transducer. **J. Acoust. Soc. Am.** 114(3):1667-1677.

Fish, J.F. and J.S. Vania. 1971. Killer whale, *Orcinus orca*, sounds repel white whales, *Delphinapterus leucas*. **Fish. Bull.** 69(3):531-535.

Fisher, H.D. 1952. The status of the harbour seal in British Columbia, with particular reference to the Skeena River. **Fish. Res. Board Can. Bull.** 93. 58 p.

Fox, C.G., R.P. Dziak and H. Matsumoto. 2002. NOAA efforts in monitoring of low-frequency sound in the global ocean. **J. Acoust. Soc. Am.** 112(5, Pt. 2):2260.

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

Frost, K. J. and L. F. Lowry. 1981. Foods and trophic relationships of cetaceans in the Bering Sea. p. 825-836 *In*: D.W. Hood and J.A. Calder (eds.) The Eastern Bering Sea shelf: oceanography and resources, Vol. 2. Univ. Wash. Press, Seattle.

Frost, K.J., L.F. Lowry and R.R. Nelson. 1984. Belukha whale studies in Bristol Bay, Alaska. pp. 187-200 *In*: B.R. Melteff and D.H. Rosenberg (eds.), Proc. workshop on biological interactions among marine mammals and commercial fisheries in the southeastern Bering Sea, Oct. 1983, Anchorage, AK. Univ. Alaska Sea Grant Rep. 84-1. Univ. Alaska, Fairbanks, AK.

Frost, K.J., L.F. Lowry and J.M Ver Hoef. 1999. Monitoring the trend of harbor seals in Prince William Sound, Alaska, after the *Exxon Valdez* oil spill. **Mar. Mamm. Sci.** 15(2):494-506.

Gabriele, C.M. 1995. Population characteristics of humpback whales in Glacier Bay and adjacent waters: 1995. Glacier Bay National Park and Preserve. Gustavus, AK.

Gabriele, C.M. and T.M. Lewis. 2000. Summary of opportunistic marine mammal sightings in Glacier Bay and Icy Strait 1994–1999. Glacier Bay National Park and Preserve, Gustavus, AK.

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

Gambell, R. 1985a. Sei whale *Balaenoptera borealis* Lesson, 1828. p. 155-170 *In:* S.H. Ridgway and R. Harrison (eds.), Handbook of Marine Mammals. Vol. 3. The Sirenians and Baleen Whales. Academic Press, London, U.K. 362 p.

Gambell, R. 1985b. Fin whale *Balaenoptera physalus* (Linnaeus, 1758). p. 171-192 *In:* S.H. Ridgway and R. Harrison (eds.), Handbook of Marine Mammals. Vol. 3. The Sirenians and Baleen Whales. Academic Press, London, U.K. 362 p.

Garshelis, D.L. and J.A. Garshelis. 1984. Movements and management of sea otters in Alaska. **J. Wildl. Manage.** 48(3):665-678.

Gedamke, J., D.P. Costa and A. Dunstan. 2001. Localization and visual verification of a complex minke whale vocalization. **J. Acoust. Soc. Am**. 109(6):3038-3047.

Gentry, R. (ed.). 2002. Report of the workshop on acoustic resonance as a source of tissue trauma in cetaceans, Silver Spring, MD, April 2002. Nat. Mar. Fish. Serv. 19 p.
Available at http://www.nmfs.noaa.gov/prot_res/PR2/Acoustics_Program/acoustics.html

Gerstein, E.R., L.A. Gerstein, S.E. Forsythe, and J.E. Blue. 1999. The underwater audiogram of a West Indian manatee (*Trichechus manatus*). **J. Acoust. Soc. Am.** 105(6):3575-3583.

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

Gisiner, R.C. (ed.). 1999. Proceedings/Workshop on the effects of anthropogenic noise in the marine environment, Bethesda, MD, Feb. 1998. Office of Naval Research, Arlington, VA. 141 p. Available at www.onr.navy.mil/sci%5Ftech/personnel/cnb%5Fsci/proceed.pdf.

Glockner, D.A. and M.J. Ferrari. 1990. Reproduction in the humpback whale (*Megaptera novaeangliae*) in Hawaiian waters, 1975-1988: The life history, reproductive rates and behaviour of known individuals identified through surface and underwater photography. **Rep. Int. Whal. Comm., Spec. Iss.** 12:161-169.

Goddard, P.D. and D.J. Rugh. 1998. A group of right whales seen in the Bering Sea in July 1996. **Mar. Mamm. Sci.** 14(2):344-349

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.

Goold, J.C. and P.J. Fish. 1998. Broadband spectra of seismic survey air-gun emissions, with reference to dolphin auditory thresholds. **J. Acoust. Soc. Am.** 103(4):2177-2184.

Greene, C.R. 1997. An autonomous acoustic recorder for shallow arctic waters**. J. Acoust. Soc. Am.** 102(5, Pt. 2):3197.

Greene, C.R., Jr. and W.J. Richardson. 1988. Characteristics of marine seismic survey sounds in the Beaufort Sea. **J. Acoust. Soc. Am.** 83(6):2246-2254.

Greene, C.R., Jr., N.S. Altman and W.J. Richardson. 1999. Bowhead whale calls. p. 6-1 to 6-23 *In*: W.J. Richardson (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. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for Western Geophysical, Houston, TX, and U.S. Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 390 p.

Greene, G.D., F.R. Engelhardt and R.J. Paterson (eds.). 1985. Proceedings of the workshop on effects of explosives use in the marine environment. Canadian Oil and Gas Lands Admin. and Environ. Prot. Branch, Ottawa, Ont. 398 p.

Gurevich, V.S. 1980. Worldwide distribution and migration patterns of the white whale (beluga), *Delphinapterus leucas*. **Rep. Intl. Whal. Comm.** 30:465-480.

Hall, J. 1979. A survey of cetaceans of Prince William Sound and adjacent waters – their numbers and seasonal movements. Unpubl. Rep. to Alaska Outer Continental Shelf Environmental Assessment Programs. NOAA OSCEAP Juneau Project Office, Juneau, AK.

Hall, J.D. and C.S. Johnson. 1972. Auditory thresholds of a killer whale (*Orcinus orca* Linnaeus). **J. Acoust. Soc. Am.** 51(2):515-517.

Hanan, D.A., D.B. Holts and A.L. Coan, Jr. 1993. The California drift gill net fishery for sharks and swordfish, 1981-82 through 1990-91. Calif. Dept. Fish and Game. **Fish. Bull.** No. 175. 95 p.

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

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.** 2:271-275.

Heyning, J.E. 1989. Cuvier's beaked whale *Ziphius cavirostris* G. Cuvier, 1823. p. 289-308 *In:* S.H. Ridgway and R.J. Harrison (eds.), Handbook of Marine Mammals. Vol. 4. River Dolphins and the Larger Toothed Whales. Academic Press, San Diego, CA. 444 p.

Hill, P.S., J. L. Laake and E. Mitchell. 1999. Results of a pilot program to document interactions between sperm whales and longline vessels in Alaska waters. NOAA Tech. Memo. NMFS-AFSC-108.

Hirst, A.G. and P.G. Rodhouse. 2000. Impacts of geophysical seismic surveying on fishing success. **Rev. Fish Biol. Fisheries** 10(1):113-118.

Hobbs, R.C. and J.A. Lerczak. 1993. Abundance of Pacific white-sided dolphin and Dall's porpoise in Alaska estimated from sightings in the North Pacific Ocean and the Bering Sea during 1987 through 1991. Annual report to the MMPA Assessment Program, Office of Protected Resources, NMFS, NOAA, 1335 East-West Highway, Silver Spring, MD. 20910.

Hobbs, R.C. and D.J. Rugh. 1999. The abundance of gray whales in the 1997/1998 southbound migration in the eastern North Pacific. Unpubl. Doc. Submitted to SCI. Comm. Int. Whal. Comm.(SC/51/AS10).

Hobbs, R.C., D.J. Rugh and D.P. DeMaster. 2000. Abundance of belugas, *Delphinapterus leucas*, in Cook Inlet, Alaska, 1994-2000. **Mar. Fish. Rev.** 62(3):37-45.

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. 2004. Marine mammal monitoring during Lamont-Doherty Earth Observatory's TAG seismic study in the Mid-Atlantic Ocean, October–November 2003. LGL Rep. TA2822-21. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory, Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 42 p.

Hooker, S.K., R.W. Baird, S. Al-Omari, S. Gowans, and H. Whitehead. 2001. Behavioural reactions of northern bottlenose whales (*Hyperoodon ampullatus*) to biopsy darting and tag attachment procedures. **Fish. Bull.** 99(2):303-308.

Horwood, J. 1987. The Sei Whale: Population Biology, Ecology, and Management. Croom Helm, Beckenham, Kent, U.K. 375 p.

Houser, D.S., R. Howard and S. Ridgway. 2001. Can diving-induced tissue nitrogen supersaturation increase the chance of acoustically driven bubble growth in marine mammals? **J. Theor. Biol.** 213(2):183-195.

Houston J. 1991. Status of Cuvier's beaked whale, *Ziphius cavirostris*, in Canada. **Can. Field Nat.** 105(2): 215-218.

Hubbard, J.D., D.J. Hansen and B.A. Mahoney. 1999. Winter sighting of beluga whales (*Delphinapterus leucas*) in Yakutat-Disenchantment Bay, Alaska. **Arctic** 52(4):411-412.

Huntington, H.P. 2000. Traditional Knowledge of the ecology of belugas, *Delphinatpterus leucas*, in Cook Inlet, Alaska. **Mar. Fish. Rev.** 62(3):134-140.

Hutchinson, D.R. and R.S. Detrick. 1984. Water gun vs. air gun: a comparison. **Mar. Geophys. Res.** 6(3):295-310.

Imler, R.H. and H.R. Sarber. 1947. Harbor seals and sea lions in Alaska. Special Scientific Report NO. 28. U.S. Dept. Inter. Fish and Wildlife Service, Washington, D.C.

Irons, D.B., D.R. Nysewander and J.L. Trapp. 1988. Prince William Sound sea otter distribution in respect to population growth and habitat type. U.S. Fish and Wildlife Service, Anchorage, AK.

IUCN (The World Conservation Union). 2003. 2003 IUCN Red List of Threatened Species. http://www.redlist.org

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. 2002. Dall's porpoise *Phocoenoides dalli*. p. 308-310. *In:* W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of Marine Mammals. Academic Press, San Diego, CA. 1414 p.

Jefferson, T.A. and B.E. Curry. 1994. Review and evaluation of potential acoustic methods of reducing or eliminating marine mammal-fishery interactions. Rep. from Mar. Mamm. Res. Prog., Texas A & M Univ., College Station, TX, for U.S. Mar. Mamm. Comm., Washington, DC. 59 p. NTIS PB95-100384.

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

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.E. and D.C. Biggs (eds.). 2003. Sperm whale seismic study in the Gulf of Mexico; Annual Report: Year 1. U.S. Dept. of the Int., Min. Manage. Serv., Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2003-069. 139 p.

Johnson, A.M. 1982. Status of Alaska sea otter populations and developing conflicts with fisheries. p. 293-299 *In*: Transactions of the 47th North American Wildlife and Natural Resources Conference, Washington, D.C.

Johnson, S.R. 2002. Marine mammal mitigation and monitoring program for the 2001 Odoptu 3-D seismic survey, Sakhalin Island Russia: Executive summary. Rep. from LGL Ltd, Sidney, B.C., for Exxon Neftegas Ltd., Yuzhno-Sakhalinsk, Russia. 49 p. Also available as Working Paper SC/02/WGW/19, Int. Whal. Comm., Western Gray Whale Working Group Meeting, Ulsan, South Korea, 22-25 October 2002. 48 p.

Julian, F. 1997. Cetacean mortality in California gill net fisheries: Preliminary estimates for 1996. Paper SC/49/SM02 presented to the International Whaling Commission, September 1997 (unpublished). 13 p.

Julian, F. and M. Beeson. 1998. Estimates for marine mammal, turtle, and seabird mortality for two California gillnet fisheries: 1990-95. **Fish. Bull.** 96:271-284.

Jurasz, C.M. and V.P. Jurasz. 1979. Feeding modes of the humpback whale, *Megaptera novaeangliae*, in southeast Alaska. **Sci. Rep. Whales Res. Instit.** 31:69-83.

Jurasz, C.M. and V. Palmer. 1979. Feeding modes of the humpback whale *(Megaptera novaeangliae)* in southeast Alaska. Whales Research Institute Science. Juneau, AK.

Kastak, D. and R.J. Schusterman. 1998. Low-frequency amphibious hearing in pinnipeds: methods, measurements, noise and ecology. **J. Acoust. Soc. Am.** 103(4): 2216-2228.

Kastak, D. and R.J. Schusterman. 1999. In-air and underwater hearing sensitivity of a northern elephant seal (*Mirounga angustirostris*). **Can. J. Zool.** 77(11):1751-1758.

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

Kastelein, R.A., P. Mosterd, B. van Santen, M. Hagedoorn, and D. de Haan. 2002. Underwater audiogram of a Pacific walrus (*Odobenus rosmarus divergens*) measured with narrow-band frequency-modulated signals. **J. Acoust. Soc. Am.** 112(5):2173-2182.

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. 2002. Giant beaked whales. p. 519-522 *In*: W.F. Perrin, B. Würsig and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals. Academic Press, San Diego.

Kenyon, K.W. 1969. The sea otter in the eastern Pacific Ocean. North American Fauna 68. U.S. Department of the Interior, Washington, D.C.

Ketten, D.R. 1991. The marine mammal ear: specializations for aquatic audition and echolocation. p. 717-750 *In*: D. Webster, R. Fay and A. Popper (eds.), The Biology of Hearing. Springer-Verlag, Berlin.

Ketten, D.R. 1992. The cetacean ear: form, frequency, and evolution. p. 53-75 *In*: J. A. Thomas, R. A. Kastelein and A. Ya Supin (eds.), Marine Mammal Sensory Systems. Plenum, New York. 773 p.

Ketten, D.R. 1994. Functional analysis of whale ears: adaptations for underwater hearing. **IEEE Proc. Underwat. Acoust.** 1:264-270.

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

Ketten, D.R. 2000. Cetacean ears. p. 43-108 *In*: W.W.L. Au, A.N. Popper and R.R. Fay (eds.), Hearing by Whales and Dolphins. Springer-Verlag, New York, NY. 485 p.

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

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

Klima, E.F., G.R. Gitschlag, and M.L. Renaud. 1988. Impacts of the explosive removal of offshore petroleum platforms on sea turtles and dolphins. **Mar. Fish. Rev.** 50(3):33-42.

Klinowska, M. 1991. Dolphins, Porpoises and Whales of the World: The IUCN Red Data Book. IUCN, Gland and Cambridge.

Koski, W.R., D.H. Thomson and W.J. Richardson. 1998. Descriptions of Marine Mammal Populations. p. 1-182 plus Appendices *In:* Point Mugu Sea Range Marine Mammal Technical Report. Rep. from LGL Ltd., King City, Ont., for Naval Air Warfare Center, Weapons Div., Point Mugu, CA, and Southwest Div. Naval Facilities Engin. Command, San Diego, CA. 322 p.

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

Kruse, S., D.K. Caldwell and M.C. Caldwell. 1999. Risso's dolphin *Grampus griseus* (G. Cuvier, 1812). p. 183-212 *In:* S.H. Ridgway and R. Harrison (eds.), Handbook of Marine Mammals. Vol. 6. The Second Book of Dolphins and the Porpoises. Academic Press, San Diego, CA. 486 p.

Kruse, G. H., M. Crow, E.E. Krygier, D.S. Lloyd, K.W. Pitcher, L.D. Rea, M. Ridgeway, R.J. Small, J. Stinson, and K.M. Wynne. 2001. A review of proposed fishery management actions and the decline of Steller sea lions *Eumetopias jubatus* in Alaska: a report by the Alaska Steller sea lion restoration team. Alaska Department of Fish and Game, Juneau, AK.

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

Kryter, K.D. 1994. The handbook of hearing and the effects of noise. Academic Press, Orlando, FL. 673 p.

Leatherwood, S. and R.R. Reeves. 1983. The Sierra Club Handbook of Whales and Dolphins. Sierra Club, San Francisco, CA. 302 p.

Leatherwood, S., D.K. Caldwell and H.E. Winn. 1976. Whales, Dolphins, and Porpoises of the Western North Atlantic. A Guide to their Identification. NOAA Tech. Rep. NMFS Circ. 396. U.S. Dep. Comm., Washington, DC.

Leatherwood, S., R.R. Reeves, W.F. Perrin, and W.E. Evans. 1982. Whales, dolphins, and porpoises of the eastern North Pacific and adjacent Arctic waters: a guide to their identification. U.S. Dep. Commer., NOAA Tech. Rpt.. NMFS Circular 444. 425 p.

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. Rept. Whales Res. Inst.Tokyo**. 35:129-157.

Lesage, V., C. Barrette, M.C.S. Kingsley, and B. Sjare. 1999. The effect of vessel noise on the vocal behavior of belugas in the St. Lawrence River estuary, Canada. **Mar. Mamm. Sci.** 15(1):65-84.

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. Society for experimental biology Seminar Series 13, Cambridge University Press.

Loughlin, T.R. 1994 . Abundance and distribution of harbor seals (*Phoca vitulina richardsi*) in southeastern Alaska during 1993. Annual report to the MMPA Assessment Program. Office of Protected Resources, NMFS, NOAA, Silver Spring, MD.

Loughlin, T.R. 1997. Using the phylogeographic method to identify Steller sea lion stocks. *In:* A. Dizon, S.J. Chivers, and W. Perrin (eds.), Molecular genetics of marine mammals, incorporating the proceedings of a workshop on the analysis of genetic data to address problems of stock identity as related to management of marine mammals. Soc. Mar. Mammal., Spec. Rep. No. 3.

Loughlin, T.R., A.S. Perlov and V.V. Vladimirov. 1992. Range-wide survey and estimation of total number of Steller sea lions in 1989. **Mar. Mamm. Sci.** 8:220-239.

Lowry, M.S. 1999. Counts of California sea lion (*Zalophus californianus*) pups from aerial color photographs and from the ground: a comparison of two methods. **Mar. Mamm. Sci.** 15:143-158.

Lowry, M.S., P. Boveng, R.J. DeLong, C.W. Oliver, B.S. Stewart, H.DeAnda, and J. Barlow. 1992. Status of the California sea lion (*Zalophus californianus californianus*) population in 1992. Admin. Rep. LJ-92-32. Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, CA 92038. 34 p.

Lowry, L.F., K.J. Frost, J.M. Ver Hoef, and R.A. Delong. 2001. Movements of satellite-tagged subadult and adult harbor seals in Prince William Sound, Alaska. **Mar. Mamm. Sci.** 17(4):835-861.

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

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.

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.

Maher, W.J. 1960. Recent records of the California gray whale (*Eschrichtius robustus*) along the north coast of Alasla. **Arctic** 13:257-265.

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., 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*: W.M. Sackinger, 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.

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. from Bolt Beranek & Newman Inc., Cambridge, MA, for U.S. Minerals Manage. Serv., Anchorage, AK. 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. from BBN Labs Inc., Cambridge, MA, for U.S. Minerals Manage. Serv., Anchorage, AK. Var. pag. NTIS PB86-218385.

Malme, C.I., B. Würsig, B., J.E. Bird, and P. Tyack. 1987. Observations of feeding gray whale responses to controlled industrial noise exposure. p 55-73 *In:* W.M. Sackinger, M.O. Jeffires, J.L. Imm, and S.D. Treacy (eds.), Port and Ocean Engineering Under Arctic Conditions. Vol. II. Symposium on noise and marine mammals. Published 1988. University of Alaska Fairbanks, Fairbanks AK.

Martel, V. M. n.d. Summary of the report on the atypical mass stranding of beaked whales in the Canary Islands in September 2002 during naval exercises. Society for the Study of Cetaceans in the Canary Islands.

Mate, B. 2003. Seasonal distribution and habitat characterization of sperm whales in the Gulf of Mexico from Argos satellite-monitored radio tracking. *In:* 15th Biennial Conference on the Biology of Marine Mammals, Greensboro, NC, 14-19 December 2003, Abstracts.

Mate, B.R. and J.T. Harvey. 1987. Acoustical deterrents in marine mammal conflicts with fisheries. ORESU-W-86-001. Oregon State Univ., Sea Grant Coll. Progr., Corvallis, OR. 116 p.

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

Mate, B.R., K.M. Stafford and D.K. Ljungblad. 1994. A change in sperm *whale* (*Physeter macrocephalus*) distribution correlated to seismic surveys in the Gulf of Mexico. **J. Acoust. Soc. Am.** 96(2):3268-3269.

Mathews, E.A. 1996. Distribution and ecological role of marine mammals (in Southeast Alaska). Supplemental Envir. Impact State., U.S. EPA, Region 10. 110 p.

Matkin, C.O., D.R. Matkin, G.M. Ellis, E. Saulitis, and D. Mc Sweeney. 1997. Movements of resident killer whales in southeastern Alaska and Prince William Sound, Alaska. **Mar. Mamm. Sci.** 13:469-475.

Mattila, D.K. L.N. Guinee and C.A. Mayo. 1987. Humpback whale songs on a north Atlantic feeding ground. **J. Mammal.** 68(4):880-883.

McCall Howard, M.P. 1999. Sperm whales *Physeter macrocephalus* in the Gully, Nova Scotia: Population, distribution, and response to seismic surveying. B.Sc. (Honors) Thesis. Dalhousie Univ., Halifax, N.S.

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.

McCauley, R.D., J. Fewtrell, A.J. Duncan, and A. Adhitya. 2002. Behavioural, physiological and pathological responses of fishes to air gun noise. **Bioacoustics** 12(2/3):318-321.

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.) Journal** 40:692-708.

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

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.

McSweeney, D.J., K.C. Chu, W.F. Dolphin, and L.N. Guinee. 1989. North Pacific humpback whale songs: a comparison of southeast Alaskan feeding ground songs with Hawaiian wintering ground songs. **Mar. Mamm. Sci.** 5(2):139-148.

Mellinger, D.K., C.D. Carson and C.W. Clark. 2000. Characteristics of minke whale (*Balaenoptera acutorostrata*) pulse trains recorded near Puerto Rico. **Mar. Mamm. Sci.** 16(4):739-756.

Merrick, R.L., T.R. Loughlin and D.G. Calkins. 1987. Decline in abundance of the northern sea lion, *Eumetopias jubatus*, in Alaska, 1956-86. **Fish. Bull.** 85:351-365.

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*: W.J. Richardson (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. from 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.

Mitchell, E.D. 1975. Report on the meeting on small cetaceans, Montreal, April 1-11, 1974. **J. Fish. Res. Bd. Can.** 32:914-91.

Mizroch, S.A. 1992. Distribution of minke whales in the North Pacific based on sightings and catch data. Unpubl. doc. Submitted to the Intl. Whal. Comm. (SC/43/Mi36).

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

Moore, S.E., K.M. Stafford, M.E. Dahlheim, C.G. Fox, H.W. Braham, J.J. Polovina, and D.E. Bain. 1998. Seasonal variation in reception of fin whale calls at five geographic areas in the North Pacific. **Mar. Mamm. Sci.** 14(3):617-627.

Moore, S. E., J.M. Waite, L.L. Mazzuca, and R.C. Hobbs. 2000. Mysticete whale abundance and observations of prey associations on the central Bering Sea shelf. **J. Cet. Res. Mgt.** 2(3): 227-234.

Moore, S.E., W.A. Watkins, M.A. Daher, J.R. Davies, and M.E. Dahlheim. 2002. Blue whale habitat associations in the Northwest Pacific: analysis of remotely-sensed data using a Geographic Information System. **Oceonagraphy** 15(3):20-25.

Møhl, B., M. Wahlberg, P.T. Madsen, A. Heerfordt, and A. Lund. 2003. The monopulsed nature of sperm whale clicks. **J. Acoust. Soc. Am.** 114(2):1143-1154.

Moore, S.E., W.A. Watkins, M.A. Daher, J.R. Davies, and M.E. Dahlheim. 2002. Blue whale habitat associations in the Northwest Pacific: analysis of remotely-sensed data using a Geographic Information System. **Oceanography** 15:20-25.

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

Murray, N.K. and F.H. Fay. 1979. The white whales or belukhas, *Delphinapterus leucas*, of Cook Inlet, Alaska. Draft prepared for June 1979 meeting of the Sub-committee on Small Cetaceans of the Scientific Committee of the Intl. Whal. Comm., University of Alaska Fairbanks, Fairbanks, AK.

Nachtigall, P.E., J.L. Pawloski and W.W.L. Au. 2003. Temporary threshold shifts and recovery following noise exposure in the Atlantic bottlenosed dolphin (*Tursiops truncatus*). **J. Acoust. Soc. Am.** 113(6):3425-3429.

Nerini, M. 1984. A review of gray whale feeding ecology. *In:* M.L. Jones, S.I. Swartz, and S. Leatherwood (eds.), The Gray Whale, *Eschrichtius robustus*. Academic Press, Inc. Orlando, FL.

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

NMFS. 1992. Recovery plan for the Steller sea lion (*Eumetopias jubatus*). Prepared by the Steller Sea Lion Recovery Team for the National Marine Fisheries Service, Silver Spring, MD.

NMFS. 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. 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 NMFS, Silver Spring, MD. 42 p.

NMFS. 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. 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.

NOAA and USN. 2001. Joint interim report: Bahamas marine mammal stranding event of 14-16 March 2000. U.S. Dep. Commer., Nat. Oceanic Atmos. Admin., Nat. Mar. Fish. Serv., Sec. Navy, Assis. Sec. Navy, Installations and Envir. 61 p.

NOAA. 2003. Alaska groundfish fisheries draft programmatic supplemental environmental impact statement.", U.S. DOC, NOAA, NMFS, Alaska Region, P.O. Box 21668, Juneau, AK 99802-1668. Available at http://na/nefsc/noaa.gov/lme/text/lme2.htm

NOAA. 2004. Stock Assessment Reports (SARs) by Species/Stock. http://www.nmfs.noaa.gov/prot_res/PR2/Stock_Assessment_Program/individual_saras.html

NRC (National Research Council). 2003. Decline of the Steller sea lion in Alaska waters. Untangling food webs and fishing nets. The National Academies Press. Washington, D.C.

O'Corry-Crowe, G.M., R.S. Suydam, A. Rosenberg, K.J. Frost, and A.E. Dizon. 1997. Phylogeography, population structure and dispersal patterns of the beluga whale *Delphinapterus leucas* in the western Nearctic revealed by mitochondrial DNA. **Mol. Ecol.** 6:955-970

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

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

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

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

Payne, R.S. and D. Webb. 1971. Orientation by means of long range acoustic signaling in baleen whales. **Ann. N.Y. Acad. Sci.** 188:110-141.

Payne, R.S. and S. McVay. 1971. Songs of humpback whales. **Science** 173(3997):585-597.

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.

Pitcher, K.W. 1989. Studies of southeastern Alaska sea otter populations: distribution, abundance, structure, range expansion and potential conflicts with shellfisheries. Cooperative Agreement No. 14-16-0009-954 with U.S. Fish and Wildlife Service. Alaska Department of Fish and Game, Anchorage, AK.

Pitcher, K.W. 1990. Major decline in number of harbor seals, *Phoca vitulina richardsi*, on Tugidak Island, Gulf of Alaska. **Mar. Mamm. Sci.** 6:121-134.

Pitcher, K.W. and D.G. Calkins. 1979. Biology of the harbor seal (*Phoca vitulina richardsi*) in the Gulf of Alaska. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 19(1983):231-310.

Pitcher, K.W. and D.C. McAllister. 1981. Movements and haul out behavior of radio-tagged harbor seals*, Phoca vitulina*. **Can. Field Nat.** 95:292-297.

Raum-Suryan, K. 2001. Trip report: brand resights of Steller sea lions in Southeast Alaska and northern British Columbia from 13 June–3 July, 2001. Unpublished report, Alaska Department of Fish and Game, Anchorage, AK.

Raum-Suryan, K. and K. Pitcher. 2000. Trip report: brand resights of Steller sea lions within Southeast Alaska and northern British Columbia from 19 June–10 July 2000. Unpublished Report, Alaska Department of Fish and Game, Anchorage, AK.

Reeves, R.R. and S. Leatherwood. 1994. Dolphins, porpoises, and whales: 1994-1998 action plan for the conservation of cetaceans. IUCN (World Conservation Union), Gland, Switzerland. 92 p.

Reeves, R.R., S. Leatherwood, S.A. Karl, and E.R. Yohe. 1985. Whaling results at Akutan (1912-39) and Port Hobron (1926-37), Alaska. **Rep. Intl. Whal. Comm.** 35:441-457

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

Reeves, R.R., E. Mitchell and H. Whitehead. 1993. Status of the northern bottlenose whale, *Hyperoodon ampullatus*. **Can. Field-Nat.** 107(4):490-508.

Reeves, R.R., R.J. Hofman, G.K. Silber, and D. Wilkinson. 1996. Acoustic deterrence of harmful marine mammal-fishery interactions: proceedings of a workshop held in Seattle, Washington, 20-22 March 1996. NOAA Tech. Memo NMFS-OPR-10. U.S. Dep. Commerce, Nat. Mar. Fish. Serv. 70 p.

Reilly, S.B. and V.G. Thayer. 1990. Blue whale (*Balaenoptera musculus*) distribution in the eastern tropical Pacific. **Mar. Mamm. Sci.** 6(4):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.

Reyes, J.C. 1991. The conservation of small cetaceans: a review. Report prepared for the Secretariat of the Convention on the Conservation of Migratory Species of Wild Animals. UNEP/CMS Secretariat, Bonn.

Rice, D.W. 1974. Whales and whale research in the eastern North Pacific. p. 170-195 *In:* W.E. Schevill (ed.), The whale problem: A status report. Harvard Press, Cambridge, MA.

Rice, D.W. 1989. Sperm whale *Physeter macrocephalus* Linnaeus, 1758. p. 177-233 *In:* S.H. Ridgway and R. Harrison (eds.), Handbook of Marine Mammals. Vol. 4. River Dolphins and the Larger Toothed Whales. Academic Press, San Diego, CA. 444 p.

Rice, D.W. 1998. Marine Mammals of the World, Systematics and Distribution. Spec. Publ. 4. Soc. Mar. Mammal., Allen Press, Lawrence, KS. 231 p.

Rice, D.W. and A.A. Wolman. 1971. The life history and ecology of the gray whale (*Eschrichtius robustus*). Soc. Mar. Mammal., Spec. Publ. 3, Allen Press, Lawrence, KS.

Rice, D.W. and A.A. Wolman. 1981. Summer distribution and numbers of fin, humpback, and gray whales in the Gulf of Alaska. Environ. Assess. Alaskan Cont. Shelf, Final Rep. Princ. Invest., NOAA, Juneau, AK 20(1983):1-45. NTIS PB85-201226.

Richardson, W.J. 1995. Marine Mammal Hearing. p. 205-240 *In:* W.J. Richardson, C.R. Greene, Jr., C.I. Malme and D.H. Thomson, Marine Mammals and Noise. Academic Press, San Diego, CA. 576 p.

Richardson, W.J. and B. Würsig. 1997. Influences of man-made noise and other human actions on cetacean behaviour. **Mar. Freshwat. Behav. Physiol.** 29(1-4):183-209.

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

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

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.

Ridgway, S.H., D.A. Carder, R.R. Smith, T. Kamolnick, C.E. Schlundt, and W.R. Elsberry. 1997. Behavioral responses and temporary shift in masked hearing threshold of bottlenose dolphins, *Tursiops truncatus*, to 1-second tones of 141 to 201 dB re 1 µPa. Tech. Rep. 1751. NRAD, RDT&E Div., Naval Command, Control & Ocean Surveillance Center, San Diego, CA. 27 p.

Riedman, M.L. 1983. Studies of the effects of experimentally produced noise associated with oil and gas exploration and development on sea otters in California. Rep. From Cent. Coastal Mar. Stud., Univ. Calif. Santa Cruz, CA, for U.S. Minerals Manage. Serv., Anchorage, AK. 92 p. NTIS PB86-218575.

Riedman, M.L. 1984. Effects of sounds associated with petroleum industry activities on the behavior of sea otters in California. p. D-1 to D-12 I: C.I. Malme, P.R. Miles, C.W. Clark, P. Tyack, and J.E. Bird, 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. From Bolt Beranek & Newman Inc., Cambridge, MA, for U.S. Minerals Manage. Serv., Anchorage, AK. NTIS PB86-218377.

Riedman, M.L. and J.A. Estes. 1990. The sea otter *Enhydra lutris*: behavior, ecology, and natural history. Biological Report; 90 (14). U.S. Fish and Wildlife Service.

Robineau, D. and A. di Natale. 1995. *Ziphius cavirostris* - Cuvier-Schnabelwal. p. 526-543 *In*: D. Robineau, R. Duguy and M. Klima (eds.), Handbuch der Säugetiere Europas. Meeressäuger. Teil IB: Wale und Delphine 2. Aula-Verlag, Wiesbaden.

Rotterman, L.M. and T. Simon-Jackson. 1988. Sea Otter (*Enhydra lutris*). *In* J.W. Lentfer (ed.), Selected marine mammals of Alaska: species accounts with research and management recommendations. Marine Mammal Commission, Washington, D.C.

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

Rugh, D. 2004. Gray whale census (2001/2002). Abstract available at: http://nmm.afsc.noaa.gov/Cetacean Assessment/GrayWhale/GrayCensus01-02.htm

Rugh, D.J., K.E.W. Shelden and A. Schulman-Janiger. 2001. Timing of the gray whale southbound migration. **J. Cet. Res. Manage.** 3(1):31-39.

SACLANT. 1998. Estimation of cetacean hearing criteria levels. Section II, Chapter 7 *In*: SACLANTCEN Bioacoustics Panel Summary Record and Report. Report by NATO SACLANT Undersea Research Center. 60 p. Available at http://enterprise.spawar.navy.mil/spawarpublicsite/

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

Saulitis, E. 1993. The behavior and vocalizations of the AT group of transient killer whales in Prince William Sound, Alaska. M.S. thesis, University of Alaska, Fairbanks. Fairbanks, AK.

Scammon, C.M. 1968. The marine mammals of the North-Western coast of North America described and illustrated: together with an account of the American whale fishery. Re-issue by Dover Publications Inc, New York. 319 p.

Scarff, J.E. 1986. Historic and present distribution of the right whale, *Eubalaena glacialis*, in the eastern North Pacific south of 50ºN and east of 180ºW. **Rep. Int. Whal. Comm., Spec. Iss.** 10:43-63.

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.** 41:467-487.

Scheffer, V.B. and J.W. Slipp. 1944. The harbor seal in Washington state. **Amer. Midl. Nat.** 33:373-416.

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.

Schusterman, R., D. Kastak, B. Southall, and C. Kastak. 2000. Underwater temporary threshold shifts in pinnipeds: tradeoffs between noise intensity and duration. **J. Acoust. Soc. Am.** 108(5, Pt. 2):2515-2516.

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

Sease, J.L., W.P. Taylor, T.R. Loughlin, and K.W. Pitcher. 2001. Aerial and land-based surveys of Steller sea lions (*Eumetopias jubatus*) in Alaska, June and July 1999 and 2000. NOAA Tech. Memo. NMFS-AFSC-122. U.S. Dept. Commer. NOAA. NMFS, Alaska Fisheries Science Center.

Sease, J.L. and A. E York. 2003. Seasonal distribution of Steller's sea lions at Rookeries and haul-out sites in Alaska. **Mar. Mamm. Sci.** 19(4):745-763.

Sergeant, D.E. 1963. Minke whales, *Balaenoptera acutorostrata* Lacépède of the western North Atlantic**. J. Fish. Res. Board Can.** 20:1489-1504.

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. 1994. Beluga whales (*Delphinapterus leucas*) in Cook Inlet – a review. Appendix *in* D.E. Withrow, K.E.W. Shelden, and D.J. Rugh. Beluga whale (*Delphinapterus leucas*) distribution and abundance in Cook Inlet, summer 1993. Annual report to the MMA Assessment Program, Office of Protected Resources, NMFS, NOAA. Silver Spring, MD.

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

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

Small, R.J., G.W. Pendleton and K.W. Pitcher. 2003. Trends in abundance of Alaska harbor seals, 1983-2001. **Mar. Mamm. Sci.** 19(2):344-362.

Smith, S.C. and H. Whitehead. 1993. Variations in the feeding success and behaviour of Galápagos sperm whales (*Physeter macrocephalus*) as they relate to oceanographic conditions. **Can. J. Zool.** 71:1991-1996.

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

Springer, A.M., J.A. Estes, G.B. van Vliet, T.M. Williams, D.F. Doak, E.M. Danner, K.A. Forney, and B. Pfister. 2003. Sequential megafaunal collapse in the North Pacific Ocean: an ongoing legacy of industrial whaling? **Proc. Nat. Acad. Sci. USA** 100(21):12223-12228.

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

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

Stewart, B.S. and S. Leatherwood. 1985. Minke whale *Balaenoptera acutorostrata* Lacépède, 1804. p. 91-136 *In:* S.H. Ridgway and R. Harrison (eds.), Handbook of Marine Mammals. Vol. 3. The Sirenians and Baleen Whales. Academic Press, London, U.K. 362 p.

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

Stone, G.S., S.K. Katona, A. Mainwaring, J.M. Allen, and H.D. Corbett. 1992. Respiration and surfacing rates of fin whales (*Balaenoptera physalus*) observed from a lighthouse tower. **Rep. Int. Whal. Comm.** 42:739-745.

Straley, J.M. 1994. Seasonal characteristics of humpback whales (*Megaptera novaeangliae*) in southeastern Alaska. Master's thesis, University of Alaska, Fairbanks. Fairbanks, AK.

Straley, J.M., C.M. Gabriele and C.S. Baker. 1995. Seasonal characteristics of humpback whales (*Megaptera novaeangliae*) in southeastern Alaska. *In:* D.R. Engstrom (ed.), Proceedings of the Third Glacier Bay Science Symposium, 1993. National Park Service, Anchorage, AK.

Terhune, J.M. 1999. Pitch separation as a possible jamming-avoidance mechanism in underwater calls of bearded seals (*Erignathus barbatus*). **Can. J. Zool.** 77(7):1025-1034.

Thompson, D., M. Sjöberg, E.B. Bryant, P. Lovell, and A. Bjørge. 1998. Behavioural and physiological responses of harbour (*Phoca vitulina*) and grey (*Halichoerus grypus*) seals to seismic surveys. p. 134 *In:* World Marine Mammal Science Conf. Abstract volume, Monaco. 160 p.

Thomson, D.H. and W.J. Richardson. 1995. Marine mammal sounds. p. 159-204 *In:* W.J. Richardson, C.R. Greene, Jr., C.I. Malme and D.H. Thomson, Marine Mammals and Noise. Academic Press, San Diego, CA. 576 p.

Thomson, D.H., J.W. Lawson and A. Muecke. 2001. Proceedings of a workshop to develop methodologies for conducting research on the effects of seismic exploration on the Canadian east coast fishery, Halifax, Nova Scotia, 7-8 September 2000. ESRF Rep. 139. Environ. Stud. Res. Funds, Calgary, Alb. 75 p.

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

Tolstoy, M., J. Diebold, S. Webb, D. Bohnenstiehl, and E. Chapp. 2004. Acoustic calibration measurements. Chapter 3 *In:* W.J. Richardson (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. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. [Advance copy of updated Chapter 3.]

Trites, A.W. and B.T. Porter. 2002. Attendance patterns of Steller sea lions (*Eumetopias jubatus*) and their young during winter. **J. Zool., Lond.** 256:547-556.

Turnock, B.J. and T.J. Quinn. 1991. The effect of responsive movement on abundance estimation using the line transect sampling. **Biometrics**. 47:701-715.

Turnpenny, A.W.H. and J.R. Nedwell. 1994. The effects on marine fish, diving mammals and birds of underwater sound generated by seismic surveys. FCR 089/94. Fawley Aquatic Res. labs. Ltd., Southampton, U.K. 52 p.

Tynan, C. 1999. Redistribution of cetaceans in the southeast Bering Sea relative to anomalous oceanographic conditions during the 1997 El Niño. *In:* H.J. Freeland, W.T. Peterson, and A. Tyler (eds.), Proceedings of the 1998 science board symposium on the impacts of the 1997-1998 El Niño event on the North Pacific Ocean and its marginal seas. PICES Scientific Report No. 10. North Pacific Marine Science Organization (PICES), Sidney, BC.

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

UNEP-WCMC. 2004. UNEP-WCMC species database: CITES-listed species. http://www.unep-wcmc.org/index.html?http://sea.unep-wcmc.org/isdb/CITES/Taxonomy/tax-gs-search1.cfm?displaylanguage=eng&source=animals~main

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

Van Waerebeek, K. and B. Würsig. 2002. Pacific white-sided dolphin and dusky dolphin. p. 859-861 *In:* W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of Marine Mammals. Academic Press. San Diego, CA. 1414 p.

Vequist, G. W. and C. S. Baker. 1987. Humpback whales in Glacier Bay, Alaska: a long-term history of habitat use. U.S. National Park Service, Glacier Bay National Park and Preserve, Gustavus, AK.

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

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.

Waite, J. 2003. Cetacean Assessment and Ecology Program: Cetacean survey. Quarterly report available at http://www.afsc.noaa.gov/Quarterly/jas2003/divrptsNMML2.htm

Waite, J.M., M.E. Dahlheim, R.C. Hobbs, S.A. Mizroch, O. von Ziegesar-Matkin, J.M. Straley, L.M. Herman, and J. Jacobsen. 1999. Evidence of a feeding aggregation of humpback whales (*Megaptera novaeangliae*) around Kodiak Island, Alaska. **Mar. Mamm. Sci.** 15:210-220.

Waite, J.M., K. Wynne and D.K. Mellinger. 2003. Documented sighting of a North Pacific right whale in the Gulf of Alaska and post-sighting acoustic monitoring. **Northw. Nat.** 84:38-43.

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

Watkins, W.A. 1981. Activities and underwater sounds of fin whales. **Sci. Rep. Whales Res. Inst. (Tokyo)** 33:83-117.

Watkins, W.A. 1986. Whale reactions to human activities in Cape Cod waters. **Mar. Mamm. Sci.** 2(4):251-262.

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. and W.E. Schevill. 1975. Sperm whales (*Physeter catodon*) react to pingers. **Deep-Sea Res.** 22(3):123-129.

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., P. Tyack, and K.E. Moore. 1987. The 20-Hz signals of finback whales (*Balaenoptera physalus*). **J. Acoust. Soc. Am.** 82(6):1901-1912.

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.

Weilgart, L.S. and H. Whitehead. 1988. Distinctive vocalizations from mature male sperm whales (*Physeter macrocephalus*). **Can. J. Zool.** 66:1931-1937.

Weller, D.W., Y.V. Ivashchenko, G.A. Tsidulko, A.M. Burdin, and R.L. Brownell, Jr. 2002. Influence of seismic surveys on western gray whales off Sakhalin Island, Russia in 2001. Working Paper SC/54/BRG14, Int. Whal. Comm., Western Gray Whale Working Group Meeting, Ulsan, South Korea, 22-25 October 2002. 12 p.

Whitehead, H. 1993. The behavior of mature male sperm whales on the Galápagos breeding grounds. **Can. J. Zool.** 66:1931-1937.

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

Whitehead, H. 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.

Wing, B.L. and K. Krieger. 1983. Humpback whale prey studies in southeastern Alaska, summer 1982. U.S. National Marine Fisheries Service, Auke Bay Laboratory, Juneau, AK.

Winn, H.E. and N.E. Reichley. 1985. Humpback whale *Megaptera novaeangliae* (Borowski, 1781). p. 241-273 *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.

Withrow, D.E. and J.C. Cesarone. 2002. Abundance and distribution of harbor seals (*Phoca vitulina*) in the Gulf of Alaska (including the south side of the Alaska Peninsula, Kodiak Island, Cook Inlet and Prince William Sound) during 2001. *In* A.L. Lopez and S.E. Moore. (eds.), Marine Mammal Protection Act and Endangered Species Act Implementation Program. NOAA, NMFS, AFSC, National Marine Mammal Laboratory, Seattle, WA.

Wolfe, R. 2000. Subsistence in Alaska: A Year 2000 Update. ADF&G, Division of Subsistence, Juneau, Alaska.

Wolfe, R.J. 2001. The subsistence harvest of harbor seals and sea lions by Alaska Natives in 2000. Technical Paper No. 266. Alaska Department of Fish and Game, Division of Subsistence, Juneau, AK.

Wolfe, R. and R. Walker. 1987. Subsistence economies in Alaska: Productivity, geography and development impacts. **Arc. Anthr.** 24(2):56-81.

Wolfe, R.J., J.A. Fall and R.T. Stanek. 2003. The subsistence harvest of harbor seals and sea lions by Alaska Natives in 2002. Technical Paper No. 277. Alaska Department of Fish and Game, Division of Subsistence. Juneau, AK.

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., T.A. Jefferson, and D.J. Schmidly. 2000. The marine mammals of the Gulf of Mexico. Texas A&M Univ. Press, College Station, TX. 232 p.

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 by Texas A&M Univ., College Station, TX, and Kamchatka Inst. Ecol. and Nature Manage., Russian Acad. Sci., Kamchatka, Russia, for Sakhalin Energy Investment Co. Ltd and Exxon Neftegaz Ltd, Yuzhno-Sakhalinsk, Russia. 101 p.

Yochem, P.K. and S. Leatherwood. 1985. Blue whale. p. 193-240 *In:* S.H. Ridgway and R Harrison (eds.), Handbook of Marine Mammals. Vol. 3. The Sirenians and Baleen Whales. Academic Press, New York. 362 p.

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

York, A.E., R.L. Merrick and T.R. Loughlin. 1996. An analysis of the Steller sea lion metapopulation in Alaska. *In*. D.R. McCullough (ed.), Metapopulations and wildlife conservation. Island Press, Washington DC.

Zerbini, A.N., P.R. Wade and J.M. Waite. 2003. Abundance and distribution of fin, humpback and minke whales from the Kenai Fjords to the Central Aleutian Islands, Alaska: summer 2001-2002. Unpublished report SC/55/O9 presented to the Scientific Committee of the International Whaling Commission.

APPENDIX A:

REVIEW OF POTENTIAL IMPACTS OF AIRGUN SOUNDS ON MARINE MAMMALS [4]

The following subsections review relevant information concerning the potential effects of airgun sounds on marine mammals. This information is included here as background for the briefer summary of this topic included in § VII of the IHA Application. This background material is little changed from corresponding subsections included in IHA Applications and EAs submitted to NMFS during 2003 for other L-DEO projects. Those documents concerned L-DEO projects in the following areas: northern Gulf of Mexico, Hess Deep in the eastern tropical Pacific, Norway, Mid-Atlantic Ocean, Bermuda, Southeast Caribbean, and southern Gulf of Mexico (Yucatan Peninsula). Much of this information has also been included in varying formats in other reviews, assessments, and regulatory applications prepared by LGL Ltd., environmental research associates. Because this review is intended to be of general usefulness, it includes references to types of marine mammals that will not be found in some specific regions.

(a) Categories of Noise Effects

The effects of noise on marine mammals are highly variable, and can be categorized as follows (based on Richardson et al. 1995):

1. The noise may be too weak to be heard at the location of the animal, i.e., lower than the prevailing ambient noise level, the hearing threshold of the animal at relevant frequencies, or both;
2. The noise may be audible but not strong enough to elicit any overt behavioral response, i.e., the mammals may tolerate it;
3. The noise may elicit behavioral reactions of variable conspicuousness and variable relevance to the well being of the animal; these can range from subtle effects on respiration or other behaviors (detectable only by statistical analysis) to active avoidance reactions;
4. Upon repeated exposure, animals may exhibit diminishing responsiveness (habituation), or disturbance effects may persist; the latter is most likely with sounds that are highly variable in characteristics, unpredictable in occurrence, and associated with situations that the animal perceives as a threat;
5. Any man-made noise that is strong enough to be heard has the potential to reduce (mask) the ability of marine mammals to hear natural sounds at similar frequencies, including calls from conspecifics, echolocation sounds of odontocetes, and environmental sounds such as surf noise or (at high latitudes) ice noise. However, intermittent airgun or sonar pulses could cause masking for only a small proportion of the time, given the short duration of these pulses relative to the inter-pulse intervals;

---

[4] By **W. John Richardson** and **Valerie D. Moulton**, LGL Ltd., environmental research associates. Revised November 2003.

6. Very strong sounds have the potential to cause temporary or permanent reduction in hearing sensitivity, or other physical effects. Received sound levels must far exceed the animal's hearing threshold for any temporary threshold shift to occur. Received levels must be even higher for a risk of permanent hearing impairment.

(b) Hearing Abilities of Marine Mammals

The hearing abilities of marine mammals are functions of the following (Richardson et al. 1995; Au et al. 2000):

1. Absolute hearing threshold at the frequency in question (the level of sound barely audible in the absence of ambient noise).
2. Critical ratio (the signal-to-noise ratio required to detect a sound at a specific frequency in the presence of background noise around that frequency).
3. The ability to localize sound direction at the frequencies under consideration.
4. The ability to discriminate among sounds of different frequencies and intensities.

Marine mammals rely heavily on the use of underwater sounds to communicate and to gain information about their surroundings. Experiments also show that they hear and may react to many man-made sounds including sounds made during seismic exploration.

Toothed Whales

Hearing abilities of some toothed whales (odontocetes) have been studied in detail (reviewed in Chapter 8 of Richardson et al. [1995] and in Au et al. [2000]). Hearing sensitivity of several species has been determined as a function of frequency. The small to moderate-sized toothed whales whose hearing has been studied have relatively poor hearing sensitivity at frequencies below 1 kHz, but extremely good sensitivity at, and above, several kHz. There are at present no specific data on the absolute hearing thresholds of most of the larger, deep-diving toothed whales, such as the sperm and beaked whales.

Despite the relatively poor sensitivity of small odontocetes at the low frequencies that contribute most of the energy in pulses of sound from airgun arrays, the sounds are sufficiently strong that their received levels sometimes remain above the hearing thresholds of odontocetes at distances out to several tens of kilometers (Richardson and Würsig 1997). However, there is no evidence that small odontocetes react to airgun pulses at such long distances, or even at intermediate distances where sound levels are well above the ambient noise level (see below).

The multibeam sonar operated from the *Ewing* emits pulsed sounds at 15.5 kHz. That frequency is within or near the range of best sensitivity of many odontocetes. Thus, sound pulses from the multibeam sonar will be readily audible to these animals when they are within the narrow angular extent of the transmitted sound beam.

Baleen Whales

The hearing abilities of baleen whales have not been studied directly. Behavioral and anatomical evidence indicates that they hear well at frequencies below 1 kHz (Richardson et al. 1995; Ketten 2000). Baleen whales also reacted to sonar sounds at 3.1 kHz and other sources centered at 4 kHz (see Richardson et al. 1995 for a review). Some baleen whales react to pinger sounds up to 28 kHz, but not to pingers or sonars emitting sounds at 36 kHz or above (Watkins 1986). In addition, baleen whales produce sounds at frequencies up to 8 kHz and, for humpbacks, to >15 kHz (Au et al. 2001). The anatomy of the baleen whale inner ear seems to be well adapted for detection of low-frequency sounds (Ketten 1991, 1992, 1994, 2000). The absolute sound levels that they can detect below 1 kHz are probably limited by increasing levels of natural ambient noise at decreasing frequencies. Ambient noise energy is higher at low frequencies than at mid frequencies. At frequencies below 1 kHz, natural ambient levels tend to increase with decreasing frequency.

The hearing systems of baleen whales are almost certainly more sensitive to low-frequency sounds than are the ears of the small toothed whales. Thus, baleen whales are likely to hear airgun pulses farther away than can small toothed whales and, at closer distances, airgun sounds may seem more prominent to baleen than to toothed whales. However, baleen whales have commonly been seen well within the distances where seismic (or sonar) sounds would be detectable and yet often show no overt reaction to those sounds. Behavioral responses by baleen whales to seismic pulses have been documented, but received levels of pulsed sounds necessary to elicit behavioral reactions are typically well above the minimum detectable levels (Malme et al. 1984, 1988; Richardson et al. 1986, 1995; McCauley et al. 2000a; Johnson 2002).

Pinnipeds

Underwater audiograms have been obtained using behavioral methods for three species of phocinid seals, two species of monachid seals, two species of otariids, and the walrus (reviewed in Richardson et al. 1995: 211*ff*; Kastak and Schusterman 1998, 1999; Kastelein et al. 2002). In comparison with odontocetes, pinnipeds tend to have lower best frequencies, lower high-frequency cutoffs, higher auditory sensitivity at low frequencies, and poorer sensitivity at the best frequency.

At least some of the phocid (hair) seals have better sensitivity at low frequencies (≤1 kHz) than do odontocetes. Below 30–50 kHz, the hearing thresholds of most species tested are essentially flat down to about 1 kHz, and range between 60 and 85 dB re 1 μPa. Measurements for a harbor seal indicate that, below 1 kHz, its thresholds deteriorate gradually to ~97 dB re 1 μPa at 100 Hz (Kastak and Schusterman 1998). The northern elephant seal (not an Atlantic/Gulf of Mexico species) appears to have better underwater sensitivity than the harbor seal, at least at low frequencies (Kastak and Schusterman 1998, 1999).

For the otariid (eared) seals, the high frequency cutoff is lower than for phocinids, and sensitivity at low frequencies (e.g., 100 Hz) is poorer than for hair seals (harbor or elephant seal).

The underwater hearing of a walrus has recently been measured at frequencies from 125 Hz to 15 kHz (Kastelein et al. 2002). The range of best hearing was from 1–12 kHz, with maximum sensitivity (67 dB re 1 μPa) occurring at 12 kHz (Kastelein et al. 2002).

Sirenians

The hearing of manatees is sensitive at frequencies below 3 kHz. A West Indian manatee that was tested using behavioral methods could apparently detect sounds from 15 Hz to 46 kHz (Gerstein et al. 1999). Thus, manatees may hear, or at least detect, sounds in the low-frequency range where most seismic energy is released. It is possible that they are able to feel these low-frequency sounds using vibrotactile receptors or because of resonance in body cavities or bone conduction.

Based on measurements of evoked potentials, manatee hearing is apparently best around 1–1.5 kHz (Bullock et al. 1982). However, behavioral testing suggests their best sensitivity is at 6 to 20 kHz (Gerstein et al. 1999). The ability to detect high frequencies may be an adaptation to shallow water, where the propagation of low frequency sound is limited (Gerstein et al. 1999).

(c) Characteristics of Airgun Pulses

Airguns function by venting high-pressure air into the water. The pressure signature of an individual airgun consists of a sharp rise and then fall in pressure, followed by several positive and negative pressure excursions caused by oscillation of the resulting air bubble. The sizes, arrangement, and firing times of the individual airguns in an array are designed and synchronized to suppress the pressure oscillations subsequent to the first cycle. The resulting downward-directed pulse has a duration of only 10 to 20 ms, with only one strong positive and one strong negative peak pressure (Caldwell and Dragoset 2000). Most energy emitted from airguns is at relatively low frequencies. For example, typical high-energy airgun arrays emit most energy at 10–120 Hz. However, the pulses contain some energy up to 500–1000 Hz and above (Goold and Fish 1998). The pulsed sounds associated with seismic exploration have higher peak levels than other industrial sounds to which whales and other marine mammals are routinely exposed. The only sources with higher or comparable effective source levels are explosions.

The peak-to-peak source levels of the 2- to 20-airgun arrays used by L-DEO during various projects range from 236 to 263 dB re 1 µPa at 1 m, considering the frequency band up to about 250 Hz. These are the nominal source levels applicable to downward propagation. The effective source levels for horizontal propagation are lower. The only man-made sources with effective source levels as high as (or higher than) a large array of airguns are explosions and high-power sonars operating near maximum power.

Several important mitigating factors need to be kept in mind. ***(1)*** Airgun arrays produce intermittent sounds, involving emission of a strong sound pulse for a small fraction of a second followed by several seconds of near silence. In contrast, some other sources produce sounds with lower peak levels, but their sounds are continuous or discontinuous but continuing for much longer durations than seismic pulses. ***(2)*** Airgun arrays are designed to transmit strong sounds downward through the seafloor, and the amount of sound transmitted in near-horizontal directions is considerably reduced. Nonetheless, they also emit sounds that travel horizontally toward non-target areas. ***(3)*** An airgun array is a distributed source, not a point source. The nominal source level is an estimate of the sound that would be measured from a theoretical point source emitting the same total energy as the airgun array. That figure is useful in calculating the expected received levels in the far field, i.e., at moderate and long distances. Because the airgun array is not a single point source, there is no one location within the near field (or anywhere else) where the received level is as high as the nominal source level.

The strengths of airgun pulses can be measured in different ways, and it is important to know which method is being used when interpreting quoted source or received levels. Geophysicists usually quote peak-to-peak levels, in bar-meters or dB re 1 µPa·m. The peak (= zero-to-peak) level for the same pulse is typically about 6 dB less. In the biological literature, levels of received airgun pulses are often described based on the "average" or "root-mean-square" (rms) level over the duration of the pulse. The rms value for a given airgun pulse is typically about 10 dB lower than the peak level, and 16 dB lower than the peak-to-peak value (Greene 1997; McCauley et al. 1998, 2000a). A fourth measure that is sometimes used is the energy level, in dB re 1 $\mu Pa^2 \cdot s$. Because the pulses are <1 s in duration, the numerical value of the energy is lower than the rms pressure level, but the units are different. Because the level of a given pulse will differ substantially depending on which of these measures is being applied, it is important to be aware which measure is in use when interpreting any quoted pulse level. In the past, NMFS has commonly referred to rms levels when discussing levels of pulsed sounds that might "harass" marine mammals.

Seismic sound received at any given point will arrive via a direct path, indirect paths that include reflection from the sea surface and bottom, and often indirect paths including segments through the bottom sediments. Sounds propagating via indirect paths travel longer distances and often arrive later than sounds arriving via a direct path. (However, sound traveling in the bottom may travel faster than that in the water, and thus may, in some situations, arrive slightly earlier than the direct arrival despite traveling a greater distance.) These variations in travel time have the effect of lengthening the duration of the received pulse. Near the source, the predominant part of a seismic pulse is about 10 to 20 ms in duration. In comparison, the pulse duration as received at long horizontal distances can be much greater. For example, for one airgun array operating in the Beaufort Sea, pulse duration was about 300 ms at a distance of 8 km (4.3 n.mi.), 500 ms at 20 km (10.8 n.mi.), and 850 ms at 73 km or 39.4 n.mi. (Greene and Richardson 1988).

Another important aspect of sound propagation is that received levels of low-frequency underwater sounds diminish close to the surface because of pressure-release and interference phenomena that occur at and near the surface (Urick 1983; Richardson et al. 1995). Paired measurements of received airgun sounds at depths of 3 m (9.8 ft) vs. 9 m (29.5 ft) or 18 m (59 ft) have shown that received levels are typically several decibels lower at 3 m (Greene and Richardson 1988). For a mammal whose auditory organs are within 0.5 or 1 m (1.6–3.3 ft) of the surface, the received level of the predominant low-frequency components of the airgun pulses would be further reduced. In deep water, the received levels at deep depths can be considerably higher than those at relatively shallow (e.g., 18 m) depths and the same horizontal distance from the airguns (Tolstoy et al. 2004).

Pulses of underwater sound from open-water seismic exploration are often detected 50–100 km (27–54 n.mi.) from the source location, even during operations in nearshore waters (Greene and Richardson 1988; Burgess and Greene 1999). At those distances, the received levels are low—below 120 dB re 1 μPa on an approximate rms basis. However, faint seismic pulses are sometimes detectable at even greater ranges (e.g., Bowles et al. 1994; Fox et al. 2002). Considerably higher levels can occur at distances out to several kilometers from an operating airgun array.

(d) Masking Effects of Seismic Surveys

Masking effects of pulsed sounds on marine mammal calls and other natural sounds are expected to be limited, although there are few specific data on this. Some whales are known to continue calling in the presence of seismic pulses. Their calls can be heard between the seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999). Although there has been one report that sperm whales cease calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994), a recent study reports that sperm whales off northern Norway continued calling in the presence of seismic pulses (Madsen et al. 2002). Masking effects of seismic pulses are expected to be negligible in the case of the smaller odontocete cetaceans, given the intermittent nature of seismic pulses plus the fact that sounds important to them are predominantly at much higher frequencies than are airgun sounds.

Most of the energy in the sound pulses emitted by airgun arrays is at low frequencies, with strongest spectrum levels below 200 Hz and considerably lower spectrum levels above 1000 Hz. These low frequencies are mainly used by mysticetes, but generally not by odontocetes, pinnipeds, or sirenians. An industrial sound source will reduce the effective communication or echolocation distance only if its frequency is close to that of the marine mammal signal. If little or no overlap occurs between the industrial noise and the frequencies used, as in the case of many marine mammals vs. airgun sounds, communication and echolocation are not expected to be disrupted. Furthermore, the discontinuous nature of seismic pulses makes significant masking effects unlikely even for mysticetes.

A few cetaceans are known to increase the source levels of their calls in the presence of elevated sound levels, or possibly to shift their peak frequencies in response to strong sound signals (Dahlheim 1987; Au 1993; Lesage et al. 1999; Terhune 1999; reviewed in Richardson et al. 1995:233*ff,* 364*ff*). These studies involved exposure to other types of anthropogenic sounds, not seismic pulses, and it is not known whether these types of responses ever occur upon exposure to seismic sounds. If so, these adaptations, along with directional hearing and preadaptation to tolerate some masking by natural sounds (Richardson et al. 1995), would all reduce the importance of masking.

(e) Disturbance by Seismic Surveys

Disturbance includes a variety of effects, including subtle changes in behavior, more conspicuous changes in activities, and displacement. In the terminology of the 1994 amendments to the MMPA, seismic noise could cause "Level B" harassment of certain marine mammals. Level B harassment is defined as "...disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering."

There has been debate regarding how substantial a change in behavior or mammal activity is required before the animal should be deemed to be "taken by Level B harassment". NMFS has recently stated that

> "…a simple change in a marine mammal's actions does not always rise to the level of disruption of its behavioral patterns. … If the only reaction to the [human] activity on the part of the marine mammal is within the normal repertoire of actions that are required to carry out that behavioral pattern, NMFS considers [the human] activity not to have caused a disruption of the behavioral pattern, provided the animal's reaction is not otherwise significant enough to be considered disruptive due to length or severity. Therefore, for example, a short-term change in breathing rates or a somewhat shortened or lengthened dive sequence that are within the animal's normal range and that do not have any biological significance (i.e., do no disrupt the animal's overall behavioral pattern of breathing under the circumstances), do not rise to a level requiring a small take authorization." (NMFS 2001, p. 9293).

Based on this guidance from NMFS, 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".

Even with this guidance, there are difficulties in defining what marine mammals should be counted as "taken by harassment". For many species and situations, we do not have detailed information about their reactions to noise, including reactions to seismic (and sonar) pulses. Behavioral reactions of marine mammals to sound are difficult to predict. Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors. If a marine mammal does react to an underwater sound by changing its behavior or moving a small distance, the impacts of the change may not be significant to the individual let alone the stock or the species as a whole. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on the animals 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 were present within a particular distance of industrial activities, or exposed to a particular level of industrial sound. This likely overestimates the numbers of marine mammals that are affected in some biologically important manner.

The definitions of "taking" in the U.S. Marine Mammal Protection Act, and its applicability to various activities, are presently (autumn 2003) under active consideration by the U.S. Congress. Some changes are likely. Also, the U.S. National Marine Fisheries Service is considering the adoption of new criteria concerning the noise exposures that are (and are not) expected to cause "takes" of various types. Thus, for projects subject to U.S. jurisdiction, changes in procedures may be required in the near future.

The sound criteria used to estimate how many marine mammals might be disturbed to some biologically-important degree by a seismic program are based on behavioral observations during studies of several species. However, information is lacking for many species. Detailed studies have been done on humpback, gray and bowhead whales, and on ringed seals. Less detailed data are available for some other species of baleen whales, sperm whales, and small toothed whales.

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 airgun pulses at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, 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. Some of the main studies on this topic are the following: Malme et al. 1984, 1985, 1988; Richardson et al. 1986, 1995, 1999; Ljungblad et al. 1988; Richardson and Malme 1993; McCauley et al. 1998, 2000a; Miller et al. 1999.

Prior to the late 1990s, it was thought that bowhead whales, gray whales, and humpback whales all begin to show strong avoidance reactions to seismic pulses at received levels of about 160 to 170 dB re 1 μPa rms, but that subtle behavioral changes sometimes become evident at somewhat lower received levels. Recent studies have shown that some species of baleen whales (bowheads and humpbacks in particular) may show strong avoidance at received levels somewhat lower than 160–170 dB re 1 μPa rms. The observed avoidance reactions involved movement away from feeding locations or statistically significant deviations in the whales' direction of swimming and/or migration corridor as they approached or passed the sound sources. In the case of the migrating 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.

Humpback Whales.—McCauley et al. (1998, 2000a) studied the responses of humpback whales off Western Australia to a full-scale seismic survey with a 16-airgun 2678-in^3 array, and to a single 20 in^3 airgun with source level 227 dB re 1 μPa·m (p-p). They found that the overall distribution of humpbacks migrating through their study area was unaffected by the full-scale seismic program. McCauley et al. (1998) did, however, document localized avoidance of the array and of the single gun. Avoidance reactions began at 5–8 km (2.7–4.3 n.mi.) from the array and those reactions kept most pods about 3–4 km (1.6–2.2 n.mi.) from the operating seismic boat. Observations were made from the seismic vessel, from which the maximum viewing distance was listed as 14 km (7.6 n.mi.). 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. Mean avoidance distance from the airgun corresponded to a received sound level of 140 dB re 1 μPa rms; this was the level at which humpbacks started to show avoidance reactions to an approaching airgun. The standoff range, i.e., the closest point of approach of the airgun to the whales, corresponded to a received level of 143 dB rms. The initial avoidance response generally occurred at distances of 5–8 km (2.7–4.3 n.mi.) from the airgun array and 2 km (1.1 n.mi.) from the single gun. However, some individual humpback whales, especially males, approached within distances 100–400 m (328–1312 ft), where the maximum received level was 179 dB re 1 μPa rms.

Humpback whales summering 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.

Bowhead Whales.—Bowhead whales on their summering grounds in the Canadian Beaufort Sea showed no obvious reactions to pulses from seismic vessels at distances of 6 to 99 km (3–53 n.mi.) and received sound levels of 107–158 dB on an approximate rms basis (Richardson et al. 1986); their general activities were indistinguishable from those of a control group. However, subtle but statistically significant changes in surfacing–respiration–dive cycles were evident upon statistical analysis. Bowheads usually did show strong avoidance responses when seismic vessels approached within a few kilometers (~3–7 km or 1.6–3.8 n.mi.) and when received levels of airgun sounds were 152–178 dB (Richardson et al. 1986, 1995; Ljungblad et al. 1988). In one case, bowheads engaged in near-bottom feeding began to turn away from a 30-airgun array with a source level of 248 dB re 1 μPa·m at a distance of 7.5 km (4 n.mi.), and swam away when it came within about 2 km (1.1 n.mi.). Some whales continued feeding until the vessel was 3 km (1.6 n.mi.) away. Feeding bowhead whales tend to tolerate higher sound levels than migrating whales before showing an overt change in behavior. The feeding whales may be affected by the sounds, but the need to feed may reduce the tendency to move away.

Migrating bowhead whales in the Alaskan Beaufort Sea seem more responsive to noise pulses from a distant seismic vessel than are summering bowheads. In 1996–98, a partially-controlled study of the effect of Ocean Bottom Cable (OBC) seismic surveys on westward-migrating bowheads was conducted in late summer and autumn in the Alaskan Beaufort Sea (Miller et al. 1999; Richardson et al. 1999). Aerial surveys showed that some westward-migrating whales avoided an active seismic survey boat by 20–30 km (10.8–16.2 n.mi.), and that few bowheads approached within 20 km (10.8 n.mi.). Received sound levels at those distances were only 116–135 dB re 1 μPa (rms). Some whales apparently began to deflect their migration path when still as much as 35 km (19 n.mi.) away from the airguns. At times when the airguns were not active, many bowheads moved into the area close to the inactive seismic vessel. Avoidance of the area of seismic operations did not persist beyond 12–24 h after seismic shooting stopped. These and other data suggest that migrating bowhead whales are more responsive to seismic pulses than were summering bowheads.

Gray Whales.—Malme et al. (1986, 1988) studied the responses of feeding 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 ceased 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. Malme at al. (1986) estimated that an average pressure level of 173 dB occurred at a range of 2.6 to 2.8 km (1.4–1.5 n.mi.) from an airgun array with a source level of 250 dB (0-pk) in the northern Bering Sea. These findings were generally consistent with the results of experiments conducted on larger numbers of gray whales that were migrating along the California coast. Malme and Miles (1985) concluded that, during migration, changes in swimming pattern occurred for received levels of about 160 dB re 1 μPa and higher, on an approximate rms basis. The 50% probability of avoidance was estimated to occur at a CPA distance of 2.5 km (1.3 n.mi.) from a 4000-in^3 array operating off central

California (CPA = closest point of approach). This would occur at an average received sound level of about 170 dB (rms). Some slight behavioral changes were noted at received sound levels of 140 to 160 dB (rms).

There was no indication that Western gray whales exposed to seismic noise were displaced from their overall feeding grounds near Sakhalin Island during seismic programs in 1997 (Würsig et al. 1999) and in 2001. However, there were indications of subtle behavioral effects and (in 2001) localized avoidance by some individuals (Johnson 2002; Weller et al. 2002).

Rorquals.—Blue, sei, fin, and minke whales have occasionally been reported in areas ensonified by airgun pulses. Sightings by observers on seismic vessels off the U.K. from 1997 to 2000 suggest that, at times of good sightability, numbers of rorquals seen are similar when airguns are shooting and not shooting (Stone 2003). Although individual species did not show any significant displacement in relation to seismic activity, all baleen whales combined were found to remain significantly further from the airguns during shooting compared with periods without shooting (Stone 2003). Baleen whale pods sighted from the ship were found to be at a median distance of about 1.6 km (0.9 n.mi.) from the array during shooting and 1.0 km (0.5 n.mi.) during periods without shooting (Stone 2003). Baleen whales, as a group, made more frequent alterations of course (usually away from the vessel) during shooting compared with periods of no shooting (Stone 2003). In addition, fin/sei whales were less likely to remain submerged during periods of seismic shooting (Stone 2003).

Discussion and Conclusions.—Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to airgun pulses at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, recent studies of humpback and especially migrating bowhead whales show that reactions, including avoidance, sometimes extend to greater distances than documented earlier. Avoidance distances often exceed the distances at which boat-based observers can see whales, so observations from the source vessel are biased.

Some baleen whales show considerable tolerance of seismic pulses. However, when the pulses are strong enough, avoidance or other behavioral changes become evident. Because the responses become less obvious with diminishing received sound level, it has been difficult to determine the maximum distance (or minimum received sound level) at which reactions to seismic become evident and, hence, how many whales are affected.

Studies of gray, bowhead, and humpback whales have determined that received levels of pulses in the 160–170 dB re 1 μPa rms range seem to cause obvious avoidance behavior in a substantial fraction of the animals exposed. In many areas, seismic pulses diminish to these levels at distances ranging from 4.5 to 14.5 km (2.4–7.8 n.mi.) from the source. A substantial proportion of the baleen whales within this distance range may show avoidance or other strong disturbance reactions to the seismic array.

Data on short-term reactions (or lack of reactions) of cetaceans to impulsive noises do not necessarily provide information about long-term effects. It is not known whether impulsive noises affect reproductive rate or distribution and habitat use in subsequent days or years. Gray whales continued to migrate annually along the west coast of North America despite intermittent seismic exploration (and much ship traffic) in that area for decades (Appendix A in Malme et al. 1984). Bowhead whales continued to travel to the eastern Beaufort Sea each summer despite seismic exploration in their summer and autumn range for many years. Bowheads were often seen in summering areas where seismic exploration occurred in preceding summers (Richardson et al. 1987). They also have been observed over periods of days or weeks in areas repeatedly ensonified by seismic pulses. However, it is not known whether the same individual bowheads were involved in these repeated observations (within and between years) in strongly ensonified areas. It is also not known whether whales that tolerate exposure to seismic pulses are stressed.

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 have been reported for toothed whales, and none similar in size and scope to the studies of humpback, bowhead and gray whales mentioned above. However, systematic work on sperm whales is underway.

Delphinids and Similar Species.—Seismic operators sometimes see dolphins and other small toothed whales near operating airgun arrays, but in general there seems to be a tendency for most delphinids to show some limited avoidance of operating seismic vessels. Authors reporting cases of small toothed whales close to the operating airguns have included Duncan (1985), Arnold (1996), and Stone (2003). When a 3959 in^3, 18-airgun array was firing off California, toothed whales behaved in a manner similar to that observed when the airguns were silent (Arnold 1996). Most, but not all, dolphins often seemed to be attracted to the seismic vessel and floats, and some rode the bow wave of the seismic vessel regardless of whether the guns were firing. However, in Puget Sound, Dall's porpoises observed when a 6000 in^3, 12–16-airgun array was firing tended to be heading away from the boat (Calambokidis and Osmek 1998).

Goold (1996a,b,c) studied the effects on common dolphins, *Delphinus delphis*, of 2D seismic surveys in the Irish Sea. Passive acoustic surveys were conducted from the "guard ship" that towed a hydrophone 180-m aft. The results indicated that there was a local displacement of dolphins around the seismic operation. However, observations indicated that the animals were tolerant of the sounds at distances outside a 1-km (0.5 n.mi.) radius from the guns (Goold 1996a). Initial reports of larger-scale displacement were later shown to represent a normal autumn migration of dolphins through the area, and were not attributable to seismic surveys (Goold 1996a,b,c).

Observers stationed on seismic vessels operating off the United Kingdom from 1997–2000 have provided data on the occurrence and behavior of various toothed whales exposed to seismic pulses (Stone 2003). Dolphins of various species often showed more evidence of avoidance of operating airgun arrays than has been reported previously for small odontocetes. Sighting rates of white-sided dolphins, white-beaked dolphins, *Lagenorhynchus* spp., and all small odontocetes combined were significantly lower during periods of shooting. Except for pilot whales, all of the small odontocete species tested, including killer whales, were found to be significantly farther from large airgun arrays during periods of shooting compared with periods of no shooting. Pilot whales showed few reactions to seismic activity. The displacement of the median distance from the array was ~0.5 km (0.3 n.mi.) or more for most species groups. Killer whales also appear to be more tolerant of seismic shooting in deeper waters.

For all small odontocete species, except pilot whales, that were sighted during seismic surveys off the United Kingdom in 1997–2000, the numbers of positive interactions with the survey vessel (e.g., bow-riding, approaching the vessel, etc.) were significantly fewer during periods of shooting. All small odontocetes combined showed more negative interactions (e.g., avoidance) during periods of shooting. Small odontocetes, including white-beaked dolphins, *Lagenorhynchus* spp., and other dolphin spp. showed a tendency to swim faster during periods with seismic shooting; *Lagenorhynchus* spp. were also observed to swim more slowly during periods without shooting. Significantly fewer white-beaked dolphins, *Lagenorhynchus* spp., harbor porpoises, and pilot whales traveled towards the vessel and/or more were traveling away from the vessel during periods of shooting.

Captive bottlenose dolphins and beluga whales exhibit changes in behavior when exposed to strong pulsed sounds similar in duration to those typically used in seismic surveys (Finneran et al. 2000, 2002). Finneran et al. (2002) exposed a captive bottlenose dolphin and white whale to single impulses from a watergun (80 in^3). As compared with airgun pulses, water gun impulses were expected to contain proportionally more energy at higher frequencies because there is no significant gas-filled bubble, and thus little low-frequency bubble-pulse energy (Hutchinson and Detrick 1984). The captive animals sometimes vocalized after exposure and exhibited a reluctance to station at the test site where subsequent exposure to impulses would be implemented (Finneran et al. 2002). Similar behaviors were exhibited by captive bottlenose dolphins and a white whale exposed to single underwater pulses designed to simulate those produced by distant underwater explosions (Finneran et al. 2000). It is uncertain what relevance these observed behaviors in captive, trained marine mammals exposed to single sound pulses may have to free-ranging animals exposed to multiple pulses. In any event, the animals tolerated rather high received levels of sound (pk-pk level >200 dB re 1 μPa) before exhibiting the aversive behaviors mentioned above.

Observations of odontocete responses (or lack of responses) to noise pulses from underwater explosions (as opposed to airgun pulses) may be relevant as an indicator of odontocete responses to very strong noise pulses. During the 1950s, small explosive charges were dropped into an Alaskan river in attempts to scare belugas away from salmon. Success was limited (Fish and Vania 1971; Frost et al. 1984). Small explosive charges were “not always effective” in moving bottlenose dolphins away from sites in the Gulf of Mexico where larger demolition blasts were about to occur (Klima et al. 1988). Odontocetes may be attracted to fish killed by explosions, and thus attracted rather than repelled by "scare" charges. Captive false killer whales showed no obvious reaction to single noise pulses from small (10 g) charges; the received level was ~185 dB re 1 μPa (Akamatsu et al. 1993). Jefferson and Curry (1994) reviewed several additional studies that found limited or no effects of noise pulses from small explosive charges on killer whales and other odontocetes. Aside from the potential for TTS, the tolerance to these charges may indicate a lack of effect or the failure to move away may simply indicate a stronger desire to eat, regardless of circumstances.

Beaked Whales.—There are no specific data on the behavioral reactions of beaked whales to seismic surveys. 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). It is likely that these beaked whales would normally show strong avoidance of an approaching seismic vessel, but this has not been documented explicitly. Northern bottlenose whales sometimes are quite tolerant of slow-moving vessels (Reeves et al. 1993; Hooker et al. 2001). However, those vessels were not emitting airgun pulses.

There are increasing indications that some beaked whales tend to strand when naval exercises, including sonar operation, are ongoing nearby (e.g., Simmonds and Lopez-Jurado 1991; Frantzis 1998; NOAA and USN 2001; Jepson et al. 2003; see also the “Strandings and Mortality” subsection, later). These strandings are apparently at least in part a disturbance response, although auditory or other injuries may also be a factor. Whether beaked whales would ever react similarly to seismic surveys is unknown. Seismic survey sounds are quite different from those of the sonars in operation during the above-cited incidents. There has been a recent (Sept. 2002) stranding of Cuvier’s beaked whales in the Gulf of California (Mexico) when the L-DEO vessel *Maurice Ewing* was conducting a seismic survey in the general area (e.g., Malakoff 2002). Another stranding of Cuvier’s beaked whales in the Galapagos occurred during a seismic survey in April 2000; however “There is no obvious mechanism that bridges the distance between this source and the stranding site” (Gentry 2002). The evidence with respect to seismic surveys and beaked whale strandings is inconclusive, and NMFS has not established a link between the Gulf of California stranding and the seismic activities (Hogarth 2002).

Sperm Whales.—All three species of sperm whales have been reported to show avoidance reactions to standard vessels not emitting airgun sounds (e.g., Richardson et al. 1995; Würsig et al. 1998). Thus, it is to be expected that they would tend to avoid an operating seismic survey vessel. There are some limited observations suggesting that sperm whales in the Southern Ocean ceased calling during some (but not all) times when exposed to weak noise pulses from extremely distant (>300 km or 162 n.mi.) seismic exploration (Bowles et al. 1994). This "quieting" was suspected to represent a disturbance effect, in part because sperm whales exposed to pulsed man-made sounds at higher frequencies often cease calling (Watkins and Schevill 1975; Watkins et al. 1985). Also, sperm whales in the Gulf of Mexico may have moved away from a seismic vessel (Mate et al. 1994).

On the other hand, recent (and more extensive) data from vessel-based monitoring programs in U.K. waters suggest that sperm whales in that area show little evidence of avoidance or behavioral disruption in the presence of operating seismic vessels (Stone 2003). These types of observations are difficult to interpret because the observers are stationed on or near the seismic vessel, and may underestimate reactions by some of the more responsive species or individuals, which may be beyond visual range. However, the U.K. results do seem to show considerable tolerance of seismic surveys by at least some sperm whales. Also, a recent study off northern Norway indicated that sperm whales continued to call when exposed to pulses from a distant seismic vessel. Received levels of the seismic pulses were up to 146 dB re 1 μPa pk-pk (Madsen et al. 2002). Similarly, a study conducted off Nova Scotia that analyzed recordings of sperm whale vocalizations at various distances from an active seismic program did not detect any obvious changes in the distribution or behavior of sperm whales (McCall Howard 1999). An experimental study of sperm whale reactions to seismic surveys in the Gulf of Mexico is presently underway (Caldwell 2002; Jochens and Biggs 2003), along with a study of the movements of sperm whales with satellite-linked tags in relation to seismic surveys (Mate 2003). During two controlled exposure experiments where sperm whales were exposed to seismic pulses at received levels up to 148 dB re 1 μPa, there was no indication of avoidance of the vessel or changes in feeding efficiency (Jochens and Biggs 2003). The received sounds were measured on an "rms over octave band with most energy" basis (P. Tyack, pers. comm. to LGL Ltd.); the broadband rms value would be somewhat higher. Although the sample size from the initial work was small (four whales during two experiments), the results are consistent with those off northern Norway.

Conclusions.—Dolphins and porpoises are often seen by observers on active seismic vessels, occasionally at close distances (e.g., bow riding). However, some studies, especially near the U.K., show localized avoidance. In contrast, recent studies show little evidence of reactions by sperm whales to airgun pulses, contrary to earlier indications.

There are no specific data on responses of beaked whales to seismic surveys, but it is likely that most if not all species show strong avoidance. There is increasing evidence that some beaked whales may strand after exposure to strong noise from sonars. Whether they ever do so in response to seismic survey noise is unknown.

Pinnipeds

Few studies of the reactions of pinnipeds to noise from open-water seismic exploration have been published (for review, see Richardson et al. 1995). However, pinnipeds have been observed during a number of seismic monitoring studies in recent years. Monitoring studies in the Beaufort Sea during 1996–2001 provide a substantial amount of information on avoidance responses (or lack thereof) and associated behavior. Pinnipeds exposed to seismic surveys have also been observed during recent seismic surveys along the USWW. Some limited data are available on physiological responses of seals exposed to seismic sound, as studied with the aid of radio telemetry. Also, there are data on the reactions of pinnipeds to various other related types of impulsive sounds.

Early observations provided considerable evidence that pinnipeds are often quite tolerant of strong pulsed sounds. During seismic exploration off Nova Scotia, grey seals exposed to noise from airguns and linear explosive charges reportedly did not react strongly (J. Parsons *in* Greene et al. 1985). An airgun caused an initial startle reaction among South African fur seals but was ineffective in scaring them away from fishing gear (Anonymous 1975). Pinnipeds in both water and air sometimes tolerate strong noise pulses from non-explosive and explosive scaring devices, especially if attracted to the area for feeding or reproduction (Mate and Harvey 1987; Reeves et al. 1996). Thus, pinnipeds are expected to be rather tolerant of, or habituate to, repeated underwater sounds from distant seismic sources, at least when the animals are strongly attracted to the area.

In the United Kingdom, a radio-telemetry study has demonstrated short-term changes in the behavior of harbor (=common) seals and grey seals exposed to airgun pulses (Thompson et al. 1998). In this study, harbor seals were exposed to seismic pulses from a 90 in^3 array (3 × 30 in^3 airguns), and behavioral responses differed among individuals. One harbor seal avoided the array at distances up to 2.5 km (1.3 n.mi.) from the source and only resumed foraging dives after seismic stopped. Another harbor seal exposed to the same small airgun array showed no detectable behavioral response, even when the array was within 500 m (1641 ft). All grey seals exposed to a single 10 in^3 airgun showed an avoidance reaction. Seals moved away from the source, increased swim speed and/or dive duration, and switched from foraging dives to predominantly transit dives. These effects appeared to be short-term as all grey seals either remained in, or returned at least once to, the foraging area where they had been exposed to seismic pulses. These results suggest that there are interspecific as well as individual differences in seal responses to seismic sounds.

Off California, visual observations from a seismic vessel showed that California sea lions "typically ignored the vessel and array. When [they] displayed behavior modifications, they often appeared to be reacting visually to the sight of the towed array. At times, California sea lions were attracted to the array, even when it was on. At other times, these animals would appear to be actively avoiding the vessel and array. " (Arnold 1996). In Puget Sound, sighting distances for harbor seals and California sea lions tended to be larger when airguns were operating; both species tended to orient away whether or not the airguns were firing (Calambokidis and Osmek 1998).

Monitoring work in the Alaskan Beaufort Sea during 1996–2001 provided considerable information regarding the behavior of seals exposed to seismic pulses (Harris et al. 2001; Moulton and Lawson 2002). These seismic projects usually involved arrays of 6 to 16 airguns with total volumes 560 to 1500 in^3. The combined results suggest that some seals avoid the immediate area around seismic vessels. In most survey years, ringed seal sightings tended to be farther away from the seismic vessel when the airguns were operating then when they were not (Moulton and Lawson 2002). However, these avoidance movements were relatively small, on the order of 100 m (328 ft) to (at most) a few hundreds of meters, and many seals remained within 100–200 m (328–656 ft) of the trackline as the operating airgun array passed by. Seal sighting rates at the water surface were lower during airgun array operations than during no-airgun periods in each survey year except 1997.

The operation of the airgun array had minor and variable effects on the behavior of seals visible at the surface within a few hundred meters of the array. The behavioral data indicated that some seals were more likely to swim away from the source vessel during periods of airgun operations and more likely to swim towards or parallel to the vessel during non-seismic periods. No consistent relationship was observed between exposure to airgun noise and proportions of seals engaged in other recognizable behaviors, e.g. "looked" and "dove". Such a relationship might have occurred if seals seek to reduce exposure to strong seismic pulses, given the reduced airgun noise levels close to the surface where "looking" occurs (Moulton and Lawson 2002).

In summary, visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds, and only slight (if any) changes in behavior. These studies show that pinnipeds frequently do not avoid the area within a few hundred meters of an operating airgun array. However, initial telemetry work suggests that avoidance and other behavioral reactions may be stronger than evident to date from visual studies.

(f) Hearing Impairment and Other Physical Effects

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds, but there has been no specific documentation of this in the case of exposure to sounds from seismic surveys. Current NMFS policy regarding exposure of marine mammals to high-level sounds is that cetaceans and pinnipeds should not be exposed to impulsive sounds exceeding 180 and 190 dB re 1 μPa (rms), respectively (NMFS 2000). Those criteria have been used in establishing the safety (=shutdown) radii planned for numerous seismic surveys. However, those criteria were established before there was any information about the minimum received levels of sounds necessary to cause auditory impairment in marine mammals. As discussed below,

- the 180 dB criterion for cetaceans is probably quite precautionary, i.e., lower than necessary to avoid Temporary Threshold Shift (TTS) let alone permanent auditory injury, at least for delphinids.
- the minimum sound level necessary to cause permanent hearing impairment 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.

Several aspects of the monitoring and mitigation measures that are now often implemented during seismic survey projects are designed to detect marine mammals occurring near the airgun array, and to avoid exposing them to sound pulses that might cause hearing impairment. In addition, many cetaceans are likely to show some avoidance of the area with ongoing seismic operations (see above). In these cases, the avoidance responses of the animals themselves will reduce or avoid the 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 include stress, neurological effects, bubble formation, resonance effects, 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 pulsed sounds.

Temporary Threshold Shift (TTS)

TTS is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter 1985). While experiencing TTS, the hearing threshold rises and a sound must be stronger in order to be heard. TTS can last from minutes or hours to (in cases of strong TTS) days. The magnitude of TTS depends on the level and duration of noise exposure, among other considerations (Richardson et al. 1995). For sound exposures at or somewhat above the TTS threshold, hearing sensitivity recovers rapidly after exposure to the noise ends. Only a 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.

Toothed Whales.—Ridgway et al. (1997) and Schlundt et al. (2000) exposed bottlenose dolphins and beluga whales to single 1-s pulses of underwater sound. TTS generally became evident at received levels of 192 to 201 dB re 1 µPa rms at 3, 10, 20, and 75 kHz, with no strong relationship between frequency and onset of TTS across this range of frequencies. At 75 kHz, one dolphin exhibited TTS at 182 dB, and at 0.4 kHz, no dolphin or beluga exhibited TTS after exposure to levels up to 193 dB (Schlundt et al. 2000). There was no evidence of permanent hearing loss; all hearing thresholds returned to baseline values at the end of the study.

Finneran et al. (2000) exposed bottlenose dolphins and a beluga whale to single underwater pulses designed to generate sounds with pressure waveforms similar to those produced by distant underwater explosions. Pulses were of 5.1 to 13 milliseconds (ms) in duration and the measured frequency spectra showed a lack of energy below 1 kHz. Exposure to those impulses at a peak received SPL (sound pressure level) of 221 dB re 1 µPa produced no more than a slight and temporary reduction in hearing.

A similar study was conducted by Finneran et al. (2002) using an 80 in^3 water gun, which generated impulses with higher peak pressures and total energy fluxes than used in the aforementioned study. Water gun impulses were expected to contain proportionally more energy at higher frequencies than airgun pulses (Hutchinson and Detrick 1984). "Masked TTS" (MTTS) was observed in a beluga after exposure to a single impulse with peak-to-peak pressure of 226 dB re 1 µPa, peak pressure of 160 kPa, and total energy flux of 186 dB re 1 $\mu Pa^2 \cdot s$. Thresholds returned to within 2 dB of pre-exposure value ~4 min after exposure. No MTTS was observed in a bottlenose dolphin exposed to one pulse with peak-to-peak pressure of 228 dB re 1 µPa, equivalent to peak pressure 207 kPa and total energy flux of 188 dB re 1 $\mu Pa^2 \cdot s$ (Finneran et al. 2000, 2002). In this study, TTS was defined as occurring when there was a 6 dB or larger increase in post-exposure thresholds; the reference to masking (<u>M</u>TTS) refers to the fact that these measurements were obtained under conditions with substantial (but controlled) background noise. Pulse duration at the highest exposure levels, where MTTS became evident in the beluga, was typically 10–13 ms.

The data quoted above all concern exposure of small odontocetes to single pulses of duration 1 s or shorter, generally at frequencies higher than the predominant frequencies in airgun pulses. With 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). The degree to which this generalization holds for other types of signals is unclear (Nachtigall et al. 2003). In particular, additional data are needed in order to determine the received sound levels at which small odontocetes would start to incur TTS upon exposure to repeated, low-frequency pulses of airgun sound with variable received levels. Given the results of the aforementioned studies and a seismic pulse duration (as received at close range) of ~20 ms, the received level of a single seismic pulse might need to be on the order of 210 dB re 1 µPa rms (~221–226 dB pk-pk) in order to produce brief, mild TTS. Exposure to several seismic pulses at received levels near 200–205 dB (rms) might result in slight TTS in a small odontocete, assuming the TTS threshold is (to a first approximation) a function of the total received pulse energy. Seismic pulses with received levels of 200–205 dB or more are usually restricted to a radius of no more than 100 m (328 ft) around a seismic vessel.

Baleen Whales.—There are no data, direct or indirect, on levels or properties of sound that are required to induce TTS in any baleen whale.

Pinnipeds.—TTS thresholds for pinnipeds exposed to brief pulses (either single or multiple) have not been measured. Two California sea lions did not incur TTS when exposed to single brief pulses with received levels (rms) of ~178 and 183 dB re 1 μPa and total energy fluxes of 161 and 163 dB re 1 $\mu Pa^2 \cdot s$ (Finneran et al. 2003). However, prolonged exposures show that some pinnipeds may incur TTS at somewhat lower received levels than do small odontocetes exposed for similar durations. For sounds of relatively long duration (20–22 min), Kastak et al. (1999) reported that they could induce mild TTS in California sea lions, harbor seals, and northern elephant seals by exposing them to underwater octave-band noise at frequencies in the 100–2000 Hz range. Mild TTS became evident when the received levels were 60–75 dB above the respective hearing thresholds, i.e., at received levels of about 135–150 dB. Three of the five subjects showed shifts of ~4.6–4.9 dB and all recovered to baseline hearing sensitivity within 24 hours of exposure. Schusterman et al. (2000) showed that TTS thresholds of these seals were somewhat lower when the animals were exposed to the sound for 40 min than for 20–22 min, confirming that there is a duration effect in pinnipeds. There are some indications that, for corresponding durations of sound, some pinnipeds may incur TTS at somewhat lower received levels than do small odontocetes (Kastak et al. 1999; Ketten et al. 2001; *cf*. Au et al. 2000).

Likelihood of Incurring TTS.—A marine mammal within a radius of ≤100 m (≤328 ft) around a typical array of operating airguns might be exposed to a few seismic pulses with levels of ≥205 dB, and possibly more pulses if the mammal moved with the seismic vessel.

As shown above, most cetaceans show some degree of avoidance of seismic vessels operating an airgun array. It is unlikely that these cetaceans would be exposed to airgun pulses at a sufficiently high level for a sufficiently long period to cause more than mild TTS, given the relative movement of the vessel and the marine mammal. However, TTS would be more likely in any odontocetes that bow-ride or otherwise linger near the airguns. While bow-riding, odontocetes would be at or above the surface, and thus not exposed to strong sound pulses given the pressure-release effect at the surface. However, bow-riding animals generally dive below the surface intermittently. If they did so while bow-riding near airguns, they would be exposed to strong sound pulses, possibly repeatedly. If some cetaceans did incur TTS through exposure to airgun sounds in this manner, this would very likely be a temporary and reversible phenomenon.

Some pinnipeds show avoidance reactions to airguns, but their avoidance reactions are not as strong or consistent as those of cetaceans (see above). Pinnipeds occasionally seem to be attracted to operating seismic vessels. As previously noted, there are no specific data on TTS thresholds of pinnipeds exposed to single or multiple low-frequency pulses. It is not known whether pinnipeds near operating seismic vessels, and especially those individuals that linger nearby, incur significant TTS.

NMFS (1995, 2000) concluded that cetaceans should not be exposed to pulsed underwater noise at received levels exceeding 180 dB re 1 μPa (rms). The corresponding limit for pinnipeds has been set at 190 dB. These sound levels are ***not*** considered to be the levels above which TTS might occur. Rather, they are 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 discussed above, TTS data that have subsequently become available imply that, at least for dolphins, TTS is unlikely to occur unless the dolphins are exposed to airgun pulses stronger than 180 dB re 1 μPa rms.

It has been shown that most large whales tend to avoid ships and associated seismic operations. In addition, ramping up airgun arrays, which is standard operational protocol for many seismic operators, should allow cetaceans to move away from the seismic source and to avoid being exposed to the full acoustic output of the airgun array. [Three species of baleen whales that have been exposed to pulses from single airguns showed avoidance (Malme et al. 1984–1988; Richardson et al. 1986; McCauley et al. 1998, 2000a,b). This strongly suggests that baleen whales will begin to move away during the initial stages of a ramp-up, when a single airgun is fired.] Thus, whales will likely not be exposed to high levels of airgun sounds. Likewise, any whales close to the trackline could move away before the sounds from the approaching seismic vessel become sufficiently strong for there to be any potential for TTS or other hearing impairment. Therefore, there is little potential for whales to be close enough to an airgun array to experience TTS. Furthermore, in the event that a few individual cetaceans did incur TTS through exposure to airgun sounds, this is a temporary and reversible phenomenon.

Permanent Threshold Shift (PTS)

When PTS occurs, there is physical damage to the sound receptors in the ear. In some 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. Physical damage to a mammal's hearing apparatus can occur if it is exposed to sound impulses that have very high peak pressures, especially if they have very short rise times (time required for sound pulse to reach peak pressure from the baseline pressure). Such damage can result in a permanent decrease in functional sensitivity of the hearing system at some or all frequencies.

There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal. However, given the possibility that mammals close to an airgun array might incur TTS, there has been speculation about the possibility that some individuals occurring very close to airguns might incur TTS (Richardson et al. 1995, p. 372*ff*).

Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage in terrestrial mammals. 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. The low-to-moderate levels of TTS that have been induced in captive odontocetes and pinnipeds during recent controlled studies of TTS have been confirmed to be temporary, with no measurable residual PTS (Kastak et al. 1999; Schlundt et al. 2000; Finneran et al. 2002; Nachtigall et al. 2003). However, very prolonged exposure to sound strong enough to elicit TTS, or shorter-term exposure to sound levels well above the TTS threshold, can cause PTS, at least in terrestrial mammals (Kryter 1985). In terrestrial mammals, the received sound level from a single non-impulsive sound exposure must be far above the TTS threshold for any risk of permanent hearing damage (Kryter 1994; Richardson et al. 1995). For impulse sounds with very rapid rise times (e.g., those associated with explosions or gunfire), a received level not greatly in excess of the TTS threshold may start to elicit PTS. Rise times for airgun pulses are rapid, but less rapid than for explosions.

Some factors that contribute to onset of PTS, at least in terrestrial mammals, are as follows:

- exposure to single very intense sound,
- repetitive exposure to intense sounds that individually cause TTS but not PTS, and
- recurrent ear infections or (in captive animals) exposure to certain drugs.

Cavanagh (2000) has reviewed the thresholds used to define TTS and PTS. Based on this review and SACLANT (1998), it is reasonable to assume that PTS might occur at a received sound level 20 dB or more above that inducing mild TTS. However, for PTS to occur at a received level only 20 dB above the TTS threshold, the animal probably would have to be exposed to a strong sound for an extended period, or to a strong sound with rather rapid rise time.

Sound impulse duration, peak amplitude, rise time, and number of pulses are the main factors thought to determine the onset and extent of PTS. Based on existing data, Ketten (1994) has noted that the criteria for differentiating the sound pressure levels that result in PTS (or TTS) are location and species-specific. PTS effects may also be influenced strongly by the health of the receiver's ear.

Given that marine mammals are unlikely to be exposed to received levels of seismic pulses that could cause TTS, it is highly unlikely that they would sustain permanent hearing impairment. If we assume that the TTS threshold for exposure to a series of seismic pulses may be on the order of 220 dB re 1 μPa (pk-pk) in odontocetes, then the PTS threshold might be as high as 240 dB re 1 μPa (pk-pk). In the units used by geophysicists, this is 10 bar-m. Such levels are found only in the immediate vicinity of the largest airguns (Richardson et al. 1995:137; Caldwell and Dragoset 2000). It is very unlikely that an odontocete would remain within a few meters of a large airgun for sufficiently long to incur PTS. The TTS (and thus PTS) thresholds of baleen whales and pinnipeds may be lower, and thus may extend to a somewhat greater distance. However, baleen whales generally avoid the immediate area around operating seismic vessels, so it is unlikely that a baleen whale could incur PTS from exposure to airgun pulses. Pinnipeds, on the other hand, often do not show strong avoidance of operating airguns.

Although it is unlikely that airgun operations during most seismic surveys would cause PTS in marine mammals, caution is warranted given the limited knowledge about noise-induced hearing damage in marine mammals, particularly baleen whales. Commonly-applied monitoring and mitigation measures, including visual monitoring, course alteration, ramp ups, and power downs or shut downs of the airguns when mammals are seen within the "safety radii", would minimize the already-low probability of exposure of marine mammals to sounds strong enough to induce PTS.

(g) Strandings and Mortality

Marine mammals close to underwater detonations of high explosive can be killed or severely injured, and the auditory organs are especially susceptible to injury (Ketten et al. 1993; Ketten 1995). Airgun pulses are less energetic and have slower rise times, and there is no proof that they can cause serious injury, death, or stranding. However, the association of mass strandings of beaked whales with naval exercises and, in a recent (2002) case, an L-DEO seismic survey, has raised the possibility that beaked whales may be especially susceptible to injury and/or behavioral reactions that can lead to stranding when exposed to strong pulsed sounds.

In March 2000, several beaked whales that had been exposed to repeated pulses from high intensity, mid-frequency military sonars stranded and died in the Providence Channels of the Bahamas Islands, and were subsequently found to have incurred cranial and ear damage (NOAA and USN 2001). Based on post-mortem analyses, it was concluded that an acoustic event caused hemorrhages in and near the auditory region of some beaked whales. These hemorrhages occurred before death. They would not necessarily have caused death or permanent hearing damage, but could have compromised hearing and navigational ability (NOAA and USN 2001). The researchers concluded that acoustic exposure caused this damage and triggered stranding, which resulted in overheating, cardiovascular collapse, and physiological shock that ultimately led to the death of the stranded beaked whales. During the event, five naval vessels used their AN/SQS-53C or -56 hull-mounted active sonars for a period of 16 h. The sonars produced narrow (<100 Hz) bandwidth signals at center frequencies of 2.6 and 3.3 kHz (-53C), and 6.8 to 8.2 kHz (-56). The respective source levels were usually 235 and 223 dB re 1 µPa, but the -53C briefly operated at an unstated but substantially higher source level. The unusual bathymetry and constricted channel where the strandings occurred were conducive to channeling sound. This, and the extended operations by multiple sonars, apparently prevented escape of the animals to the open sea. In addition to the strandings, there are reports that beaked whales were no longer present in the Providence Channel region after the event, suggesting that other beaked whales either abandoned the area or perhaps died at sea (Balcomb and Claridge 2001).

Other strandings of beaked whales associated with operation of military sonars have also been reported (e.g., Simmonds and Lopez-Jurado 1991; Frantzis 1998). In these cases, it was not determined whether there were noise-induced injuries to the ears or other organs. Another stranding of beaked whales (15 whales) happened on 24–25 September 2002 in the Canary Islands, where naval maneuvers were taking place. A recent paper concerning the Canary Islands stranding concluded that cetaceans might be subject to decompression injury in some situations (Jepson et al. 2003). If so, this might occur if they ascend unusually quickly when exposed to aversive sounds. Previously it was widely assumed that diving marine mammals are not subject to the bends or air embolism.

It is important to note that seismic pulses and mid-frequency sonar pulses are quite different. Sounds produced by the types of airgun arrays used to profile sub-sea geological structures are broadband with most of the energy below 1 kHz. Typical military mid-frequency sonars operate at frequencies of 2 to 10 kHz, generally with a relatively narrow bandwidth at any one time (though the center frequency may change over time). Because seismic and sonar sounds have considerably different characteristics and duty cycles, 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 pulses can, in special circumstances, lead to hearing damage and, indirectly, mortality suggests that caution is warranted when dealing with exposure of marine mammals to any high-intensity pulsed sound.

As discussed earlier, there has been a recent (Sept. 2002) stranding of two Cuvier's beaked whales in the Gulf of California (Mexico) when a seismic survey by the L-DEO/NSF vessel R/V *Maurice Ewing* was underway in the general area (Malakoff 2002). The airgun array in use during that project was the *Ewing*'s 20-airgun 8490-in^3 array. This might be a first indication that seismic surveys can have effects, at least on beaked whales, similar to the suspected effects of naval sonars. However, the evidence linking the Gulf of California strandings to the seismic surveys is inconclusive, and to this date is not based on any physical evidence (Hogarth 2002; Yoder 2002). The ship was also operating its multibeam bathymetric sonar at the same time but, as discussed elsewhere, this sonar had much less potential than the aforementioned naval sonars to affect beaked whales. Although the link between the Gulf of California strandings and the seismic (plus multibeam sonar) survey is inconclusive, this plus the various incidents involving beaked whale strandings "associated with" naval exercises suggests a need for caution in conducting seismic surveys in areas occupied by beaked whales.

(h) Non-auditory Physiological Effects

Possible types of non-auditory physiological effects or injuries that might theoretically occur in marine mammals exposed to strong underwater sound might include stress, neurological effects, bubble formation, resonance effects, and other types of organ or tissue damage. There is no proof that any of these effects occur in marine mammals exposed to sound from airgun arrays. However, there have been no direct studies of the potential for airgun pulses to elicit any of these effects. If any such effects do occur, they would probably be limited to unusual situations when animals might be exposed at close range for unusually long periods.

Long-term exposure to anthropogenic noise may have the potential of causing physiological stress that could affect the health of individual animals or their reproductive potential, which in turn could (theoretically) cause effects at the population level (Gisiner [ed.] 1999). However, there is essentially no information about the occurrence of noise-induced stress in marine mammals. Also, it is doubtful that any single marine mammal would be exposed to strong seismic sounds for sufficiently long that significant physiological stress would develop. This is particularly so in the case of seismic surveys where the tracklines are long and/or not closely spaced, as is the case for most two-dimensional seismic surveys.

Gas-filled structures in marine animals have an inherent fundamental resonance frequency. If stimulated at this frequency, the ensuing resonance could cause damage to the animal. There may also be a possibility that high sound levels could cause bubble formation in the blood of diving mammals that in turn could cause an air embolism, tissue separation, and high, localized pressure in nervous tissue (Gisiner [ed.] 1999; Houser et al. 2001). A recent workshop (Gentry [ed.] 2002) was held to discuss whether the stranding of beaked whales in the Bahamas in 2000 might have been related to air cavity resonance or bubble formation in tissues caused by exposure to noise from naval sonar. A panel of experts concluded that resonance in air-filled structures was not likely to have caused this stranding. Among other reasons, the air spaces in marine mammals are too large to be susceptible to resonant frequencies emitted by mid- or low-frequency sonar; lung tissue damage has not been observed in any mass, multi-species stranding of beaked whales; and the duration of sonar pings is likely too short to induce vibrations that could damage tissues (Gentry [ed.] 2002). Opinions were less conclusive about the possible role of gas (nitrogen) bubble formation/growth in the Bahamas stranding of beaked whales. Workshop participants did not rule out the possibility that bubble formation/growth played a role in the stranding and participants acknowledged that more research is needed in this area. The only available information on acoustically-mediated bubble growth in marine mammals is modeling assuming prolonged exposure to sound.

As noted in the preceding subsection, a recent paper (Jepson et al. 2003) has suggested that cetaceans can at times be subject to decompression sickness. If so, this could be another mechanism by which exposure to strong sounds could, indirectly, result in non-auditory injuries and perhaps death.

In summary, very little is known about the potential for seismic survey sounds to cause either auditory impairment or other non-auditory physical effects in marine mammals. Available data suggest that such effects, if they occur at all, would be limited to short distances. However, the available data do not allow for meaningful quantitative predictions of the numbers (if any) of marine mammals that might be affected in these ways. Marine mammals that show behavioral avoidance of seismic vessels, including most baleen whales, some odontocetes, and some pinnipeds, are unlikely to incur auditory impairment or other physical effects.

Literature Cited

Literature mentioned in this Appendix is listed in the overall Literature Cited section earlier in this document.