Request by the University of Alaska Geophysics Institute for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during a Marine Geophysical Survey by the R/V *Marcus G. Langseth* in the Arctic Ocean, September–October 2011

submitted by

University of Alaska Geophysics Institute
900 Yukon Drive
Fairbanks, AK 99775

to

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

Application Prepared by

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

3 March 2011
Revised 31 March and 5 May 2011

LGL Report TA4882-3

TABLE OF CONTENTS

Page

Request by the University of Alaska Geophysics Institute for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during a Marine Geophysical Survey by the R/V *Marcus G. Langseth* in the Arctic Ocean, September–October 2011

SUMMARY

The University of Alaska Geophysics Institute (UAGI), with research funding from the National Science Foundation (NSF), plans to conduct a marine seismic survey in the Arctic Ocean during September–October 2011. The survey will take place in International Waters and in the Exclusive Economic Zone (EEZ) of the U.S.A. The seismic study will use a towed array of 10 airguns with a total discharge volume of ~1830 in^3. UAGI requests that it be issued an Incidental Harassment Authorization (IHA) allowing non-lethal takes of marine mammals incidental to the planned seismic survey. This request is submitted pursuant to Section 101 (a) (5) (D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371 (a) (5).

Several species of cetaceans and pinnipeds inhabit the parts of the Arctic Ocean where this cruise is proposed to occur. Species listed as ***endangered*** under the U.S. Endangered Species Act (ESA) and managed by NMFS may occur in certain portions of the survey area, most notably the bowhead whale, and (although very unlikely) the fin and humpback whale. Other species of concern that might occur in the area are the ***threatened*** spectacled and Steller's eiders.

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

I. OPERATIONS TO BE CONDUCTED

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

Overview of the Activity

UAGI plans to conduct a seismic survey in the Arctic Ocean from the R/V *Marcus G. Langseth*. The *Langseth* is operated by Lamont-Doherty Earth Observatory (L-DEO), a part of Columbia University, under a cooperative agreement with the NSF. The survey will occur in International Waters and within the EEZ of the U.S.A., encompassing the area 72.5–77°N, 160–175°W (Fig. 1). The project is scheduled to occur ~5 September–9 October 2011. Some minor deviation from these dates is possible, depending on logistics and weather. The proposed survey will include collection of seismic reflection data across the transition from the Chukchi Shelf to the Chukchi Borderland to define the apparent change in structure between two large continental blocks. This study will test existing tectonic models and

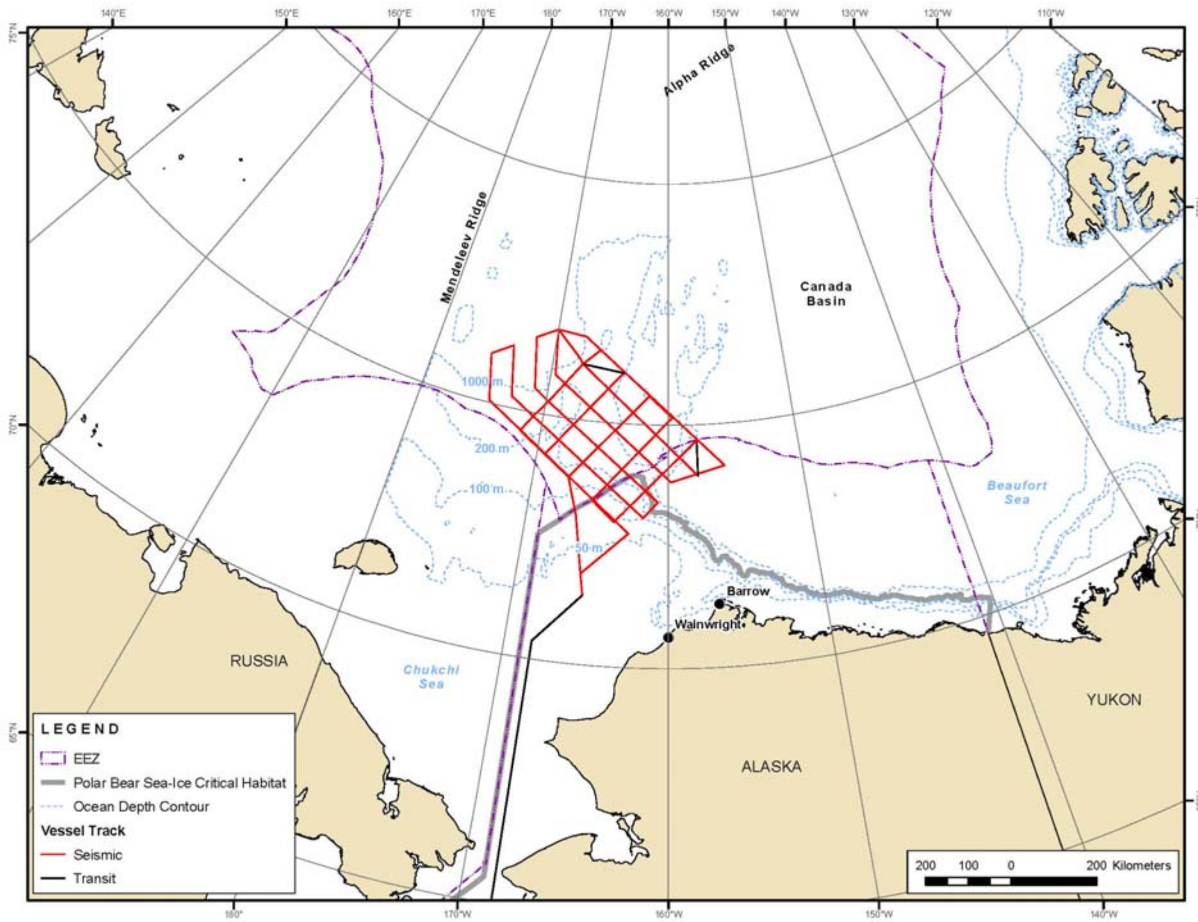

FIGURE 1. Proposed location of UAGI's September–October 2011 Arctic Ocean seismic survey lines. The precise track may vary somewhat from this proposed version depending on ice conditions.

develop new constraints on the development of the Amerasian Basin, and will substantially advance our understanding of the Mesozoic history of this basin. In addition, these data will enable the formulation of new tectonic models for the history of this region, which will improve our understanding of the surrounding continents.

The source vessel, the R/V *Marcus G. Langseth*, will deploy an array of 10 airguns as an energy source at a tow depth of 6 m. The receiving system will consist of a 2-km long hydrophone streamer. As the airgun array is towed along the survey lines, the hydrophone streamer will receive the returning acoustic signals and transfer the data to the on-board processing system. In addition, at least 72 sonobuoys will be deployed in order to record seismic refraction data. The *Langseth* will be avoiding the ice edge, and an ice expert will be available to provide daily guidance and to predict ice movements.

The program will consist of a total of ~5502 km of survey lines, not including transits to and from the survey area when airguns will not be in use (Fig. 1). Water depths within the study area range from ~30–3800 m. Just over half of the survey effort (55%) will occur in water 100–1000 m deep, 32% will take place in water >1000 m deep, and 13% will occur in water depths <100 m. There will be additional seismic operations in the survey area associated with turns, airgun testing, and repeat coverage of any areas where initial data quality is sub-standard. In addition to the operations of the airgun array, a multibeam echosounder (MBES) and a sub-bottom profiler (SBP) will also be operated from the *Langseth* continuously throughout the cruise. A 75-kHz acoustic Doppler current profiler (ADCP) may also be used.

All planned geophysical data acquisition activities will be conducted by L-DEO with on-board assistance by the scientists who have proposed the study. The Principal Investigator (PI) is Dr. Bernard Coakley of UAGI. The vessel will be self-contained, and the crew will live aboard the vessel for the entire cruise.

Vessel Specifications

The R/V *Marcus G. Langseth* will be used as the source vessel. The *Langseth* will tow the 10-airgun array along predetermined lines (Fig. 1). The *Langseth* will also tow the hydrophone streamer and deploy the sonobuoys. When the *Langseth* is towing the airgun array as well as the hydrophone streamer, the turning rate of the vessel while the gear is deployed is limited. Thus, the maneuverability of the vessel is limited during operations with the streamer.

The *Langseth* has a length of 71.5 m, a beam of 17.0 m, and a maximum draft of 5.9 m. The *Langseth* was designed as a seismic research vessel, with a propulsion system designed to be as quiet as possible to avoid interference with the seismic signals. The ship is powered by two Bergen BRG-6 diesel engines, each producing 3550 hp, which drive the two propellers directly. Each propeller has four blades, and the shaft typically rotates at 600 or 750 revolutions per minute (rpm). The vessel also has an 800 hp bowthruster, which is not used during seismic acquisition. The operation speed during seismic acquisition is typically 7.4–9.3 km/h. When not towing seismic survey gear, the *Langseth* typically cruises at 18.5 km/h. The *Langseth* has a range of 25,000 km (the distance the vessel can travel without refueling).

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

Other details of the *Langseth* include the following:

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

Airgun Description

During the survey, the airgun array to be used will consist of 10 airguns, with a total volume of ~1830 in^3. The airgun array will consist of a mixture of Bolt 1500LL and Bolt 1900LLX airguns, set in a typical configuration of one of the *Langseth*'s four linear arrays or "strings" (Fig. 2); the first and last airguns in the strings are spaced 16 m apart. The airgun array will be towed ~100 m behind the *Langseth*. The shot interval will be 15 s. The firing pressure of the array is 1950 psi. During firing, a brief (~0.1 s) pulse of sound is emitted. The airguns will be silent during the intervening periods.

The tow depth of the array will be 6 m. Because the actual source is a distributed sound source (10 airguns) rather than a single point source, the highest sound levels measurable at any location in the water will be less than the nominal source level. In addition, the effective source level for sound propagating in near-horizontal directions will be substantially lower than the nominal source level applicable to downward propagation because of the directional nature of the sound from the airgun array.

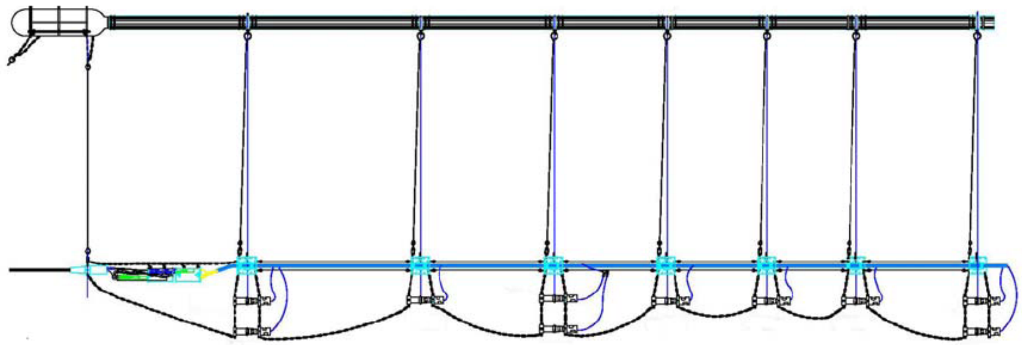

FIGURE 2. One linear airgun array or string with ten airguns.

10-Airgun Array Specifications

Energy Source	Ten 1950 psi Bolt airguns; 40–360 in^3
Source output (downward)	0-pk is 19.6 bar-m (246 dB re 1 μPa·m); pk-pk is 39.4 bar·m (252 dB)
Air discharge volume	~1830 in^3
Dominant frequency components	2–188 Hz

Acoustic Measurement Units

Received sound levels have been predicted by Marine Acoustics, Inc. (MAI), in relation to distance and direction from the airguns, for the 10-airgun array. The MAI model was site specific; sound velocity profiles, bathymetry, and bottom composition were used to model propagation at seven sites 120–2727 m deep in the survey area that represented different physiographic provinces described by Jakobsson et al. (2003). The source model used was the CASS/GRAB model, and propagation was modeled using the Range-Dependent Acoustic Model (RAM) (Zingarelli and King 2005). The detailed modeling report can be found in Appendix A1 of the EA.

Received sound levels for a single 40-in^3 airgun were modeled by L-DEO. Figure 3 illustrates modeled received sound levels for a single airgun operating in deep water. The tow depth has minimal effect on the maximum near-field output and the shape of the frequency spectrum for the single airgun; thus, the predicted safety radii are essentially the same at different tow depths. As the L-DEO model does not allow for bottom interactions, and thus is most directly applicable to deep water and to relatively short ranges, correction factors were used to estimate safety radii in shallow and intermediate-depth water as was done for previous L-DEO surveys from the *Langseth*. A detailed description of the L-DEO modeling effort is provided in Appendix A2 of the EA. The predicted sound contours for the 40-in^3 mitigation airgun are shown as sound exposure levels (SEL) in decibels (dB) re 1 $\mu Pa^2 \cdot s$. SEL is a measure of the received energy in the pulse and represents the sound pressure level (SPL) that would be measured if the pulse energy were spread evenly across a 1-s period. Because actual seismic pulses are less than 1 s in duration in most situations, this means that the SEL value for a given pulse is usually lower than the SPL calculated for the actual duration of the pulse (see Appendix B of the EA). The advantage of working with SEL is that the SEL measure accounts for the total received energy in the pulse, and biological effects of pulsed sounds are believed to depend mainly on pulse energy (Southall et al. 2007). In contrast, SPL for a given pulse depends greatly on pulse duration. A pulse with a given SEL can be long or short depending on the extent to which propagation effects have "stretched" the pulse duration. The SPL will be low if the duration is long and higher if the duration is short, even though the pulse energy (and presumably the biological effects) are the same.

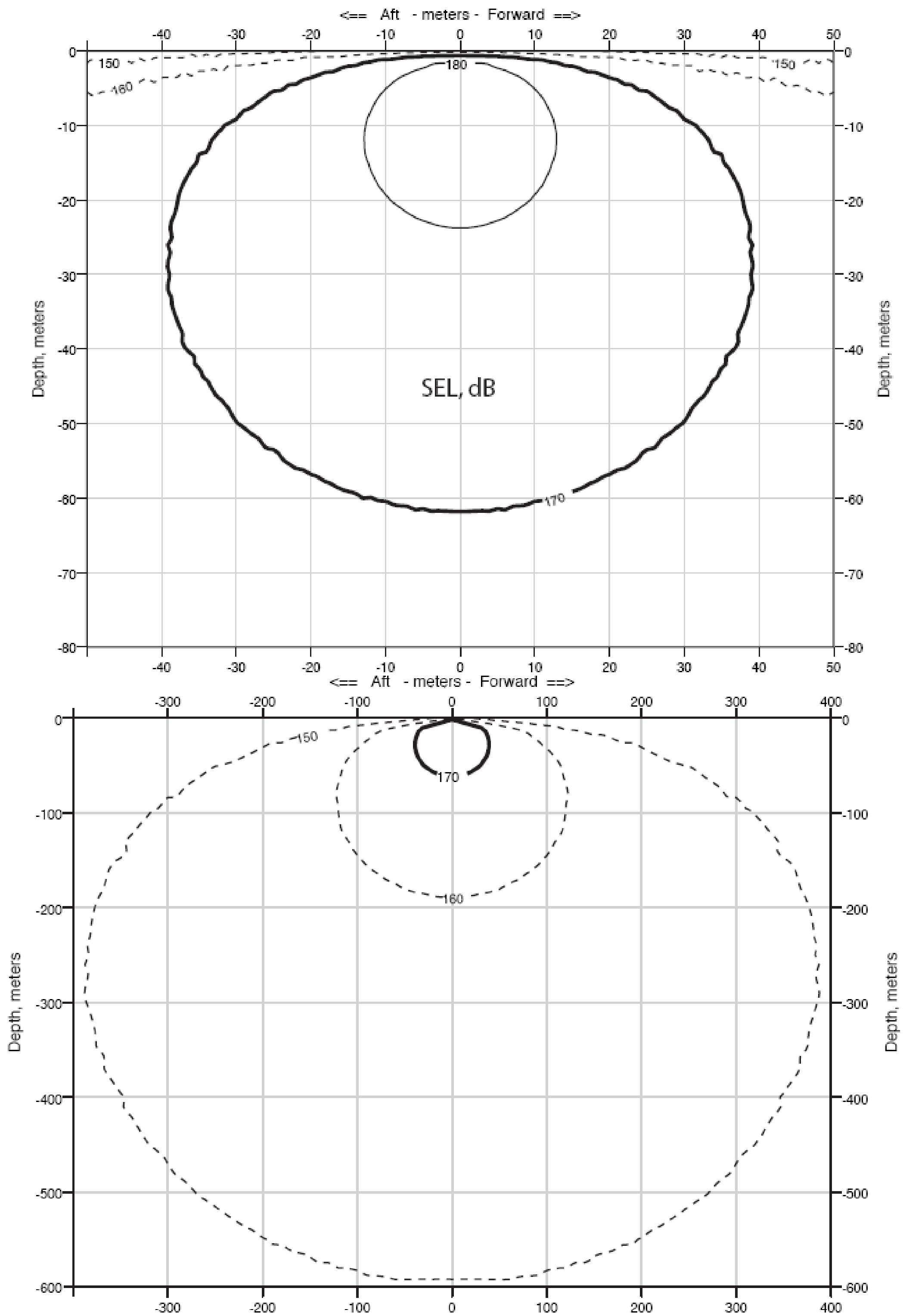

FIGURE 3. Modeled received sound levels (SELs) from a single 40-in^3 airgun operating in deep water, which is planned for use as a mitigation airgun. Received rms levels (SPLs) are expected to be ~10 dB higher.

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

Predicted Sound Levels

Table 1 shows the distances at which three rms sound levels are expected to be received from the 10-airgun array and a single airgun. For the 10-airgun array, distances were modeled at seven sites; the distances in Table 1 are the averages from the sites in each depth range. The 180- and 190-dB re 1 μPa_{rms} distances are the safety criteria as specified by NMFS (2000) and are applicable to cetaceans and pinnipeds, respectively. If marine mammals are detected within or about to enter the appropriate exclusion zone, the airguns will be powered down (or shut down if necessary) immediately.

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

Description of Operations

The source vessel, the R/V *Marcus G. Langseth*, will deploy an array of 10 airguns as an energy source at a tow depth of 6 m. The receiving system for the returning acoustic signals will consist of a 2-km hydrophone streamer. As the airgun array is towed along the survey lines, the hydrophone streamer will receive the returning acoustic signals and transfer the data to the on-board processing system. At least 72 sonobuoys will be deployed to record seismic refraction data

TABLE 1. Maximum predicted distances to which sound levels ≥190, 180, and 160 dB re 1 μPa_{rms} could be received in various water-depth categories during the proposed survey in the Arctic Ocean. The distances for the 10-airgun array are the averages of modeled 95% percentile distances at modeling sites in each depth range (see text and Appendix A1 of the EA).

Source and Volume	Tow Depth (m)	Water Depth	Predicted RMS Radii (m)		
			190 dB	180 dB	160 dB
Single Bolt airgun 40 in^3	6	Deep (>1000 m)	12	40	385
		Intermediate (100–1000 m)	18	60	578
		Shallow (<100)	150	296	1050
1 string 10 airguns 1830 in^3	6	Deep (>1000 m)	130	425	14,070
		Intermediate (200–1000 m)	130	1400	13,980
		Shallow (<200)	190	1870	14,730

* The tow depth has minimal effect on the maximum near-field output and the shape of the frequency spectrum for the single 40 in^3 airgun; thus, the predicted safety radii are essentially the same at any tow depth.

The planned seismic survey will consist of ~5502 km of survey lines, not including transits to and from the survey area when airguns will not be in use (Fig. 1). In addition to the operations of the airgun array, a Kongsberg EM 122 MBES and a Knudsen Chirp 3260 SBP will also be operated from the *Langseth* continuously throughout the cruise.

Multibeam Echosounder, Sub-bottom Profiler, and Acoustic Doppler Current Profilers

Along with the airgun operations, additional acoustical systems will be operated during the cruise. The ocean floor will be mapped with the Kongsberg EM 122 MBES and a Knudsen 320B SBP. These sound sources will be operated from the *Langseth* continuously throughout the cruise. An ADCP (RDI OS75-kHz) may also be used.

Multibeam Echosounder

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

Hydrographic Sub-bottom Profiler (Knudsen Chirp 3260)

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

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

Maximum source output (downward)	222 dB re 1 μPa·m
Dominant frequency components	3.5 kHz
Nominal beam width	~27 degrees
Ping duration	up to 64 ms

Acoustic Doppler Current Profiler (R D Instruments Ocean Surveyor 75)

The Ocean Surveyor 75 is an ADCP operating at a frequency of 75 kHz, producing a ping every 1.4 s. The system is a four-beam phased array with a beam angle of 30°. Each beam has a width of 4° and there is no overlap. Maximum output power is 1 kW with a maximum depth range of 700 m.

II. Dates, Duration, and Region of Activity

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

The survey will occur in the area 72.5–77°N, 160–175°W in International Waters and within the EEZ of the U.S.A. (Fig. 1). Water depths in the survey area range from ~30 m to 3800 m. The exact dates of the activities depend on logistics and weather conditions. The *Langseth* will depart from Dutch Harbor on ~5 September 2011 and sail northeast to arrive at ~72.5ºN, 162ºW, where the seismic survey will begin, >200 km from Barrow. The entire cruise will last for ~34 days, and it is estimated that the total seismic survey time will be ~25 days depending on ice conditions. Seismic survey work is scheduled to terminate near the starting point at ~72.4ºN, 164ºW on ~6 October; the vessel will then sail south to Dutch Harbor for arrival on 9 October. There could be extra days of seismic shooting, if the collected data are of substandard quality.

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 nine cetacean species, five species of pinnipeds, and one marine carnivore are known to or may occur in or near the proposed study area (Table 2). Three of these species, the bowhead whale, humpback whale, and fin whale, are listed as ***endangered*** under the ESA, and the polar bear is listed as ***threatened*** under the ESA.

The marine mammals that occur in the proposed survey area belong to three taxonomic groups: odontocetes (toothed cetaceans, such as beluga whale and narwhal), mysticetes (baleen whales), and carnivora (pinnipeds and polar bears). Cetaceans and pinnipeds (except walrus) are the subject of the IHA Application to NMFS; in the U.S., the walrus and polar bear are managed by the U.S. Fish and Wildlife Service (USFWS).

The marine mammal species most likely to be encountered during the seismic survey include two cetacean species (beluga and bowhead whale) and two pinniped species (ringed and bearded seal). However, most of these species will occur in low numbers and are most common within 100 km of shore, where no seismic work is planned to take place. The marine mammal most likely to be encountered throughout the cruise is the ringed seal.

TABLE 2. The habitat, abundance, and conservation status of marine mammals that could occur in or near the proposed study area in the Arctic Ocean.

Species	Habitat	Regional abundance	ESA[1]	IUCN[2]	CITES[3]
Mysticetes					
Bowhead whale, *Balaena mysticetus*	Pack ice, coastal	11,836[4]	EN	LC	I
Gray whale, *Eschrichtius robustus*	Coastal, lagoons	19,126[5]	DL	LC	I
Humpback whale, *Megaptera novaeangliae*	Shelf, coastal	20,800[6]	EN	LC	I
Minke whale, *Balaenoptera acutorostrata*	Shelf, coastal	810[7]	NL	LC	I
Fin whale, *Balaenoptera physalus*	Slope, mostly pelagic	13,620-18,680[8]	EN	EN	I
Odontocetes					
Beluga whale, *Delphinapterus leucas*	Offshore, coastal, Ice edges	42,968[9]	NL	NT	II
Narwhal, *Monodon monoceros*	Offshore, Ice edge	N.A.[10]	NL	NT	II
Killer whale, *Orcinus orca*	Widely distributed	N.A.	NL	DD	II
Harbor porpoise, *Phocoena phocoena*	Coastal, inland waters, shallow offshore waters	48,215[11]	NL	LC	II
Pinnipeds					
Pacific walrus, *Odobenus rosmarus*	Coastal, pack ice, ice floes	~200,00-246,000[16]	R	DD	III
Bearded seal, *Erignathus barbatus*	Pack ice, open water	250,000-300,000[12]	LP	LC	–
Spotted seal, *Phoca largha*	Pack ice, open water, coastal haulouts	~59,214[13]	NL	DD	–
Ringed seal, *Pusa hispida*	Landfast ice, pack ice, open water	>249,000[14]	LP	LC	–
Ribbon seal, *Histriophoca fasciata*	Pack ice, open water	90,000–100,000[15]	NL	DD	–
Ursids					
Polar bear, *Ursus maritimus*	Pack ice	4700[17]	T	VU	II

N.A. = Not available

[1] U.S. Endangered Species Act: EN = Endangered, T = Threatened, NL = Not listed, R = In review for listing, LP = In listing process, DL = Delisted.

[2] Classifications are from the IUCN *Red List of Threatened Species* (IUCN 2010): EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient.

[3] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2011): Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled; Appendix III: protected in at least one country, which has asked other CITES Parties for assistance in controlling the trade.

[4] Based on 2003-2004 surveys (Koski et al. 2008).

[5] Eastern North Pacific gray whale population (Allen and Angliss 2010).

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

[7] Central-eastern Bering Sea (Allen and Angliss 2010).

[8] North Pacific (Ohsumi and Wada 1974).

[9] Sum of Eastern Chukchi Sea and Beaufort Sea stocks (Allen and Angliss 2010)

[10] Baffin Bay and Canadian Arctic archipelago population (COSEWIC 2004).

[11] Bering Sea stock (Allen and Angliss 2010).

[12] Based on early estimates of the Bering-Chukchi Sea population (see Allen and Angliss 2010)

[13] Alaska stock based on aerial surveys in 1992 (Allen and Angliss 2010).

[14] Minimum estimate for Beaufort and Eastern Chukchi Sea populations (Allen and Angliss 2010)

[15] Bering Sea population in the mid 1970s (Allen and Angliss 2010).

[16] 1975-1990 (Allen and Angliss 2010).

[17] Chukchi Sea and northern and southern Beaufort Sea populations combined (Aars et al. 2006).

Seven additional cetacean species—narwhal, killer whale, harbor porpoise, gray whale, minke whale, fin whale, and humpback whale—could occur in the project area but are unlikely to be encountered during the survey because they are primarily coastal species or rare because they are outside of their normal range in the survey area in the Arctic Ocean. The gray whale is a coastal species that occurs regularly in continental shelf waters along the Chukchi Sea coast in summer and to a lesser extent along the Beaufort Sea coast. Recent evidence from monitoring activities in the Chukchi and Beaufort seas during industry seismic surveys suggests that the harbor porpoise, also a coastal species, and the minke whale, both of which have been considered uncommon or rare in the Chukchi and Beaufort seas, may be increasing in numbers in these areas (Funk et al. 2010). Small numbers of killer whales have also been recorded during recent industry surveys, along with a few sightings of fin and humpback whales. The narwhal occurs in Canadian waters and occasionally in the Beaufort Sea, but is rare there and not expected to be encountered.

Additional pinniped species that could be encountered during the proposed survey include the spotted seal, ribbon seal, and Pacific walrus. Spotted seals are more abundant in the Chukchi Sea and occur in small numbers in the Beaufort Sea. The ribbon seal is uncommon in the Chukchi Sea, and there are few sightings in the Beaufort Sea. The Pacific walrus is common in the Chukchi Sea but uncommon in the Beaufort Sea, and not likely to occur in the far offshore waters of the proposed survey area in the Arctic Ocean. None of these species would likely be encountered during the proposed cruise other than perhaps during transit periods to or from the survey area.

Polar bears occur on the pack ice in low densities. As the vessel will avoid the ice edge, it is unlikely that many polar bears would be encountered in the open-water study area.

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

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

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

Sections III and IV are integrated here to minimize repetition.

(1) Mysticetes

Bowhead Whale

The bowhead whale only occurs at high latitudes in the northern hemisphere and has a disjunct circumpolar distribution (Reeves 1980). It is one of only three whale species that spends its entire life in the Arctic. The bowhead whale is listed as ***endangered*** under the ESA, ***least concern*** on the IUCN Red List of Threatened Species (IUCN 2010), and it is listed in CITES Appendix I (UNEP-WCMC 2011) (Table 2). Of four or five stocks recognized worldwide by the International Whaling Commission (IWC), the Bering–Chukchi–Beaufort (BCB) Stock is the one that occurs in Alaskan waters. The latest, and preliminary, abundance estimate for 2003–2004 is 11,836 (95% CI = 6795–20,618), based on a photographic survey conducted in spring 2003 (Koski et al. 2008). Between 1978 and 2001, the population is estimated to have increased at a rate of ~3.4% per year (George et al. 2004; Zeh and Punt 2005).

The BCB Stock winters in the central and western Bering Sea and summers in the Canadian Beaufort Sea and Amundsen Gulf (Moore and Reeves 1993). Spring migration through the western

Beaufort Sea occurs through offshore ice leads, generally from mid-April through mid-June (Braham et al. 1984; Moore and Reeves 1993). In recent years, whale migration has occurred in early April and at times in late March (Quakenbush and Huntington 2010). The whales make the return migration west through the Alaskan Beaufort Sea in the fall to wintering areas in the Bering Sea. Satellite tracking data indicate that some bowhead whales continue migrating west past Barrow and through the Chukchi Sea to Russian waters before turning south toward the Bering Sea (Quakenbush 2007). Some bowheads may reach ~75°N latitude during the westward fall migration (Quakenbush et al. 2010a). Other researchers have also reported a westward movement of bowhead whales through the northern Chukchi Sea during fall migration (Moore et al. 1995, 2000b; Mate et al. 2000).

Fall migration into Alaskan waters is primarily during September and October. However, in recent years a small number of bowheads have been seen or heard offshore from the Prudhoe Bay region during the last week of August (Treacy 1993; LGL and Greeneridge 1996; Greene 1997; Greene et al. 1999a, 2007; Blackwell et al. 2004, 2010). Consistent with this, Nuiqsut whalers have stated that the earliest arriving bowheads have apparently reached the Cross Island area earlier in recent years than formerly (T. Napageak, pers. comm.).

Bowheads tend to migrate west in deeper water (farther offshore) during years with higher-than-average ice coverage than in years with less ice (Moore 2000; Treacy et al. 2006). The migration corridor ranged from ~30 km offshore during light ice years to ~80 km offshore during heavy ice years (Treacy et al. 2006). In addition, the sighting rate tends to be lower in heavy ice years (Treacy 1997:67). During fall migration, most bowheads migrate west in water ranging from 15 to 200 m deep (Miller et al. 2002). Some individuals enter shallower water, particularly in light ice years, but very few whales are ever seen shoreward of the barrier islands in the Alaskan Beaufort Sea. Survey coverage far offshore in deep water is usually limited, and offshore movements may have been underestimated. However, the main migration corridor is over the continental shelf.

Westbound bowheads typically reach the Barrow area in mid-September, and are in that area until late October (e.g., Brower 1996). In recent years bowhead whales have been seen near Barrow in late August and, if ice conditions are favorable, in early August (Huntington and Quakenbush 2009). Whaling near Barrow can continue into October, depending on the quota and conditions.

Sekiguchi et al. (2008) reported one sighting of an aggregation of ~30 bowheads during vessel-based operations ~130 km north of Cape Lisburne on 9 August 2007. Bowhead whales were not reported by vessel-based observers during cruises in the Arctic Ocean north of Barrow in August–September 2005, July–August 2006, August–September 2009, or August–September 2010 (Haley 2006; Haley and Ireland 2006; Mosher et al. 2009; Beland and Ireland 2010). One bowhead whale that was satellite-tagged in Barrow on 23 September 2008 traveled 330 km northwest of Barrow (~73°N; 163°W), just south of and near the southern extent of the proposed survey area in water depths ~200 m. One whale tagged in late August 2007 traveled further northwest (~75°N; 176°W), near of the western extent of the proposed survey area in water depths of 600 m (Quakenbush et al. 2010a). One whale tagged in the fall of 2009 traveled as far as ~76°N; 179°W, its path intersecting with the proposed survey area (Quakenbush et al. 2010b).

Given the recent telemetry data (Quakenbush et al. 2010a,b), some bowheads are expected to be encountered during the proposed survey >200 km offshore in the Arctic Ocean.

Gray Whale

There are two extant populations of gray whales—the Eastern North Pacific Stock that ranges between summer grounds in the Chukchi and Beaufort seas to wintering lagoons in Baja, California, and the remnant Western North Pacific Stock that summers mainly in the Sea of Okhotsk, particularly in the waters off northeastern Sakhalin Island. The larger eastern Pacific or California gray whale population recovered significantly from commercial whaling during its protection under the ESA; the population was delisted from the ESA in 1994. The latest (2006–2007) population size estimate is 19,126 (Allen and Angliss 2010).

Eastern Pacific gray whales breed and calve in the protected waters along the west coast of Baja, California, and the east coast of the Gulf of California from January to April (Swartz and Jones 1981; Jones and Swartz 1984). At the end of the breeding and calving season, most of these gray whales migrate ~8000 km, generally along the west coast, to the main summer feeding grounds in the northern Bering and Chukchi seas (Tomilin 1957; Rice and Wolman 1971; Braham 1984; Nerini 1984; Moore et al. 2003; Bluhm et al. 2007).

Most summering gray whales congregate in the northern Bering Sea, particularly off St. Lawrence Island and in the Chirikov Basin (Moore et al. 2000a), and in the southern Chukchi Sea. More recently, Moore et al. (2003) suggested that gray whale use of Chirikov Basin has decreased, likely as a result of the combined effects of changing currents resulting in altered secondary productivity dominated by lower quality food. The northeastern-most of the recurring feeding areas is in the northeastern Chukchi Sea southwest of Barrow (Clarke et al. 1989). Moore et al. (2000b) reported that during the summer, gray whales in the Chukchi Sea were clustered along the shore primarily between Cape Lisburne and Point Barrow and were associated with shallow, coastal shoal habitat. In autumn, gray whales were clustered near shore at Point Hope and between Icy Cape and Point Barrow, and in offshore waters northwest of Point Barrow at Hanna Shoal and southwest of Point Hope. Based on aerial surveys of nearshore waters of the eastern Chukchi Sea, Thomas et al. (2010) reported that gray whale sighting rates and abundance were greater in the 0–5 km offshore band in 2006, and in the 25–30 km band in 2007 and 2008; they suggested that the difference in distribution may have been attributable to differences in food availability and perhaps ice conditions.

Only a small number of gray whales enter the Beaufort Sea east of Point Barrow. In recent years, ice conditions have become lighter near Barrow, and gray whales may have become more common. Several gray whale sightings were reported during both vessel-based and aerial surveys in the Beaufort Sea during 2006-2008 (Funk et al. 2010) and in 2010 (Beland and Ireland 2010). Several single gray whales have been seen farther east in the Canadian Beaufort Sea (Rugh and Fraker 1981; LGL Ltd., unpubl. data), indicating that small numbers must travel through the Alaskan Beaufort during some summers. However, no gray whales were sighted during cruises north of Barrow in 2002, August–September 2005, July–August 2006, or August–September 2009 (Harwood et al. 2005; Haley 2006; Haley and Ireland 2006; Mosher et al. 2009). Given that most gray whales are typically seen nearshore, and the seismic survey is proposed to occur far offshore, no more than a few gray whales are expected to be in the region at the time of the proposed survey.

Humpback Whale

The humpback whale is found throughout all of the oceans of the world (Clapham 2002). The species is listed as ***endangered*** under the ESA, ***least concern*** on the IUCN Red List of Threatened Species (IUCN 2010), and it is listed in CITES Appendix I (UNEP-WCMC 2011) (Table 2). The worldwide population of humpback whales is divided into northern and southern ocean populations, but genetic analyses suggest some gene flow (either past or present) between the North and South Pacific oceans (e.g., Baker et al. 1993; Caballero et al. 2001). Based on a collaborative study involving numerous jurisdictions, the North Pacific stock has been recently estimated at 18,302 whales (excluding calves; Calambokidis et al. 2008). Barlow et al. (2009) provided a bias-corrected abundance estimate of 20,800. Overall, the North Pacific stock is considered to be increasing.

In the Bering Sea, humpback whales have been sighted southwest of St. Lawrence Island, in the southeastern Bering Sea, and north of the central Aleutian Islands (Moore et al. 2002; Allen and Angliss 2010). Recently there have been sightings of humpback whales in the Chukchi Sea and a single sighting in the Beaufort Sea (Greene et al. 2007; Funk et al. 2010). Haley et al (2010) reported three humpback whales during vessel-based surveys in the Chukchi Sea in 2007 and one sighting in 2008. A humpback whale sighting was also made during the 2009 Chukchi Offshore Monitoring in Drilling Area (COMIDA) aerial surveys (COMIDA 2011). Greene et al. (2007) reported and photographed a humpback whale cow/calf pair east of Barrow near Smith Bay in 2007. No humpback whales were reported during cruises in the Arctic Ocean north of Barrow in August–September 2005, July–August 2006, August–September 2009, or August–September 2010 (Haley 2006; Haley and Ireland 2006; Mosher et al. 2009; Beland and Ireland 2010). Humpback whales could occur in the Chukchi Sea and possibly in the Beaufort Sea but would be unlikely to occur in the offshore waters of the proposed survey area in the Arctic Ocean.

Minke Whale

The minke whale has a cosmopolitan distribution that spans polar, temperate, and tropical regions (Jefferson et al. 2008). In the Northern Hemisphere, minke whales are usually seen in coastal areas, but can also be seen in pelagic waters during northward migrations in spring and summer, and southward migration in autumn (Stewart and Leatherwood 1985).

The minke whale's range extends into the Chukchi Sea. During recent vessel-based surveys in the Chukchi Sea, three, three, and 10 minke whales were sighted in 2006, 2007, and 2008, respectively (Haley et al. 2010); another minke whale was detected in the Chukchi Sea in 2008 by Brueggeman (2009). Savarese et al. (2010) reported one minke whale in the Beaufort Sea during vessel-based operations in 2007. However, no minke whales were sighted during cruises in the Arctic Ocean north of Barrow in August–September 2005, July–August 2006, August–September 2009, or August–September 2010 (Haley 2006; Haley and Ireland 2006; Mosher et al. 2009; Beland and Ireland 2010). Minke whales sometimes occur in areas with minimal ice cover, but it is unlikely that minke whales would be encountered during the proposed survey in the Arctic Ocean.

Fin Whale

The fin whale is widely distributed in all the world's oceans (Gambell 1985), but typically occurs in temperate and polar regions from 20° to 70° north and south of the equator (Perry et al. 1999). It is listed as ***endangered*** under the ESA and on the IUCN Red List of Threatened Species (IUCN 2010), and it is listed in CITES Appendix I (UNEP-WCMC 2011).

The North Pacific fin whale population summers from the Chukchi Sea to California (Gambell 1985), but does not range into the Alaskan Beaufort Sea or waters of the northern Chukchi Sea. Recently a fin whale was recorded in the southern Chukchi Sea during vessel-based surveys in 2006 (LGL Ltd. unpubl. data), and four fin whales were sighted in the Chukchi Sea in 2008 (Haley et al. 2010). National Marine Mammal Laboratory (NMML) observers also saw and photographed a fin whale off Point Lay in 2008 during aerial surveys (COMIDA 2011). Fin whales were not recorded during vessel-based or aerial surveys in the Beaufort Sea in 2006–2008 (Funk et al. 2010) and were not sighted during surveys in the Arctic Ocean during August–September 2005, July–August 2006, August–September 2009, or August–September 2010 (Haley 2006; Haley and Ireland 2006; Mosher et al. 2009; Beland and Ireland 2010). Fin whales likely would not be encountered in the proposed survey area in the Arctic Ocean.

(2) Odontocetes

Beluga

The beluga whale is an arctic and subarctic species that includes several populations in Alaska and northern European waters. It has a circumpolar distribution in the Northern Hemisphere and occurs between 50º and 80ºN (Reeves et al. 2002). It is distributed in seasonally ice-covered seas and migrates to warmer coastal estuaries, bays, and rivers in summer for molting (Finley 1982). Of five distinct beluga stocks recognized in Alaska (O'Corry-Crowe et al. 1997), only the Beaufort Sea and Eastern Chukchi Sea stocks could be encountered during the proposed survey. Based on a partial survey in 1992 of the known range of the Beaufort Sea Stock, the population was estimated at 39,258 (Allen and Angliss 2010). Based on 1989–1991 surveys concentrated on the 170-km long Kasegaluk Lagoon where belugas are known to occur during the open-water season, a minimum population size of 3710 was estimated; the surveys on which it was based did not include offshore areas where belugas are also likely to occur.

Both stocks of belugas may share common wintering grounds in the pack ice of the central Bering Sea (O'Corry-Crowe et al. 1997). In summer, whales from the Eastern Chukchi Sea Stock are known to congregate in Kasegaluk Lagoon, but evidence from a small number of satellite-tagged animals suggests that some of these whales may subsequently range into the Arctic Ocean north of the Beaufort Sea. Suydam et al. (2005a) put satellite tags on 23 beluga whales captured in Kasegaluk Lagoon in late June and early July 1998–2002. Five of these whales moved far into the Arctic Ocean and into the pack ice to 79–80°N. These and other whales moved to areas as far as 1100 km offshore between Barrow and the Mackenzie River Delta, spending time in water with 90% ice coverage.

Belugas from the Beaufort Sea Stock migrate from the Bering Sea through offshore waters of western and northern Alaska and summer in the eastern Beaufort Sea. Most whales migrate into the Beaufort Sea in April or May, although some whales may pass Point Barrow as early as late March and as late as July (Braham et al. 1984; Ljungblad et al. 1984). Much of the population enters the Mackenzie River estuary for a short period during July–August to molt their epidermis, but they spend most of the summer in offshore waters of the eastern Beaufort Sea, Amundsen Gulf, and more northerly areas (Davis and Evans 1982; Harwood et al. 1996; Richard et al. 2001). Belugas are rarely seen in the central Alaskan Beaufort Sea during the early summer. During late summer and autumn, most belugas migrate westward far offshore near the pack ice (Frost et al. 1988; Hazard 1988; Clarke et al. 1993; Miller et al. 1999).

Moore (2000) and Moore et al. (2000b) suggested that beluga whales select deeper slope water independent of ice cover. However, during the westward migration in late summer and autumn, small numbers of belugas are sometimes seen near the north coast of Alaska (e.g., Johnson 1979). The main fall migration corridor of beluga whales is ~100+ km north of the coast. Satellite-linked telemetry data show that some belugas of this population migrate west considerably farther offshore, as far north as 76–78ºN (Richard et al. 1997, 2001). Belugas were not recorded, however, during arctic cruises in August–September 2005, July–August 2006, August–September 2009, or August–September 2010 (Haley 2006; Haley and Ireland 2006; Mosher et al. 2009; Beland and Ireland 2010).

Beluga whales from the eastern Chukchi Sea Stock are an important subsistence resource for residents of the village of Point Lay, adjacent to Kasegaluk Lagoon, and other villages in northwest Alaska. Each year, hunters from Point Lay drive belugas into the lagoon to a traditional hunting location. The belugas have been predictably sighted near the lagoon from late June through mid- to late July (Suydam et al. 2001). In 2007, ~70 belugas were harvested at Kivalina located southeast of Point Hope.

The beluga whale is the most likely cetacean species to occur in the proposed project area.

Narwhal

The narwhal has a discontinuous arctic distribution (Hay and Mansfield 1989; Reeves et al. 2002). A large population inhabits Baffin Bay, West Greenland, and the eastern part of the Canadian Arctic archipelago, and much smaller numbers inhabit the Northeast Atlantic/East Greenland area. Narwhals are associated with sea ice. In the spring, as the ice breaks up, they follow the receding ice edge and enter deep sounds and fjords, where they remain during the summer and early fall (Reeves et al. 2002). As the ice reforms, narwhals move to offshore areas in the pack ice (Reeves et al. 2002), living in leads in the heavy pack ice throughout the winter.

Innes et al. (2002) estimated a population size of 45,358 narwhals in the Canadian Arctic, although little of the area was surveyed. There are scattered records of narwhal in Alaskan waters, where the species is considered extralimital (Reeves et al. 2002). Narwhals were not recorded during cruises in the Arctic Ocean during August–September 2005, July–August 2006, August–September 2009, or August–September 2010 (Haley 2006; Haley and Ireland 2006; Mosher et al. 2009; Beland and Ireland 2010). Narwhals are unlikely to be encountered during the proposed survey.

Killer Whale

The killer whale is cosmopolitan and globally fairly abundant. It is very common in temperate waters, but also frequents the tropics and waters at high latitudes; it appears to prefer coastal areas, but is also known to occur in deep water (Dahlheim and Heyning 1999). The greatest abundance is thought to occur within 800 km of major continents (Mitchell 1975), and the highest densities occur in areas with abundant prey. Both resident and transient stocks have been described as well as an "offshore" ecotype. The resident and transient types are believed to differ in several aspects of morphology, ecology, and behavior (Allen and Angliss 2010).

Killer whales are known to inhabit almost all coastal waters of Alaska, extending from southeast Alaska through the Aleutian Islands to the Bering and Chukchi seas (Allen and Angliss 2010). Killer whales probably do not occur regularly in the Beaufort Sea although sightings have been reported there (Leatherwood et al. 1986; Lowry et al. 1987). George et al. (1994) reported that they and local hunters see a few killer whales at Point Barrow each year. Killer whales are more common southwest of Barrow in the southern Chukchi Sea and the Bering Sea. Killer whales from either the North Pacific resident or transient stock could occur in the Chukchi Sea. Observers onboard industry vessels in the Chukchi Sea recorded two killer whales in 2006 and one killer whale in 2008 (Haley et al. 2010). No killer whales were seen during aerial or vessel surveys in the Beaufort Sea during 2006–2008 (Funk et al. 2010). The killer whale was not sighted during cruises in the Arctic Ocean during August–September 2005, July–August 2006, August–September 2009, or August–September 2010 (Haley 2006; Haley and Ireland 2006; Mosher et al. 2009; Beland and Ireland 2010).

Killer whales are unlikely to be encountered during the proposed seismic survey.

Harbor Porpoise

The harbor porpoise is a small odontocete that inhabits shallow, coastal waters—temperate, subarctic, and arctic—in the Northern Hemisphere (Read 1999). Harbor porpoises occur mainly in shelf areas where they can dive to depths of at least 220 m and stay submerged for more than 5 min (Harwood and Wilson 2001). Harbor porpoises typically occur in small groups of only a few individuals and tend to avoid vessels (Richardson et al. 1995).

The subspecies *P. p. vomerina* ranges from the Chukchi Sea, Pribilof Islands, Unimak Island, and the southeastern shore of Bristol Bay south to San Luis Obispo Bay, California. During recent vessel-based surveys in the Chukchi Sea, the harbor porpoise was one of the most abundant cetaceans sighted during summer and fall 2006–2008 (Haley et al. 2010). Point Barrow, Alaska, is the approximate northeastern extent of its regular range (Suydam and George 1992), though there are extralimital records east to the mouth of the Mackenzie River in Canada and recent sightings in the Beaufort Sea near Prudhoe Bay during aerial surveys in 2006-2008 (Christie et al. 2010; LGL Limited, unpubl. data). Observers onboard industry vessels reported one sighting in the Beaufort Sea in 2006 but none in 2007 or 2008 (Savarese et al. 2010). Harbor porpoises were not recorded during aerial surveys in the Beaufort Sea in 2002–2004 (Monnett and Treacy 2005), nor during cruises in the Arctic Ocean during August–September 2005, July–August 2006, August–September 2009, or August–September 2010 (Haley 2006; Haley and Ireland 2006; Mosher et al. 2009; Beland and Ireland 2010).

Given that the harbor porpoise is mainly a shallow-water species, no encounters with this species are expected in the far offshore waters where the seismic survey is to occur.

(3) Pinnipeds

Pacific Walrus

The walrus occurs in moving pack ice over shallow water of the circumpolar arctic coast (King 1983). There are two recognized subspecies of walrus: the Pacific walrus and Atlantic walrus (*O. r. divergens* and *O. r. rosmarus*, respectively.). Only the Pacific subspecies may potentially occur in the proposed seismic survey area. The Pacific walrus is not listed under the ESA, but the Center for Biological Diversity petitioned the Secretary of Interior to list Pacific walrus as a threatened or endangered species under the ESA primarily as a result of potential impacts from global climate change and associated retreat of the pack ice (CBD 2008). In September 2009, the USFWS announced that a full status review was being launched. A 1990 survey produced a conservative population estimate of ~200,000, but no current estimate is available (USFWS 2009). The estimated average annual walrus mortality from the average subsistence harvest in Russia and the U.S. during 1996–2009 was 5789, which included animals wounded but not retrieved (Allen and Angliss 2010).

Walruses are most commonly found near the southern margins of the pack ice as opposed to deep in the pack where few open leads (polynyas) exist to afford access to the sea for foraging (Estes and Gilbert 1978; Fay 1982; Gilbert 1989). Walruses are not typically found in areas of >80% ice cover (Fay 1982). Ice serves as an important mobile platform providing walruses with a place to rest and nurse their young that is safe from predators and near feeding grounds. Pacific walruses feed primarily on benthic invertebrates, occasionally fish and cephalopods, and more rarely, some adult males may prey on other pinnipeds (Riedman 1990). Walruses typically feed in depths of 10–80 m (Vibe 1950, Fay 1982; Reeves et al. 2002). In Bristol Bay, 98% of satellite locations of tagged walruses were in water depths of 60 m or less (Chadwick and Hills 2005).

The Pacific walrus ranges from the Bering Sea to the Chukchi Sea, occasionally moving into the East Siberian and Beaufort seas. Walruses are migratory, moving south with the advancing ice in autumn and north as the ice recedes in spring (Fay 1981). In the summer, most of the population of Pacific walrus moves to the Chukchi Sea, but several thousands aggregate in the Gulf of Anadyr and in Bristol Bay (Allen and Angliss 2010). Limited numbers of walruses inhabit the Beaufort Sea during the open water season, and they are considered extralimital east of Point Barrow (Sease and Chapman 1988). The northeast Chukchi Sea west of Barrow is the northeastern extent of the main summer range of the walrus, and only a few individuals are seen farther east in the Beaufort Sea (e.g., Harwood et al. 2005; Funk et al. 2010). During a survey through the northern Chukchi Sea/Arctic Ocean in August–September 2005, two sightings of a total of seven walruses were made between 71.5 and 73°N, 164ºW, just south of and near the southern extent of the proposed survey area in water depths <70 m (Haley and Ireland 2006). No walruses were sighted during surveys in the Arctic Ocean during July–August 2006, August–September 2009, or August–September 2010 (Haley 2006; Mosher et al. 2009; Beland and Ireland 2010).

Walrus are not expected to be encountered in the survey area because they occur in pack ice and the *Langseth* will completely avoid ice during the entire cruise.

Bearded Seal

The bearded seal is associated with sea ice and has a circumpolar distribution, generally south of 80ºN (Jefferson et al. 2008). In waters around Alaska, it occurs over the continental shelves of the Bering, Chukchi, and Beaufort seas and Arctic Ocean. An early estimate of the Bering-Chukchi Sea population was ~300,000, but there is no reliable estimate of the current population size (Allen and Angliss 2010). The bearded seal is currently in the listing process under the ESA. In September 2008, NMFS published a finding that a petitioned action to list it and other ice seals as ***threatened*** or ***endangered*** might be warranted and initiated a status review (NMFS 2008a).

During the open-water period, bearded seals occur mainly in relatively shallow areas, because they are predominantly benthic feeders (Burns 1981). They prefer areas of water no deeper than 200 m (e.g., Harwood et al. 2005). Bearded seals have occasionally been reported to maintain breathing holes in sea ice and broken areas within the pack ice, particularly if the water depth is <200 m. Bearded seals apparently also feed on ice-associated organisms when they are present, and this allows a few bearded seals to live in areas considerably deeper than 200 m.

Seasonal movements of bearded seals are directly related to the advance and retreat of sea ice and to water depth (Kelly 1988). During winter, most bearded seals in Alaskan waters are found in the Bering Sea. In the Chukchi and Beaufort seas, favorable conditions are more limited, and consequently, bearded seals are less abundant there during winter. From mid-April to June, as the ice recedes, some of the bearded seals that overwintered in the Bering Sea migrate northward through the Bering Strait. During the summer, they are found near the widely fragmented margin of multi-year ice covering the continental shelf of the Chukchi Sea and in nearshore areas of the central and western Beaufort Sea. In the Beaufort Sea, bearded seals rarely use coastal haulouts.

In some areas, bearded seals are associated with the ice year-round; however, they usually move shoreward into open water areas when the pack ice retreats to areas with water depths greater than 200 m. During the summer, when the Bering Sea is ice-free, the most favorable bearded seal habitat is found in the central or northern Chukchi Sea/Arctic Ocean along the margin of the pack ice. Suitable habitat is more limited in the Beaufort Sea where the continental shelf is narrower and the pack ice edge frequently occurs seaward of the shelf and over water too deep for benthic feeding. The preferred habitat in the western and central Beaufort Sea during the open water period is the continental shelf seaward of the scour zone. Vessel surveys in the Arctic Ocean have reported much lower percentages of bearded compared to ringed seals during cruises in the Arctic Ocean in 2005, 2006, and 2010 (Haley 2006; Haley and Ireland 2006; Beland and Ireland 2010). One bearded seal was sighted in the Arctic Ocean during August–September 2009 (Mosher et al. 2009).

Small numbers of bearded seals would likely be encountered at tracklines in shallow (<200-m) water in the southern part of the proposed survey area.

Spotted Seal

The spotted seal (also known as largha seal) occurs in the Beaufort, Chukchi, Bering, and Okhotsk seas, and south to the northern Yellow Sea and western Sea of Japan (Shaughnessy and Fay 1977). The spotted seal is not listed under the ESA. However, in September 2008, NMFS published a finding that a petitioned action to list it and other ice seals as ***threatened*** or ***endangered*** might be warranted and initiated a status review (NMFS 2008a). In October 2009, NMFS issued a proposed ***threatened*** status for the southern distinct population segment (DPS), which occurs in the Yellow Sea and Sea of Japan, and not-warranted status for the Okhotsk and Bering Sea DPSs (NMFS 2008b). Based on an actual minimum count of 4145 hauled out seals, Allen and Angliss (2010) estimated the Alaskan population at 59,214.

During summer, spotted seals are found primarily in the Bering and Chukchi seas, but some range into the Beaufort Sea (Rugh et al. 1997; Lowry et al. 1998). At this time of year, spotted seals haul out on land part of the time, but also spend extended periods at sea. The seals are commonly seen in bays, lagoons and estuaries, but also range far offshore as far north as 69–72ºN. In summer, they are rarely seen on the pack ice, except when the ice is very near to shore. As the ice cover thickens with the onset of winter, spotted seals leave the northern portions of their range and move into the Bering Sea (Lowry et al. 1998).

Spotted seals have been sighted during open-water seismic programs and barge operations in the Alaskan Beaufort Sea (Moulton and Lawson 2002; Greene et al. 2007; Savarese et al. 2010) and during vessel-based seismic surveys and aerial surveys in the Chukchi Sea during 2006-2008 (Brueggeman 2009; Funk et al. 2010). No spotted seals were recorded on arctic cruises during August–September 2005, July–August 2006, August–September 2009, or August–September 2010 (Haley 2006; Haley and Ireland 2006; Mosher et al. 2009; Beland and Ireland 2010). Spotted seals would be unlikely to occur in the proposed survey area although some spotted seals could be encountered during transit periods.

Ribbon Seal

The ribbon seal is found along the pack-ice margin in the southern Bering Sea during late winter and early spring, and it moves north as the pack ice recedes during late spring to early summer (Burns 1970; Burns et al. 1981). The ribbon seal is not listed under the ESA. In December 2008, NMFS published a finding that a petition to list the ribbon seal as ***threatened*** or ***endangered*** was not warranted at that time (NMFS 2008c).

Little is known about ribbon seal summer and fall distribution, but a review of sightings during the summer suggested that they move into the southern Chukchi Sea (Kelly 1988). During a recent satellite telemetry program, a number of ribbon seals tagged in the Bering Sea in May had moved to the Chukchi Sea by July (NMML 2009). However, ribbon seals appeared to be relatively rare in the northern Chukchi Sea during recent vessel and aerial surveys in summer and fall of 2006–2008 (Brueggeman 2009; Funk et al. 2010). Ribbon seals do not normally occur in the Beaufort Sea, although three recent ribbon seal sightings were reported during vessel-based surveys in the Beaufort Sea in 2008 (Savarese et al 2010). No ribbon seals were recorded on cruises in the Arctic Ocean during August–September 2005, July–August 2006, August–September 2009, or August–September 2010 (Haley 2006; Haley and Ireland 2006; Mosher et al. 2009; Beland and Ireland 2010).

Ringed Seal

The ringed seal has a circumpolar distribution and occurs in all seas of the Arctic Ocean (King 1983). In September 2008, NMFS published a finding that a petitioned action to list it and other ice seals under the ESA as ***threatened*** or ***endangered*** might be warranted and initiated a status review (NMFS 2008a), and as of December 2010, the ringed seal in the listing process.. Past population estimates in the

Bering-Chukchi-Beaufort area ranged from 1–1.5 million (Frost 1985) to 3.3–3.6 million (Frost et al. 1988), but a current estimate is not available (Allen and Angliss 2010).

Ringed seals are closely associated with ice, and in summer they often occur along the receding ice edges or farther north in the pack ice. During winter, ringed seals occupy landfast ice and offshore pack ice, maintaining breathing holes in the ice and occupying lairs in accumulated snow where they give birth and nurse their pups (Smith and Stirling 1975). In winter and spring, the highest densities of ringed seals are found on stable shorefast ice. However, in some areas where there is limited fast ice but wide expanses of pack ice, including the Beaufort Sea, Chukchi Sea, and Baffin Bay, total numbers of ringed seals on pack ice may exceed those on shorefast ice (Burns 1970; Stirling et al. 1982; Finley et al. 1983).

Ringed seals are year-round residents in the northern Chukchi and Beaufort seas and are the most frequently encountered seal species in the area. In the Chukchi Sea, the ringed seal was the most abundant seal species sighted during vessel-based surveys in 2006–2008, with densities up to 0.129/km^2 in the fall (Haley et al 2010). In the Beaufort Sea, the ringed seal was also the most abundant seal species during similar fall vessel-based surveys, with densities up to 0.103/km^2 (Savarese et al. 2010). Many unidentified seals during these surveys may have also been ringed seals, thus actual densities may have been higher. In the Arctic Ocean, the ringed seal was also the most frequently sighted marine mammal species during Arctic cruises in August–September 2005 (35 sightings; Haley and Ireland 2006), July–August 2006 (48 sightings; Haley 2006), August–September 2009 (30 sightings; Mosher et al. 2009), and August–September 2010 (29 sightings; Beland and Ireland 2010).

The ringed seal is the marine mammal most likely to be encountered during the proposed survey.

(4) Carnivora

Polar Bear

The polar bear has a circumpolar distribution throughout the northern hemisphere (Amstrup et al. 1986); it occurs in relatively low densities throughout most ice-covered areas (DeMaster and Stirling 1981). It is listed as ***threatened*** under the ESA, ***vulnerable*** on the IUCN Red List of Threatened Species (IUCN 2010), and it is listed in CITES Appendix II (UNEP-WCMC 2011). In addition to the U.S. Marine Mammal Protection Act (MMPA) of 1973, the polar bear is protected by the International Agreement on the Conservation of Polar Bears, ratified in 1976 by Canada, Denmark, Norway, Russia (former USSR), and the U.S. Article II of the agreement states, "Each contracting party…shall manage polar bear populations in accordance with sound conservation practices based on the best scientific data." Current world population estimates are ~20,000–30,000 (Derocher et al. 1998; Aars et al. 2006). On 7 December 2010, Federally Designated Critical Habitat for polar bear was listed (50 CFR Part 17). The critical habitat is designated in three units: sea-ice critical habitat, terrestrial denning critical habitat, and barrier island critical habitat (USFWS 2010). Sea-ice critical habitat within the U.S. EEZ is shown in Figure 1.

Polar bears are divided into 19 relatively distinct populations or management units although there may be overlap of some individuals among populations (Aars et al. 2006; USFWS 2008). Individuals from three populations could occur in the proposed survey area: the Southern Beaufort Sea population (~1500), ranging from the Baillie Islands, Canada, to near Point Lay, Alaska; the Chukchi Sea population (~2000), from most of the Chukchi Sea and the northern Bering Sea; and the Northern Beaufort Sea population (~1200), located in Canadian waters primarily north of the Southern Beaufort Sea and extending into Amundsen Gulf. USFWS (2008) designated the Northern Beaufort Sea population as stable, the Southern Beaufort Sea population as declining, and the Chukchi Sea population as data deficient. Data from tracking studies indicate wide-ranging movements of individual bears and overlap among polar bear populations (Garner et al. 1990; Amstrup 1995; Durner and Amstrup 1995).

Polar bears usually forage in areas where there are high concentrations of ringed seals which is their primary prey, and bearded seals (Larsen 1985; Stirling and McEwan 1975). This includes areas of landfast ice, as well as moving pack ice. They typically range as far north as 88°N (Ray 1971; Durner and Amstrup 1995) where the population thins dramatically. However, polar bears have been observed across the Arctic, including close to the North Pole (van Meurs and Splettstoesser 2003). During a cruise in the Arctic Ocean in August–September 2005, there were 21 sightings of 27 polar bears, most between ~80 and 82°N with one at ~87ºN (Haley and Ireland 2006). During a cruise in the Arctic Ocean in July–August 2006, there were three sightings of nine polar bears at ~73 and 78°N, all on ice (Haley 2006). During a cruise in the Arctic Ocean in August–September 2009, there were nine sightings of 11 polar bears between ~79 and 82°N (Mosher et al. 2009). Sixteen polar bears were seen on the ice during a seismic survey in the Arctic Ocean in August–September 2010 (Beland and Ireland 2010).

Although the proposed survey area appears to overlap sea-ice critical habitat within the U.S. EEZ, this would only occur if sea ice was present in the area where the *Langseth* will be operating. However, as the *Langseth* will be avoiding the pack ice, neither polar bears or their critical habitat are expected to be encountered in the survey area.

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.

UAGI requests an IHA pursuant to Section 101 (a) (5) (D) of the Marine Mammal Protection Act (MMPA) for incidental take by harassment during its planned seismic survey in the Arctic Ocean during September–October 2011.

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

VI. NUMBERS OF MARINE MAMMALS THAT COULD BE TAKEN

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

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

VII. Anticipated Impact on Species or Stocks

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

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

- First we summarize the potential impacts on marine mammals of airgun operations, as called for in § VII. A more comprehensive review of the relevant background information appears in Appendix B of the EA.
- Then we discuss the potential impacts of operations by the echosounders and ADCP.
- Finally, we estimate the numbers of marine mammals that could be affected by the proposed survey it the Arctic Ocean during September–October 2011. This section includes a description of the rationale for the estimates of the potential numbers of harassment "takes" during the planned survey, as called for in § VI.

Summary of Potential Effects of Airgun Sounds

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

Tolerance

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

Masking

Masking effects of pulsed sounds (even from large arrays of airguns) on marine mammal calls and other natural sounds are expected to be limited, although there are very few specific data on this. Because of the intermittent nature and low duty cycle of seismic pulses, animals can emit and receive sounds in the relatively quiet intervals between pulses. However, in exceptional situations, reverberation occurs for much or all of the interval between pulses (e.g., Simard et al. 2005; Clark and Gagnon 2006) which could mask calls. Some baleen and toothed whales are known to continue calling in the presence of seismic pulses, and their calls usually can be heard between the seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999a,b; Nieukirk et al. 2004; Smultea et al. 2004; Holst et al. 2005a,b, 2006; Dunn and Hernandez 2009). However, Clark and Gagnon (2006) reported that fin whales in the northeast Pacific Ocean went silent for an extended period starting soon after the onset of a seismic survey in the area. Similarly, there has been one report that sperm whales ceased calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994). However, more recent studies found that they continued calling in the presence of seismic pulses (Madsen et al. 2002; Tyack et al. 2003; Smultea et al. 2004; Holst et al. 2006; Jochens et al. 2008). Dolphins and porpoises commonly are heard calling while airguns are operating (e.g., Gordon et al. 2004; Smultea et al. 2004; Holst et al. 2005a,b; Potter et al. 2007). The sounds important to small odontocetes are predominantly at much higher frequencies than are the dominant components of airgun sounds, thus limiting the potential for masking. In general, masking effects of seismic pulses are expected to be minor, given the normally intermittent nature of seismic pulses. Masking effects on marine mammals are discussed further in Appendix B (4) of the EA.

Disturbance Reactions

Disturbance includes a variety of effects, including subtle to conspicuous changes in behavior, movement, and displacement. Based on NMFS (2001, p. 9293), NRC (2005), and Southall et al. (2007), we assume that simple exposure to sound, or brief reactions that do not disrupt behavioral patterns in a potentially significant manner, do not constitute harassment or "taking". By potentially significant, we mean "in a manner that might have deleterious effects to the well-being of individual marine mammals or their populations".

Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors (Richardson et al. 1995; Wartzok et al. 2004; Southall et al. 2007; Weilgart 2007). If a marine mammal does react briefly to an underwater sound by changing its behavior or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or population. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on individuals and populations could be significant (e.g., Lusseau and Bejder 2007; Weilgart 2007). Given the many uncertainties in predicting the quantity and types of impacts of noise on marine mammals, it is common practice to estimate how many mammals would be present within a particular distance of industrial activities and/or exposed to a particular level of industrial sound. In most cases, this approach likely overestimates the numbers of marine mammals that would be affected in some biologically-important manner.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Most studies of sperm whales exposed to airgun sounds indicate that the sperm whale shows considerable tolerance of airgun pulses (e.g., Stone 2003; Moulton et al. 2005, 2006a; Stone and Tasker 2006; Weir 2008). In most cases the whales do not show strong avoidance, and they continue to call (see Appendix B of the EA for review). However, controlled exposure experiments in the Gulf of Mexico indicate that foraging behavior was altered upon exposure to airgun sound (Jochens et al. 2008; Miller et al. 2009; Tyack 2009).

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

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

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

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

Hearing Impairment and Other Physical Effects

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds. TTS has been demonstrated and studied in certain captive odontocetes and pinnipeds exposed to strong sounds (reviewed in Southall et al. 2007). However, there has been no specific documentation of TTS let alone permanent hearing damage, i.e., permanent threshold shift (PTS), in free-ranging marine mammals exposed to sequences of airgun pulses during realistic field conditions. Current NMFS policy regarding exposure of marine mammals to high-level sounds is that cetaceans and pinnipeds should not be exposed to impulsive sounds with received levels ≥180 dB and 190 dB re 1 μPa_{rms}, respectively (NMFS 2000). These criteria have been used in establishing the exclusion (=shut-down) zones planned for the proposed seismic survey. However, these criteria were established before there was any information about minimum received levels of sounds necessary to cause auditory impairment in marine mammals. As discussed in Appendix B (6) of the EA and summarized here,

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

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

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

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

Temporary Threshold Shift.—TTS is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter 1985). While experiencing TTS, the hearing threshold rises and a sound must be stronger in order to be heard. At least in terrestrial mammals, TTS can last from minutes or hours to (in cases of strong TTS) days. For sound exposures at or somewhat above the TTS threshold, hearing sensitivity in both terrestrial and marine mammals recovers rapidly after exposure to the noise ends. Few data on sound levels and durations necessary to elicit mild TTS have been obtained for marine mammals, and none of the published data concern TTS elicited by exposure to multiple pulses of sound. Available data on TTS in marine mammals are summarized in Southall et al. (2007). Based on these data, the received energy level of a single seismic pulse (with no frequency weighting) might need to be ~186 dB re 1 $\mu Pa^2 \cdot s$ (i.e., 186 dB SEL or ~196–201 dB re 1 μPa_{rms}) in order to produce brief, mild TTS[1]. Exposure to several strong seismic pulses that each have received levels near 190 dB re 1 μPa_{rms} might result in cumulative exposure of ~186 dB SEL and thus slight TTS in a small odontocete assuming the TTS threshold is (to a first approximation) a function of the total received pulse energy; however, this 'equal-energy' concept is an oversimplification. The distances from the *Langseth*'s airguns at which the received energy level (per pulse, flat-weighted) would be expected to be ≥190 dB re 1 μPa_{rms} are estimated in Table 1. Levels ≥190 dB re 1 μPa_{rms} are expected to be restricted to radii no more than 190 m (Table 1). For an odontocete closer to the surface, the maximum radius with ≥190 dB re 1 μPa_{rms} would be smaller.

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

For baleen whales, there are no data, direct or indirect, on levels or properties of sound that are required to induce TTS. The frequencies to which baleen whales are most sensitive are assumed to be lower than those to which odontocetes are most sensitive, and natural background noise levels at those low frequencies tend to be higher. As a result, auditory thresholds of baleen whales within their frequency band of best hearing are believed to be higher (less sensitive) than are those of odontocetes at their best frequencies (Clark and Ellison 2004). From this, it is suspected that received levels causing

---

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

TTS onset may also be higher in baleen whales (Southall et al. 2007). In any event, no cases of TTS are expected given the strong likelihood that baleen whales would avoid the approaching airguns (or vessel) before being exposed to levels high enough for TTS to occur, and the mitigation measures that are planned.

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

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

Permanent Threshold Shift.—When PTS occurs, there is physical damage to the sound receptors in the ear. In severe cases, there can be total or partial deafness, whereas in other cases, the animal has an impaired ability to hear sounds in specific frequency ranges (Kryter 1985).

There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal, even with large arrays of airguns. However, given the possibility that mammals close to an airgun array might incur at least mild TTS, there has been further speculation about the possibility that some individuals occurring very close to airguns might incur PTS (e.g., Richardson et al. 1995, p. 372*ff*; Gedamke et al. 2008). Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage, but repeated or (in some cases) single exposures to a level well above that causing TTS onset might elicit PTS.

Relationships between TTS and PTS thresholds have not been studied in marine mammals, but are assumed to be similar to those in humans and other terrestrial mammals. PTS might occur at a received sound level at least several decibels above that inducing mild TTS if the animal were exposed to strong sound pulses with rapid rise time—see Appendix B (6) of the EA. Based on data from terrestrial mammals, a precautionary assumption is that the PTS threshold for impulse sounds (such as airgun pulses as received close to the source) is *at least* 6 dB higher than the TTS threshold on a peak-pressure basis, and probably >6 dB (Southall et al. 2007). On an SEL basis, Southall et al. (2007:441-4) estimated that received levels would need to exceed the TTS threshold by at least 15 dB for there to be risk of PTS. Thus, for cetaceans they estimate that the PTS threshold might be an M-weighted SEL (for the sequence of received pulses) of ~198 dB re 1 μPa^2·s (15 dB higher than the M_{mf}-weighted TTS threshold, in a beluga, for a watergun impulse), where the SEL value is cumulated over the sequence of pulses. Additional assumptions had to be made to derive a corresponding estimate for pinnipeds, as the only available data on TTS-thresholds in pinnipeds pertain to non-impulse sound. Southall et al. (2007) estimate that the PTS threshold could be a cumulative M_{pw}-weighted SEL of ~186 dB re 1 μPa^2·s in the harbor seal exposed to impulse sound. The PTS threshold for the California sea lion and northern elephant seal would probably be higher, given the higher TTS thresholds in those species.

Southall et al. (2007) also note that, regardless of the SEL, there is concern about the possibility of PTS if a cetacean or pinniped received one or more pulses with peak pressure exceeding 230 or 218 dB re 1 μPa (peak), respectively. Thus, PTS might be expected upon exposure of cetaceans to *either* SEL ≥198 dB re 1 μPa^2·s *or* peak pressure ≥230 dB re 1 μPa. Corresponding proposed dual criteria for pinnipeds (at least harbor seals) are ≥186 dB SEL and ≥218 dB peak pressure (Southall et al. 2007). These estimates are all first approximations, given the limited underlying data, assumptions, species differences, and evidence that the "equal energy" model may not be entirely correct. A peak pressure of ≥230 dB re 1 μPa (3.2 bar·m, 0-pk) would only be found within a few meters of the largest (360-in^3) airguns in the planned airgun array (e.g., Caldwell and Dragoset 2000). A peak pressure of 218 dB re 1 μPa could be received somewhat farther away; to estimate that specific distance, one would need to apply a model that accurately calculates peak pressures in the near-field around an array of airguns.

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

Stranding and Mortality.— Marine mammals close to underwater detonations of high explosives can be killed or severely injured, and the auditory organs are especially susceptible to injury (Ketten et al. 1993; Ketten 1995). However, explosives are no longer used for marine waters for commercial seismic surveys or (with rare exceptions) for seismic research; they have been replaced entirely by airguns or related non-explosive pulse generators. Airgun pulses are less energetic and have slower rise times, and there is no specific evidence that they can cause serious injury, death, or stranding even in the case of large airgun arrays. However, the association of strandings of beaked whales with naval exercises and, in one case, an L-DEO seismic survey (Malakoff 2002; Cox et al. 2006), has raised the possibility that beaked whales exposed to strong "pulsed" sounds may be especially susceptible to injury and/or behavioral reactions that can lead to stranding (e.g., Hildebrand 2005; Southall et al. 2007). Appendix B (6) of the EA provides additional details.

Specific sound-related processes that lead to strandings and mortality are not well documented, but may include (1) swimming in avoidance of a sound into shallow water; (2) a change in behavior (such as a change in diving behavior) that might contribute to tissue damage, gas bubble formation, hypoxia, cardiac arrhythmia, hypertensive hemorrhage or other forms of trauma; (3) a physiological change such as a vestibular response leading to a behavioral change or stress-induced hemorrhagic diathesis, leading in turn to tissue damage; and (4) tissue damage directly from sound exposure, such as through acoustically mediated bubble formation and growth or acoustic resonance of tissues. Some of these mechanisms are unlikely to apply in the case of impulse sounds. However, there are increasing indications that gas-bubble disease (analogous to “the bends”), induced in supersaturated tissue by a behavioral response to acoustic exposure, could be a pathologic mechanism for the strandings and mortality of some deep-diving cetaceans exposed to sonar. The evidence for this remains circumstantial and associated with exposure to naval mid-frequency sonar, not seismic surveys (Cox et al. 2006; Southall et al. 2007).

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

There is no conclusive evidence of cetacean strandings or deaths at sea as a result of exposure to seismic surveys, but a few cases of strandings in the general area where a seismic survey was ongoing have led to speculation concerning a possible link between seismic surveys and strandings. Suggestions that there was a link between seismic surveys and strandings of humpback whales in Brazil (Engel et al. 2004) were not well founded (IAGC 2004; IWC 2007). In Sept. 2002, there was a stranding of two Cuvier’s beaked whales in the Gulf of California, Mexico, when the L-DEO vessel R/V *Maurice Ewing* was operating a 20-airgun, 8490-in^3 airgun array in the general area. The link between the stranding and the seismic surveys was inconclusive and not based on any physical evidence (Hogarth 2002; Yoder 2002). Nonetheless, the Gulf of California incident plus the beaked whale strandings near naval exercises involving use of mid-frequency sonar suggests a need for caution in conducting seismic surveys in areas occupied by beaked whales until more is known about effects of seismic surveys on those species (Hildebrand 2005). No injuries of beaked whales are anticipated during the proposed study because none occur in the proposed study area.

Non-auditory Physiological Effects.—Non-auditory physiological effects or injuries that theoretically might occur in marine mammals exposed to strong underwater sound include stress, neurological effects, bubble formation, resonance, and other types of organ or tissue damage (Cox et al. 2006; Southall et al. 2007). Studies examining such effects are limited. However, resonance effects (Gentry 2002) and direct noise-induced bubble formation (Crum et al. 2005) are implausible in the case of exposure to an impulsive broadband source like an airgun array. If seismic surveys disrupt diving patterns of deep-diving species, this might perhaps result in bubble formation and a form of “the bends”, as speculated to occur in beaked whales exposed to sonar. However, there is no specific evidence of this upon exposure to airgun pulses.

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

Possible Effects of Multibeam Echosounder Signals

The Kongsberg EM 122 MBES will be operated from the source vessel during the planned study. Information about this equipment was provided in § I. Sounds from the MBES are very short pings, occurring for 2–15 ms once every 5–20 s, depending on water depth. Most of the energy in the sound emitted by this MBES is at frequencies near 12 kHz, and the maximum source level is 242 dB re 1 $\mu Pa_{rms} \cdot m_{rms}$. The beam is narrow (1–2º) in fore-aft extent and wide (150º) in the cross-track extent. Each ping consists of eight (in water >1000 m deep) or four (<1000 m deep) successive fan-shaped transmissions (segments) at different cross-track angles. Any given mammal at depth near the trackline would be in the main beam for only one or two of the nine segments. Also, marine mammals that encounter the Kongsberg EM 122 are unlikely to be subjected to repeated pings because of the narrow fore–aft width of the beam and will receive only limited amounts of energy because of the short pings. Animals close to the ship (where the beam is narrowest) are especially unlikely to be ensonified for more than one 2–15 ms ping (or two pings if in the overlap area). Similarly, Kremser et al. (2005) noted that the probability of a cetacean swimming through the area of exposure when an MBES emits a ping is small. The animal would have to pass the transducer at close range and be swimming at speeds similar to the vessel in order to receive the multiple pings that might result in sufficient exposure to cause TTS.

Navy sonars that have been linked to avoidance reactions and stranding of cetaceans (1) generally have a longer signal duration than the Kongsberg EM 122, and (2) are often directed close to horizontally vs. more downward for the MBES. The area of possible influence of the MBES is much smaller—a narrow band below the source vessel. The duration of exposure for a given marine mammal can be much longer for a naval sonar. During L-DEO's operations, the individual ping will be very short, and a given mammal would not receive many of the downward-directed pings as the vessel passes by. Possible effects of an MBES on marine mammals are outlined below.

Masking

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

Behavioral Responses

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

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

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

Hearing Impairment and Other Physical Effects

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

Given the maximum source level of 242 dB re 1 $\mu Pa \cdot m_{rms}$ (see § I), the received level for an animal within the MBES beam 100 m below the ship would be ~202 dB re 1 μPa_{rms}, assuming 40 dB of spreading loss over 100 m (circular spreading). Given the narrow beam, only one ping is likely to be received by a given animal as the ship passes overhead. The received energy level from a single ping of duration 15 ms would be about 184 dB re 1 $\mu Pa^2 \cdot s$, i.e., 202 dB + 10 log (0.015 s). That is below the TTS threshold for a cetacean receiving a single non-impulse sound (195 dB re 1 $\mu Pa^2 \cdot s$) and even further below the anticipated PTS threshold (215 dB re 1 $\mu Pa^2 \cdot s$) (Southall et al. 2007). In contrast, an animal that was only 10 m below the MBES when a ping is emitted would be expected to receive a level ~20 dB higher, i.e., 204 dB re 1 $\mu Pa^2 \cdot s$ in the case of the EM120. That animal might incur some TTS (which would be fully recoverable), but the exposure would still be below the anticipated PTS threshold for cetaceans. As noted by Burkhardt et al. (2008), cetaceans are very unlikely to incur PTS from operation of scientific sonars on a ship that is underway.

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

Possible Effects of the Sub-bottom Profiler Signals

An SBP will also be operated from the source vessel during the planned study. Details about this equipment were provided in § I. Sounds from the SBP are very short pings, occurring for up to 64 ms once every second. Most of the energy in the sound emitted by the SBP is at 3.5 kHz, and the beam is directed downward. The sub-bottom profiler on the *Langseth* has a maximum source level of 222 dB re 1 µPa · m (see § I). Kremser et al. (2005) noted that the probability of a cetacean swimming through the area of exposure when a bottom profiler emits a ping is small—even for an SBP more powerful than that on the *Langseth*—if the animal was in the area, it would have to pass the transducer at close range and in order to be subjected to sound levels that could cause TTS.

Masking

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

Behavioral Responses

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

Hearing Impairment and Other Physical Effects

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

Possible Effects of Acoustic Doppler Current Profiler Signals

An ADCP will be operated during the proposed program. Sounds from the ADCP are very short, occurring every 0.65 ms to 1.4 s. Most of the energy in the sound emitted is at high frequencies (~75 kHz). The ADCP produces sounds that are within the range of frequencies used by odontocetes that occur or may occur in the area of the planned survey.

Masking

Whereas the ADCP produce 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 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

When a 38-kHz echosounder and a 150-kHz ADCP were transmitting during studies in the Eastern Tropical Pacific, baleen whales showed no significant responses, while spotted and spinner dolphins were detected slightly more often and beaked whales less often during visual surveys (Gerrodette and Pettis 2005). Marine mammal behavioral reactions to other sound sources are discussed above. Responses to the ADCP are likely to be similar to those for other sources if received at the same levels. The signals from the ADCP are weaker than those from the echosounders and the airguns. Therefore, behavioral responses are not expected unless marine mammals are very close to the source.

Hearing Impairment and Other Physical Effects

Source levels of the ADCP are lower than those of the airguns, which are discussed above. It is unlikely that the ADCP produces sound 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.

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

All anticipated takes would be "takes by harassment", involving temporary changes in behavior; the mitigation measures to be applied will minimize the possibility of injurious takes. In the sections below, we describe the methods used to estimate the number of potential exposures to various received sound levels and present estimates of the numbers of marine mammals that could be affected during the proposed seismic program. The estimates are based on a consideration of the number of marine mammals that could be disturbed appreciably by operations with the 10-airgun array to be used during ~5500 km of seismic surveys in the Arctic Ocean north of the Chukchi Sea. The sources of distributional and numerical data used in deriving the estimates are described in the next subsection.

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

Basis for Estimating "Take by Harassment"

Moore et al. (2000b) did not report densities, but reported sightings and effort data for belugas, bowhead whales, and gray whales from aerial surveys in the Beaufort and Chukchi seas during summer (July–August) and fall (September–October) 1982–1991. We calculated densities using data from the Chukchi Sea for the fall in depth strata 35–50 m, 51–200 m, and >200 m, mean group sizes from the Beaufort Whale Aerial Survey Project (BWASP) database, and values for trackline detection probability bias and availability bias, *f(0)* and *g(0)*[2], from Harwood et al. (1996) for belugas, Thomas et al. (2002) for

[2] Trackline detection probability bias is associated with diminishing sightability with increasing lateral distance from the trackline [*f*(0)]. Availability bias refers to the fact that there is less-than-100% probability of sighting an animal that is present along the survey trackline, and it is measured by *g*(0).

bowhead whales, and Forney and Barlow (1998) for gray whales. Most Moore et al. (2000b) sightings were south of the proposed seismic survey area. Based on the lack of any beluga whale sightings and very low densities of bowheads (0.0003–0.0044/km^2) and gray whales (0.0026–0.0042/km^2) during non-seismic periods of industry vessel operations in the Chukchi Sea in September–October 2006–2008 (Haley et al. 2010), and the lack of beluga, bowhead, or gray whale sightings during arctic cruises by the *Healy* in August–September 2005 or July–August 2006 (Haley 2006; Haley and Ireland 2006), the calculated densities are likely considerable overestimates. Accordingly, they were reduced by an order of magnitude. Densities were calculated for depths >200 m and <200 m; in the latter case, the densities were effort-weighted averages of the 35–50 m and 51–200 m densities.

Six other cetacean species were included in Table 2 and described in § III and IV. Because the harbor porpoise is mainly a shallow-water species, it is not expected to occur in the survey area. Narwhals are considered extralimital in Alaska, and any vagrants likely would be associated with sea ice. The *Langseth* is not ice-strengthened and will completely avoid ice, so encounters with narwhals are not expected. There is evidence of the occasional occurrence of humpback, minke, fin, and killer whales in the northern Chukchi Sea, but because they occur so infrequently in the Chukchi Sea, little to no data are available for the calculation of densities. Minimal, arbitrary densities have therefore been assigned to these species to allow for chance encounters.

The Pacific walrus, under USFWS jurisdiction, is not expected to be encountered in the survey area because it occurs in pack ice, and the *Langseth* will completely avoid ice during the entire cruise. Four species of pinnipeds under NMFS jurisdiction could be encountered in the proposed seismic survey area: ringed seal, bearded seal, ribbon seal, and spotted seal. Bengtson et al. (2005) reported ringed and bearded seal densities in nearshore fast ice and pack ice and offshore pack ice based on aerial surveys in May–June 1999 and May 2000; ringed seal but not bearded seal densities were corrected for haulout behavior. We used densities from the offshore stratum (12P). Bearded seal densities were used for water depths <200 m and were assumed to be 0 in water depths >200 m because they are predominantly benthic feeders. The fall densities of ringed seals in the open water of the offshore survey area have been estimated as $^1/_{10}$ of the spring pack ice densities because ringed seals are strongly associated with sea ice and begin to reoccupy nearshore fast ice areas as it forms in the fall. The resulting densities (.081/km^2 in 1999 and .023/km^2 in 2000) are similar to ringed seal density estimates (0.016/km^2 to 0.069/km^2) from industry vessel operations during summer 2006–2008 (Haley et al. 2010).

Little information is available on spotted seal or ribbon seal densities in offshore areas of the Chukchi Sea. Spotted seal density in the summer were estimated by multiplying the ringed seal density by 0.02. This calculation was based on the ratio of the estimated Chukchi populations of the two species: 8% of the Alaskan population of spotted seals is present in the Chukchi Sea during the summer and fall (Rugh et al. 1997), the Alaskan population of spotted seals is 59,214 (Allen and Angliss 2010), and the population of ringed seals in the Alaskan Chukchi Sea is >208,000 (Bengtson et al. 2005). The ribbon seal density that we used is based on two ribbon seal sightings reported during industry vessel operations in the Chukchi Sea in 2006–2008 (Haley et al. 2010).

The polar bear, under USFWS jurisdiction, is not expected to be encountered in the survey area because it occurs on fast or pack ice, and the *Langseth* will completely avoid ice during the entire cruise. However, as a precautionary measure, we have requested a small number of takes.

Table 3 gives the estimated densities of marine mammals expected to occur in the survey area. As noted above, there is some uncertainty about the representativeness of the data and assumptions used in the calculations. Because few data were available for the survey area, we calculated densities based on

TABLE 3. Expected densities of marine mammals in the offshore survey area of the Arctic Ocean north of the Chukchi Sea in September–October 2011. Cetacean densities are corrected for *f*(0) and *g*(0) biases. Species listed as endangered are in italics.

Species	Density (#/1000 km^2) in depths <200 m	Density (#/1000 km^2) in depths >200 m
Mysticetes		
Bowhead Whale	*1.87*	*0*
Gray Whale	1.48	0
Fin Whale	*0.01*	*0.01*
Humpback Whale	*0.01*	*0.01*
Minke Whale	0.01	0.01
Odontocetes		
Beluga	1.65	6.78
Narwhal	0	0
Killer whale	0.01	0.01
Harbor Porpoise	0	0
Pinnipeds		
Walrus	0	0
Bearded Seal	14.18	0
Spotted Seal	0.98	0.98
Ringed Seal	48.92	48.92
Ribbon Seal	0.27	0.27
Carnivora		
Polar bear	0	0

densities observed in adjacent areas of the northern Chukchi Sea, adjusted downward by various assumed factors (see above). For species seen only rarely in the northern Chukchi Sea, we arbitrarily assigned low densities. It is not known how closely the densities that were used reflect the actual densities that will be encountered; however, the approach used here is believed to be the best available at this time.

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

It should be noted that the following estimates of "takes by harassment" assume that the surveys will be fully completed; in fact, the ensonified areas calculated using the planned number of line-kilometers ***have been increased by 25%*** to accommodate turns, lines that may need to be repeated, equipment testing, etc. As is typical during offshore ship surveys, inclement weather and equipment malfunctions are likely to cause delays and may limit the number of useful line-kilometers of seismic operations that can be undertaken. The *Langseth* is not ice-strengthened and will completely avoid ice, so it is very likely that the survey will not be completed because ice likely will be present. Furthermore, any marine mammal sightings within or near the designated exclusion zone will result in the shut down of seismic operations as a mitigation measure. Thus, the following estimates of the numbers of marine mammals potentially exposed to 160-dB sounds are precautionary, and probably overestimate the actual numbers of marine mammals that might be involved. These estimates assume that there will be no ice, weather, equipment, or mitigation delays, which is highly unlikely.

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

Number of Cetaceans that could be Exposed to ≥160 dB.—The number of different individuals that could be exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} on one or more occasions can be estimated by considering the expected density of animals in the area along with the total marine area that would be within the 160-dB radius around the operating airgun array on at least one occasion. The number of possible exposures (including repeated exposures of the same individuals) can be estimated by considering the total marine area that would be within the 160-dB radius around the operating airguns, including areas of overlap. In the proposed survey, the seismic lines are widely spaced in the survey area, so few individual mammals would be exposed more than once during the survey; the area including overlap is only 1.3× the area excluding overlap. Thus, few individual marine mammals would be exposed more than once during the survey. Moreover, it is unlikely that a particular animal would stay in the area during the entire survey.

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

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

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

For species whose densities were the same regardless of water depth, we used ensonified areas for all water depths to calculate numbers exposed. For species whose densities were different in water depths <200 m and >200 m (see Table 3), we used ensonified areas for tracklines in water depths <200 m and the sum of the ensonified areas in water depths 200–1000 and >1000 m and applied them to the different densities.

Table 4 shows the estimates of the number of different individual marine mammals that potentially could be exposed to ≥160 dB re 1 μPa_{rms} during the seismic survey if no animals moved away from the survey vessel, and the ***Requested Take Authorization***.

Applying the approach described above, ~122,530 km^2 (~153,163 km^2 including the 25% contingency) would be within the 160-dB isopleth on one or more occasions during the survey. For <200 m and >200 m depth ranges, the areas are 38,188 km^2 (47,736 km^2 including the 25% contingency) and 84,342 km^2 (105,427 km^2 including the 25% contingency), respectively. Because this approach does not allow for turnover in the mammal populations in the study area during the course of the survey, the actual number of individuals exposed could be underestimated in some cases. However, the approach assumes that no marine mammals will move away from or toward the trackline as the *Langseth* approaches in response to increasing sound levels prior to the time the levels reach 160 dB, which will result in overestimates for those species known to avoid seismic vessels.

TABLE 4. Estimates of the possible numbers of marine mammals exposed to ≥160 dB during UAGI's proposed seismic program in the Arctic Ocean north of the Chukchi Sea, 5 September–9 October 2011. The proposed sound source is a 10-gun array with a total discharge volume of 1830 in^3. 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 some may alter their behavior when levels are lower (see text). Species in italics are listed under the U.S. ESA as endangered. The rightmost column of numbers (in boldface) shows the numbers of "harassment takes" for which authorization is requested.

Species	Number[1]	% Regional Pop'n²	Requested Take Authorization
Mysticetes			
Bowhead whale	*89*	*0.85*	***89***
Gray whale	71	0.35	**71**
Humpback whale	*2*	*0.01*	***2***
Minke whale	2	0.02	**2**
Fin whale	*2*	*0.01*	***2***
Odontocetes			
Beluga whale	794	1.85	**794**
Narwhal	0	0	**0**
Killer whale	2	NA	**2**
Harbor porpoise	0	0	**0**
Pinnipeds			
Pacific walrus	0	0	**0**
Bearded seal	677	0.25	**677**
Spotted seal	150	0.25	**150**
Ringed seal	7492	3.01	**7492**
Ribbon Seal	42	0.04	**42**
Carnivora			
Polar bear	0	0	**5**

[1] Estimates are based on densities from Table 3 and ensonified areas (including 25% contingency) of 47,736 km^2 in water depths <200m and 105,427 km^2 in water depths >200 m.

² Regional population size estimates are from Table 2.

The estimate of the number of individual cetaceans that could be exposed to seismic sounds with received levels ≥160 dB re 1 μPa_{rms} during the proposed survey is 962 (Table 4). That total includes 93 **endangered** whales (89 bowheads, 2 humpbacks, and 2 fin whales), which (if realistic) would represent 0.85%, 0.01%, and 0.01%, respectively, of the regional populations (Table 4). The beluga is expected to be the most common cetacean species in the study area; the estimate of the number of belugas that could be exposed is 794 or 1.85% of the regional population (Table 4).

***Number of Pinnipeds that might be Exposed to ≥160 dB*.—**The methods described previously for cetaceans were also used to calculate numbers of pinnipeds that could be exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms}. Based on the estimated densities, 8361 pinnipeds, mostly (89.6%) ringed seals, could be exposed to airgun sounds ≥160 dB re 1 μPa_{rms}.

***Number of Polar Bears that might be Exposed to ≥160 dB*.—**The polar bear, under USFWS jurisdiction, is not expected to be encountered in the survey area because it occurs on fast or pack ice and the *Langseth* will completely avoid ice during the entire cruise. However, as a precautionary measure, we have requested a small number of takes.

Conclusions

The proposed survey in the Arctic Ocean will involve towing an airgun array that will introduce pulsed sounds into the ocean, along with simultaneous operation of an MBES, SBP, and ADCP. Routine vessel operations, other than the proposed operations by the airguns, are conventionally assumed not to affect marine mammals sufficiently to constitute "taking". No "taking" of marine mammals is expected in association with echosounder operations given the considerations discussed in § I, i.e., sounds are beamed downward, the beam is narrow, and the pulses are extremely short.

Cetaceans.—Strong avoidance reactions by several species of mysticetes to seismic vessels operating large arrays of airguns have been observed at ranges up to 6–8 km and occasionally as far as 20–30 km 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 (Miller et al. 2005). During autumn seismic surveys in the Beaufort Sea, some bowhead whales displayed avoidance upon exposure to received sound levels ≥130 dB (rms) while migrating west (Richardson et al. 1986, 1999). It is possible that a larger number of bowhead whales than estimated may be disturbed if reactions occur at ≥130 dB (rms).

Odontocete reactions to seismic pulses are usually assumed to be limited to lesser distances from the airgun(s) than are those of mysticetes, probably in part because odontocete low-frequency hearing is less sensitive than that of mysticetes. However, at least when in the Canadian Beaufort Sea in summer, belugas appear to be fairly responsive to seismic surveys, with few being sighted within 10–20 km during aerial surveys (Miller et al. 2005).

Taking into account the moderately-sized airgun array to be used and mitigation measures that are planned, effects on cetaceans are generally expected to be restricted to avoidance of a limited 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 relatively low percentages of the population sizes in the Arctic 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 varying proportions of the populations of each species in the Arctic Ocean and adjacent waters (Table 4). For species listed as ***Endangered*** under the ESA, our estimates include two fin whales, two humpback whales, and ~0.85% of the Bering-Chukchi-Beaufort bowhead whale population of >10,545+ (Table 4).

The requested "take authorization" of the number of individuals that could be exposed to ≥160 dB re 1 μPa_{rms} likely overestimates the actual number of animals that will be exposed to and will react to the seismic sounds. The reasons for that conclusion are outlined above. The relatively short-term exposures are unlikely to result in any long-term negative consequences for the individuals or their populations.

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

Pinnipeds.—A few pinniped species are likely to be encountered in the study area, but the ringed seal is by far the most abundant marine mammal that will be encountered during the seismic survey. An estimated 7492 ringed seals, 677 bearded seals, 150 spotted seals, and 42 ribbon seals may be exposed to airgun sounds at received levels ≥160 dB re 1 μPa_{rms} during the seismic survey. It is probable that only a small percentage of those would actually be disturbed. The Pacific walrus, under USFWS jurisdiction, is not expected to be encountered in the survey area because it occurs in pack ice, and the *Langseth* will completely avoid ice during the entire cruise.

As for cetaceans, the short-term exposures of pinnipeds to airgun sounds are not expected to result in any long-term negative consequences for the individuals or their populations.

Polar Bears.—The polar bear, under USFWS jurisdiction, is not expected to be encountered in the survey area because it occurs on fast or pack ice, and the *Langseth* will completely avoid ice during the entire cruise. However, as a precautionary measure, we have requested a small number of takes.

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 be prominent 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, including patterns of family life, artistic expression, and community religious and celebratory activities. Because of the importance of subsistence, NSF offers guidelines for science coordination with native Alaskans (see http://www.arcus.org/guidelines/).

(a) Subsistence Hunting for Marine Mammals

In the North Slope Borough (NSB) of Alaska, marine mammals are legally hunted by Alaska Natives along the Beaufort Sea coast (from the communities of Barrow, Nuiqsut, and Kaktovik) and from communities along the Chukchi Sea (Wainwright, Point Lay, and Point Hope). Species hunted include bowhead whales, beluga whales, ringed, spotted, and bearded seals, walrus, and polar bears.

Bowhead whale hunting is the key activity in the subsistence economies of Barrow and two smaller communities to the east, Nuiqsut and Kaktovik. Bowhead whales are also hunted by communities along the Chukchi Sea. Whale harvests have a great influence on social relations by strengthening the sense of Inupiat culture and heritage in addition to reinforcing family and community ties.

An overall quota system for the hunting of bowhead whales was established by the IWC in 1977; the quota is now regulated through an agreement between NMFS and the Alaska Eskimo Whaling Commission (AEWC). The AEWC allots the number of bowhead whales that each whaling community may harvest annually (USDI/BLM 2005; NMFS 2008d).

The community of Barrow hunts bowhead whales in both the spring and fall during the whales' seasonal migrations along the coast. Often, the bulk of the Barrow bowhead harvest is taken during the spring hunt. However, with larger quotas in recent years, it is common for a substantial fraction of the annual Barrow quota to remain available for the fall hunt (Table 5). The communities of Nuiqsut and Kaktovik participate only in the fall bowhead harvest. The spring hunt at Barrow occurs after leads open because of the deterioration of pack ice; the spring hunt typically occurs from early April until the first week of June. The fall migration of bowhead whales that summer in the eastern Beaufort Sea typically begins in late August or September. The location of the fall subsistence hunt depends on ice conditions and (in some years) industrial activities that influence the bowheads movements as they move west

Table 5. Number of bowhead whale landing by year at Barrow, Cross Island (Nuiqsut), and Kaktovik, 1993–2008. Barrow numbers include the total number of whales landed for the year followed by the numbers landed during the fall hunt in parenthesis. Cross Isl. (Nuiqsut) and Kaktovik landings are in autumn.

Year	Point Hope	Wainwright	Barrow	Cross Island	Kaktovik
1993	2	5	23 (7)	3	3
1994	5	4	16 (1)	0	3
1995	1	5	19 (11)	4	4
1996	3	3	24 (19)	2	1
1997	4	3	30 (21)	3	4
1998	3	3	25 (16)	4	3
1999	2	5	24 (6)	3	3
2000	3	5	18 (13)	4	3
2001	4	6	27 (7)	3	4
2002	0	1	22 (17)	4	3
2003	4	5	16 (6)	4	3
2004	3	4	21 (14)	3	3
2005	7	4	29 (13)	1	3
2006	0	2	22 (19)	4	3
2007	3	4	20 (7)	3	3
2008	2	2	21(12)	4	3

Sources: USDI/BLM and references therein; Burns et al. (1993); Koski et al. (2005); Suydam et al. 2004, 2005, 2006, 2007, 2008, 2009.

(Brower 1996). In the fall, subsistence hunters use aluminum or fiberglass boats with outboards. Hunters prefer to take bowheads close to shore to avoid a long tow during which the meat can spoil, but Braund and Moorehead (1995) report that crews may (rarely) pursue whales as far as 80 km offshore. The autumn hunt at Barrow usually begins in mid September, and mainly occurs in the waters east and northeast of Point Barrow. The whales have usually left the Beaufort Sea by late October (Treacy 2002a,b). Along the Chukchi Sea coast, bowhead whales are only hunted during the spring, between March and June.

The scheduling and location far (>200 km) offshore of this seismic survey has been discussed with representatives of those concerned with the subsistence bowhead hunt, most notably the AEWC and the Barrow Whaling Captains' Association. No major concerns were expressed (see further in § IV(11), below). The proposed survey will not have any impacts on the spring bowhead whale hunt by communities along the Chukchi Sea.

Beluga whales are available to subsistence hunters at Barrow in the spring when pack-ice conditions deteriorate and leads open up. Belugas may remain in the area through June and sometimes into July and August in ice-free waters. Hunters usually wait until after the spring bowhead whale hunt is finished before turning their attention to hunting belugas. Few, if any, belugas are taken by Kaktovik and Nuiqsut hunters, and only during the fall whale harvest. Along the Chukchi Sea, belugas are hunted during the spring and in the summer (between July and August) by residents of Wainwright and Point Hope. Near Point Lay, belugas are taken in June and July. During 2002–2006, Alaska Native subsistence hunters took a mean annual number of 25.4 beluga whales from the Beaufort Sea stock and 59 from the eastern Chukchi Sea stock. The average annual harvest of beluga whales taken by Barrow for 1962–1982 was five (MMS 1996).

The Alaska Beluga Whale Committee recorded that 23 beluga whales had been harvested by Barrow hunters from 1987 to 2002, ranging from 0 in 1987, 1988, and 1995 to the high of 8 in 1997 (Fuller and George 1999; Alaska Beluga Whale Committee 2002 *in* USDI/BLM 2005).

The timing of the proposed survey is after the spring and summer beluga harvest, and the survey initiates >200 km offshore, which would be well outside the area where seismic surveys would influence any late beluga hunting by Barrow hunters. Although hunting of beluga from Point Hope may extend into September, off Point Hope, the vessel will ~80 km from the coast, in transit northward to the study area.

Ringed seals are hunted by villagers along the Beaufort Sea coast mainly from October through June. Hunting for these smaller mammals is concentrated during winter because bowhead whales, bearded seals, and caribou are available through other seasons. Winter leads in the area off Point Barrow and along the barrier islands of Elson Lagoon to the east are used for hunting ringed seals. The average annual ringed seal harvest by the community of Barrow from the 1960s through much of the 1980s has been estimated as 394 (Table 6). Along the Chukchi Sea coast, ringed seals are mainly taken between May and September near Wainwright, and throughout the year by Point Lay and Point Hope hunters. As the seismic survey will occur far offshore, the survey will not affect ringed seals in the nearshore areas where they are hunted. It is unlikely that accessibility to ringed seals during the subsistence hunt could be impaired during the *Langseth*'s transit to and from the study area when the airguns are not operating. Although some hunting in the Chukchi Sea does occur as far as 32 km from shore, the area affected during transit would be in close proximity to the ship.

The ***spotted seal*** subsistence hunt on the Beaufort Sea coast peaked in July and August, at least in 1987–1990, but involves few animals. Spotted seals typically migrate south by October to overwinter in the Bering Sea. Admiralty Bay, <60 km to the east of Barrow, is a location where spotted seals are harvested. Spotted seals are also occasionally hunted in the area off Point Barrow and along the barrier islands of Elson Lagoon to the east (USDI/BLM 2005). The average annual spotted seal harvest by the community of Barrow from 1987–1990 was one (Braund et al. 1993; Table 6). Spotted seals become less abundant at Nuiqsut and Kaktovik, and few spotted seals are harvested at these villages. Along the Chukchi Sea coast, seals are mainly taken between May and September near Wainwright, and throughout the year by Point Lay and Point Hope hunters.

The seismic survey will take place at least 200 km offshore from the preferred nearshore harvest area of these seals. It is unlikely that accessibility to spotted seals during the subsistence hunt could be impaired during the *Langseth*'s transit to and from the study area when the airguns are not operating. Although some hunting in the Chukchi Sea does occur as far as 40 km from shore, the area affected during transit would be in close proximity to the ship.

Bearded seals, although not favored for their meat, are important to subsistence activities in Barrow because of their skins. Six to nine bearded seal hides are used by whalers to cover each of the skin-covered boats traditionally used for spring whaling. Because of their valuable hides and large size, bearded seals are specifically sought. Bearded seals are harvested during the summer months in the Beaufort Sea (USDI/BLM 2005). The animals inhabit the environment around the ice floes in the drifting ice pack, so hunting usually occurs from boats in the drift ice. Braund et al. (1993) estimated that 174 bearded seals were harvested annually at Barrow from 1987 to 1990 (Table 6). The majority of bearded seal harvest sites from 1987 to 1990 was within ~24 km of Point Barrow (Braund et al. 1993), well inshore of the proposed survey, which is to take place >200 km offshore. Along the Chukchi Sea coast, bearded seals are mainly taken between May and September near Wainwright, during the spring and summer by Point Hope hunters, and throughout the year by Point Lay hunters.

TABLE 6. Average annual take of marine mammals other than bowhead whales harvested by the community of Barrow (as compiled by LGL Alaska 2004).

Beluga Whales	Ringed Seals	Bearded Seals	Spotted Seals
5 **	394 *	174*	1*

* Average annual harvest for years 1987-90 (Braund et al. 1993).

** Average annual harvest for years 1962-82 (MMS 1996).

It is unlikely that accessibility to bearded seals during the subsistence hunt could be impaired during the *Langseth*'s transit to and from the study area when the airguns are not operating. Although hunting of bearded seals in the Chukchi can occur as far as 40 km from shore, the area affected during transit would be in close proximity to the ship.

USFWS has monitored the harvest of ***polar bears*** in Alaska using a mandatory marking, tagging, and reporting program implemented in 1988. Polar bears are harvested in the winter and spring, but comprise a small percentage of the annual Native subsistence harvest. Braund et al. (1993) reported that ~2% of the total edible pounds harvested by Barrow residents from 1987 to 1989 involved polar bears USFWS estimated that, from 2003 to 2007, the average annual harvest of polar bears in Alaska was ~37 (Allen and Angliss 2010). That would include harvests at other smaller communities besides Barrow. It is not expected that the seismic survey will interfere with polar bear subsistence hunting because of the limited annual harvest documented by USFWS and the fact that the subsistence hunt typically takes place in the winter and spring, either well after or well before the scheduled survey.

Walruses are hunted primarily from June through mid August on the Beaufort Sea coast from west of Point Barrow southwest to Peard Bay. Walruses rarely occur in the Beaufort Sea north and east of Barrow and become less abundant farther east. The harvest effort peaks in July. The annual walrus harvest by Barrow residents was 7–206 during 1990–2002 (Fuller and George 1999; Schliebe 2002 *in* USDI/BLM 2005). Walruses are also hunted in the late spring and summer along the Chukchi Sea coast. The timing of the proposed survey is after the walrus harvest and far from any hunting areas. Even if hunting were to occur in the fall, it is unlikely that accessibility to walruses during the subsistence hunt could be impaired during the *Langseth*'s transit to and from the study area when the airguns are not operating. The area affected, in any case, would be an area in close proximity to the ship.

In the event that both marine mammals and hunters were near the *Langseth* when it begins operating north of Barrow, the proposed project potentially could impact the availability of marine mammals for the harvest in a very small area immediately around the *Langseth*. However, the majority of marine mammals are taken by hunters within ~33 km from shore (Braund et al. 1993), and the *Langseth* will not commence the seismic survey until it is >200 km offshore.

Operations in the Arctic Ocean are scheduled to occur in early September–early October, and most hunting does not occur at that time of year. The bowhead hunt near Barrow could be underway, as well as hunting for ice seals by communities throughout the NSB. However, the seismic survey will take place >200 km offshore and most hunting in the Chukchi Sea is done in nearshore areas, particularly during the open-water season. Thus, the proposed project is not expected to have any significant impacts to the availability of marine mammals for subsistence harvest.

(b) Subsistence Fishing

Subsistence fishing is conducted by Alaska Natives through the year, but most actively during the summer and fall months. On average, subsistence fishing provides ~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 ~60–62% from finfish and 2% from shellfish (ADF&G 2005). Barrow residents often fish for camp food while hunting, so the range of subsistence fishing is widespread. Marine subsistence fishing occurs during the harvest of other subsistence resources in the summer. Fishing occurs in areas much closer to shore than where the survey will be conducted (MMS 1996), thus subsistence fishing activity will not be affected by the proposed survey.

Seismic surveys can, at times, cause changes in the catchability of fish. Airgun operations are not planned to occur within 200 km of shore. However, in the highly unlikely event that subsistence fishing (or hunting) is occurring within 5 km of the *Langseth*'s trackline, the airgun operations will be suspended until the *Langseth* is >5 km away.

(c) Consultation with Communities in the North Slope Borough

UAGI has worked with the people of the NSB to identify and avoid areas of potential conflict. The project's (PI) contacted Dr. Glenn Sheehan of the Barrow Arctic Science Consortium and NSB biologist, Dr. Robert Suydam, on 7 January 2010 to inform them of the proposed study and the elements intended to minimize potential subsistence conflict. The PI presented the proposed UAGI survey at a meeting of the AEWC in Barrow on 11 February 2010. He explained the survey plans to the local residents, including NSB Department of Wildlife Management biologists, Craig George and Robert Suydam, consulted with stakeholders about their concerns, and discussed the aspects of the survey designed to mitigate impacts. No major concerns were expressed. The PI also attended the 2011 AEWC meeting on 17–18 February; representatives from all NSB communities attended. The only concern expressed was that AEWC would like a good communication link with the *Langseth* during the survey.

A Barrow resident knowledgeable about the mammals and fish of the area is expected to be included as a PSO aboard the *Langseth.* Although his primary duties will be as a member of the PSO team responsible for implementing the monitoring and mitigation requirements, he will also be able to act as liaison with hunters and fishers if they are encountered at sea. However, the proposed activity has been timed so as to avoid overlap with the main harvests of marine mammals (especially bowhead whales), and is not expected to affect the success of subsistence fishers.

IX. Anticipated Impact on Habitat

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

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

Effects on Fish

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

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

Hastings and Popper (2005), Popper 2009, and Popper and Hastings (2009a,b) provided recent critical reviews of the known effects of sound on fish. The following sections provide a general synopsis of the available information on the effects of exposure to seismic and other anthropogenic sound as relevant to fish. The information comprises results from scientific studies of varying degrees of rigor plus some anecdotal information. Some of the data sources may have serious shortcomings in methods, analysis, interpretation, and reproducibility that must be considered when interpreting their results (see Hastings and Popper 2005). Potential adverse effects of the program's sound sources on marine fish are then noted.

Pathological Effects

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

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

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

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

Physiological Effects

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

Behavioral Effects

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

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

Effects on Fisheries

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

No active fishing is expected to be conducted within the study area during the time of the survey. Any on-going fisheries near the project area would be subsistence, and much closer to shore than the actual survey.

Effects on Invertebrates

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

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

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

Pathological Effects

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

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

Physiological Effects

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

Behavioral Effects

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

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

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

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

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

XI. MITIGATION MEASURES

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

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

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

Planning Phase

This survey was originally proposed to be scheduled in 2010 on the icebreaker USCGC *Healy*. Appropriate seismic equipment to meet the scientific requirements however could not be obtained in time for a survey to be conducted in 2010. The seismic equipment is integral to the success of the science mission; faulty or undependable equipment would put the mission at risk and a significant amount of funding would be lost. As a consequence, the survey was postponed until appropriate and reliable equipment could be obtained.

The R/V Langseth, the primary seismic vessel in the academic fleet, had a proposed 2011 schedule which included several surveys in the Alaska region. Given its proximity, the vessel operator and technicians, UNOLS schedulers, and NSF considered the possibility of the *Langseth* supporting the proposed action. The *Langseth* is not an ice-strengthened vessel and must especially consider safety-of-operations while towing a significant amount of equipment behind the vessel; it therefore cannot operate in ice conditions that would pose serious hazards to the vessel and crew. After consideration of the operational challenges, however, it was concluded that the Langseth would be able to support the activity if it remained in ice-free waters. An ice expert would be available to help provide guidance during any operations. An additional aspect of using the *Langseth* to support the activity would be that another research vessel would not need to be moved into the area to support the activity, thereby reducing vessel presence in the region.

The PI worked with L-DEO and NSF to identify potential time periods to carry out the survey in 2011, taking into consideration key factors such as environmental conditions (i.e., ice conditions, the seasonal presence of marine mammals and sea birds), weather conditions, and equipment. The project's proposed timeframe avoids the eastward (spring) bowhead migration, but overlaps with that of the westward fall migration and the subsistence bowhead hunt along the north shore of Alaska near Barrow. To avoid disturbance, the seismic survey has been scheduled to depart from Dutch Harbor in early

September and remain at least 200 km from Barrow during transit to and from the survey area, which is ~250–800 km northeast of Barrow. Also, to reduce potential effects, the size of the energy source was reduced from the *Langseth*'s 36-airgun, 6600-in^3 array to a 10-gun, 1830-in^3 array.

Proposed Exclusion Zones

Received sound levels for the 10-airgun array have been predicted by Marine Acoustics, Inc. (MAI) in relation to distance and direction from the airguns, and received sound levels for a single 40-in^3 mitigation airgun have been predicted by L-DEO. Table 1 shows the distances at which three rms sound levels are expected to be received from the 10-airgun array and a single airgun. The 180- and 190-dB levels are shut-down criteria applicable to cetaceans and pinnipeds, respectively, as specified by NMFS (2000); these levels were used to establish the EZs. If the PSO detects marine mammal(s) within or about to enter the appropriate EZ, the airguns will be powered down (or shut down if necessary) immediately (see below).

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

Mitigation During Operations

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

Power-down Procedures

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

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

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

- it is visually observed to have left the EZ, or
- it has not been seen within the zone for 15 min in the case of small odontocetes (or pinnipeds), or
- it has not been seen within the zone for 30 min in the case of mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, and beaked whales.

The airgun array will be ramped up gradually after the marine mammal has cleared the safety zone. Ramp-up procedures are described below.

Shut-down Procedures

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

Ramp-up Procedures

A ramp-up procedure will be followed when the airgun array begins operating after a specified period without airgun operations or when a power down has exceeded that period. It is proposed that, for the present cruise, this period would be ~8 min. Similar periods (~8–10 min) were used during previous L-DEO surveys.

Ramp up will begin with the smallest airgun in the array (40 in^3). Airguns will be added in a sequence such that the source level of the array will increase in steps not exceeding 6 dB per 5-min period over a total duration of ~15 to 20 min. During ramp up, the PSOs will monitor the EZ, and if marine mammals are sighted, a power down or shut down will be implemented as though the full array were operational.

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

XII. Plan of Cooperation

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

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

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

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

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

UAGI and the AEWC will develop a "Plan of Cooperation" for the 2011 Arctic Ocean seismic survey, in consultation with representatives of the Barrow whaling community. The Plan of Cooperation will cover the initial phases of UAGI's Arctic Ocean seismic survey planned to occur 5 September to 9 October. The purpose of this plan will be to identify measures that will be taken to minimize any adverse effects on the availability of marine mammals for subsistence uses, and to ensure good communication between the project scientists and the community of Barrow. UAGI is working with the people of Barrow to identify and avoid areas of potential conflict.

The PI initially contacted Dr. Glenn Sheehan of the Barrow Arctic Science Consortium and the NSB Department of Wildlife Management biologist, Dr. Robert Suydam, on 7 January 2010 to inform them of the prolapsed study and the elements intended to minimize potential subsistence conflict. The PI presented the proposed survey at a meeting of the AEWC in Barrow on 11 February 2010 and again on 17-18 February 2011. The PI explained the survey plans to the locals residents, including NSB biologists, Robert Suydam and Craig George, consulted with stakeholders about their concerns, and discussed the aspects of the survey designed to mitigate impacts. The PI also presented the study at the Arctic Open Water meeting in Anchorage on 7–8 March 2011. The Ice Seal Committee has also been informed about the survey.

A Barrow resident knowledgeable about the mammals and fish of the area will be included as a member of the PSO team aboard the *Langseth.* Although his primary duties will be as a member of the PSO team responsible for implementing the monitoring and mitigation requirements, he will also be able to act as liaison with hunters and fishers if they are encountered at sea. However, the proposed activity has been timed so as to avoid overlap with the main harvests of marine mammals (especially bowhead whales), and is not expected to affect the success of subsistence fishers.

In the past, the bulk of the Barrow bowhead harvest is taken during the spring hunt. The proposed survey is scheduled for the fall, from 5 September to 9 October. Some whales are also taken during the autumn hunt at Barrow usually beginning in mid September, and mainly in the waters east and northeast of Point Barrow. The proposed survey is located far to the north and west of Point Barrow. The scheduling and location far (>200 km) offshore of this seismic survey has been discussed with representatives of those concerned with the subsistence bowhead hunt, most notably the AEWC and the Barrow Whaling Captains' Association. No major concerns have been expressed. The timing of the proposed survey is after the beluga harvest and would occur well outside the area where seismic surveys would influence any late beluga hunting by Barrow hunters. Whaling does not occur during the late summer/fall in the Chukchi Sea.

Although ringed seals are available year-round, the seismic survey will not occur during the primary period when these seals are harvested. Also, the seismic survey in offshore waters will not influence ringed, spotted, or bearded seals in the nearshore areas where they are hunted. It is unlikely that accessibility to walruses and other pinnipeds during the subsistence hunt could be impaired during the *Langseth*'s traverse north of Barrow to the starting point of the seismic survey in September and October. The area affected, in any case, would be an area in close proximity to the ship. The airguns would not be operating at this time. Similarly, it is not expected that the seismic survey will interfere with polar bear subsistence hunting because of the limited annual harvest documented by USFWS and the fact that the subsistence hunt typically takes place in the winter and spring, either well after or well before the scheduled survey.

In the highly unlikely event that subsistence fishing (or hunting) is occurring within 5 km of the *Langseth*'s trackline, the airgun operations will be suspended until the *Langseth* is >5 km away.

Meetings with whaling captains, other community representatives, the AEWC, NSB, and any other parties to the plan have been and will continue to be held as necessary to negotiate the terms of the plan and to coordinate the planned seismic survey operation with subsistence whaling activity.

The proposed Plan of Cooperation may address the following:

- Operational agreement and communications procedures
- Where/when agreement becomes effective
- General communications scheme
- On-board Inupiat observer
- Conflict avoidance
- Seasonally sensitive areas
- Vessel navigation
- Marine mammal monitoring activities
- Measures to avoid impacts to marine mammals
- Measures to avoid conflicts in areas of active whaling
- Emergency assistance
- Dispute resolution process

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...

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

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

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

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

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

When mammals are detected within or about to enter the designated exclusion zone, the airguns will immediately be powered down or shut down if necessary. The PSO(s) will continue to maintain watch to determine when the animal(s) are outside the exclusion zone. Airgun operations will not resume until the animal has left the exclusion zone.

Passive Acoustic Monitoring

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

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

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

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

PSO Data and Documentation

The vessel-based monitoring will provide data to estimate the numbers of marine mammals exposed to various received sound levels, to document any apparent disturbance reactions or lack thereof, and thus to estimate the numbers of mammals potentially "taken" by harassment. It will also provide the information needed in order to power down or shut down the airguns at times when mammals are present in or near the EZ. When a sighting is made, the following information about the sighting will be recorded:

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

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

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

Results from the vessel-based observations will provide

1. The basis for real-time mitigation (airgun power down or shut down).

2. Information needed to estimate the number of marine mammals potentially taken by harassment, which must be reported to NMFS.
3. Data on the occurrence, distribution, and activities of marine mammals in the area where the seismic study 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.

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

XIV. Coordinating Research to Reduce and Evaluate Incidental Take

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

UAGI and NSF will coordinate the planned marine mammal monitoring program associated with the seismic survey in the Arctic Ocean (as summarized in § XI and XIII) with other parties that may have interest in the area and/or be conducting marine mammal studies in the same region during the proposed seismic survey. No other marine mammal studies are expected to occur in the study area at the proposed time. However, other industry-funded seismic surveys may be occurring in the northeast Chukchi and/or western Beaufort Sea closer to shore, and those projects are likely to involve marine mammal monitoring. Coordination of monitoring programs can occur during and after the planned open-water peer review meeting in Anchorage during 7-8 March 2011. UAGI and NSF have coordinated, and will continue to coordinate, with other applicable Federal, State, and Borough agencies, and will comply with their requirements.

XV. Literature Cited

Marine Mammals and Acoustics

Aars, J., N.J. Lunn, and A.E. Derocher (eds.) 2006. Polar bears: proceedings of the 14th working meeting of the IUCN/SSC Polar Bear Specialist Group, 20–24 June, Seattle, WA, USA. IUCN, Gland, Switzerland. 189 p.

Allen, B.M. and R.P. Angliss (eds). 2010. Alaska marine mammal stock assessments, 2010. Draft, April 2010. U.S. Dep. Commer., NOAA Tech. Memo. 247 p.

Amstrup, S.C. 1995. Movements, distribution, and population dynamics of polar bears in the Beaufort Sea. Ph.D. Dissertation. Univ. Alaska–Fairbanks, Fairbanks, AK. 299 p.

Amstrup, S.C., I. Stirling, and J.W. Lentfer. 1986. Past and present status of polar bears in Alaska. **Wildl. Soc. Bull.** 14(3):241-254.

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

Baird, R.W., D.L. Webster, D.J. McSweeney, A.D. Ligon, G.S. Schorr, and J. Barlow. 2006. Diving behavior and ecology of Cuvier's (*Ziphius cavirostris*) and Blainville's (*Mesoplodon densirostris*) beaked whales in Hawaii. **Can. J. Zool.** 84(8):1120-1128.

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

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

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

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

Barlow, J. J. Calambokidis, E.A. Falcone, C.S. Baker, A.M. Burdin, P.J. Clapham, J.K.B. Ford, C.M. Gabriele, R.G. LeDuc, D.K. Mattila, T.J. Quinn, L. Rojas-Bracho, J.M. Straley, B.L. Taylor, J. Urban R., P. Wade, D.W. Weller, B.H. Witteveen, and M. Yamaguchi. 2009. Humpback whale abundance in the North Pacific estimated by phographic capture-recapture with bias correction from simulation studies. p. 25 *In:* Abstr. 18th Bienn. Conf. Biol. Mar. Mamm., Québec, Oct. 2009. 306 p.

Barry, S.B., A.C. Cucknell, and N. Clark. 2010. A direct comparison of bottlenose and common dolphin behaviour during seismic surveys when airguns are and are not being utilized. Abstract *In:* Second International Conference on the Effects of Noise on Aquatic Life, Cork, Ireland, 15–20 August 2010.

Beland, J. and D. Ireland. 2010. Marine mammal monitoring and mitigation during a marine geophysical survey in the Arctic Ocean, August-September 2010: 90-day Report. LGL Rep. P1123-1. Rep. from LGL Alaska Research Assoc. Inc., Anchorage, AK, for U.S. Geological Survey, Menlo Park, CA. Nat. Mar. Fish. Serv., Silver Spring, MD, and U.S. Fish & Wild. Serv., Anchorage, AK. 53 p.

Blackwell, S.B., R.G. Norman, C.R. Greene Jr., M.W. McLennan, T.L. McDonald, and W.J. Richardson. 2004. Acoustic monitoring of bowhead whale migration, autumn 2003. p. 71 to 744 *In*: Richardson, W.J. and M.T. Williams (eds.), Monitoring of industrial sounds, seals, and bowhead whales near BP's Northstar oil development, Alaskan Beaufort Sea, 1999–2003. [Dec. 2004 ed.] LGL Rep. TA4002. Rep. from LGL Ltd. (King City, Ont.), Greeneridge Sciences Inc. (Santa Barbara, CA) and WEST Inc. (Cheyenne, WY) for BP Explor. (Alaska) Inc., Anchorage, AK. 297 p. + Appendices A - N on CD-ROM.

Blackwell, S.B., C.R. Greene, Jr., T.L. McDonald, M.W. McLennan, C.S. Nations, R.G. Norman, and A. Thode. 2010. Beaufort Sea acoustic monitoring program. Chapter 8 *In*: D.W. Funk, R. Rodrigues, D.S. Ireland, and W.R. Koski (eds.), Joint monitoring program in the Chukchi and Beaufort seas, open water seasons, 2006–2008. LGL Alaska Rep. P1050-2. Rep. from LGL Alaska Research Associates, Inc., LGL Ltd., Greeneridge Sciences, Inc., and JASCO Research, Ltd., for Shell Offshore, Inc. and other Industry contributors, National Marine Fisheries Service, and U.S. Fish and Wildlife Service. 506 p. + app.

Bluhm, B.A., K.O. Coyle, B. Konar, and R. Highsmith. 2007. High gray whale relative abundances associated with an oceanographic front in the south-central Chukchi Sea. **Deep-sea Res. II** 54:2919-2933.

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

Braham, H.W. 1984. Distribution and migration of gray whales in Alaska. p. 249-266 *In*: M.L. Jones, S.L. Swartz, and S. Leatherwood (eds.), The gray whale *Eschrichtius robustus*. Academic Press, Orlando, FL. 600 p.

Braham, H.W., B.D. Krogman and G.M. Carroll. 1984. Bowhead and white whale migration, distribution, and abundance in the Bering, Chukchi, and Beaufort seas, 1975–78. NOAA Tech. Rep. NMFS SSRF-778. USDOC/NOAA/NMFS. 39 p. NTIS PB84-157908.

Braund, S.R. and E.L. Moorehead. 1995. Contemporary Alaska Eskimo bowhead whaling villages. p. 253-279 *In:* A.P. McCartney (ed.), Hunting the largest animals/Native whaling in the western Arctic and Subarctic. Studies in whaling 3. Can. Circumpolar Inst., Univ. Alberta, Edmonton, Alb. 345 p.

Braund, S.R., K. Brewster, L. Moorehead, T. Holmes, and J. Kruse. 1993. North Slope subsistence study/Barrow 1987, 1988, 1989. OCS Study MMS 91-0086. Rep. from Stephen R. Braund & Assoc. and Inst. Social & Econ. Res., Univ. Alaska, Anchorage, AK. 466 p.

Brower, H., Jr. 1996. Observations on locations at which bowhead whales have been taken during the fall subsistence hunt (1988 through 1995) by Eskimo hunters based in Barrow, Alaska. North Slope Borough Dep. Wildl. Manage., Barrow, AK. 8 p. Revised 19 Nov. 1996.

Brueggeman, J. 2009. 90–day report of the marine mammal monitoring program for the ConocoPhillips Alaska shallow hazards survey operations during the 2008 open water season in the Chukchi Sea. Rep from Canyon Creek Consulting LLC, Seattle, WA, for ConocoPhillips Alaska, Inc.

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

Burns, J.J. 1970. Remarks on the distribution and natural history of pagophilic pinnipeds in the Bering and Chukchi Seas. **J. Mammal**. 51(3):445-454.

Burns, J.J. 1981. Bearded seal *Erignathus barbatus* Erxleben, 1777. p. 145-170 *In*: S.H. Ridgway and R.J. Harrison (eds.), Handbook of marine mammals, Vol. 2: Seals. Academic Press, New York, NY. 359 p.

Burns, J.J., J.J. Montague and C.J. Cowles (eds.). 1993. The bowhead whale. Spec. Publ. 2, Soc. Mar. Mamm., Lawrence, KS. 787 p.

Burns, J.J., L.H. Shapiro, and F.H. Fay. 1981. Ice as marine mammal habitat in the Bering Sea. *In*: D.W. Hoome and J.A. Calder (eds.), The eastern Bering Sea shelf: oceanography and resources, Vol. II. Juneau, AK. OMPA, BLM.

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

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

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

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

Castellote, M., C.W. Clark, and M.O. Lammers. 2010. Acoustic compensation to shipping and airgun noise by Mediterranean fin whales (*Balaenoptera physalus*). Abstract *In*: Second International Conference on The Effects of Noise on Aquatic Life, Cork, Ireland, 15–20 August 2010.

CBD (Center for Biological Diversity). 2008. Petition to list the Pacific walrus (*Odobenus rosmarus divergens*) as a threatened or endangered species under the Endangered Species Act. 7 February 2008. Center for Biological Diversity, San Francisco, CA. Accessed in February 2010 at http://www.biologicaldiversity.org/species/mammals/Pacific_walrus/pdfs/CBD-Pacific-walrus-petition.pdf

Chadwick, V.J. and S. Hills. 2005. Movements of walruses radio-tagged in Bristol Bay, Alaska. **Arctic** 58(2):192-202.

Christi, K., C. Lyons, and W.R. Koski. 2010. Beaufort Sea aerial monitoring program. Chapter 7 *In*: D.W. Funk, D.S. Ireland, R. Rodrigues, and W.R. Koski (eds), Joint monitoring program in the Chukchi and Beaufort seas, open water seasons, 2006–2008. LGL Alaska Rep. P1050-2. Rep. from LGL Alaska Research Associates, Inc., LGL Ltd., Greeneridge Sciences, Inc., and JASCO Research, Ltd., for Shell Offshore, Inc. and other Industry contributors, National Marine Fisheries Service, and U.S. Fish and Wildlife Service. 506 p. + app.

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.

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

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

Clarke, J.T., S.E. Moore, and D.K. Ljungblad. 1989. Observations on gray whale (*Eschrichtius robustus*) utilization patterns in the northeastern Chukchi Sea, July–October 1982–1987. **Can. J. Zool**. 67(11):2646-2654.

Clarke, J.T., S.E. Moore, and M.M. Johnson. 1993. Observations on beluga fall migration in the Alaskan Beaufort Sea, 1982–1987, and northeastern Chukchi Sea, 1982–1991. **Rep. Int. Whal. Comm**. 43:387-396.

COMIDA. 2011. Chukchi Offshore Monitoring in Drilling Area. National Marine Mammal Laboratory cetacean assessment and ecology program, bowhead whale aerial surveys: Preliminary data. Accessed in March 2011 at http://www.afsc.noaa.gov/nmml/cetacean/bwasp/index.php.

COSEWIC. 2004. COSEWIC assessment and update status report on the narwhal *Monodon monoceros* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. vii + 50 p. Accessed in February 2010 at http://www.sararegistry.gc.ca/virtual_sara/files/cosewic/sr_narwhal_e.pdf.

Cox, T.M., T.J. Ragen, A.J. Read, E. Vos, R.W. Baird, K. Balcomb, J. Barlow, J. Caldwell, T. Cranford, L. Crum, A. D'Amico, G. D'Spain, A. Fern ndez, J. Finneran, R. Gentry, W. Gerth, F. Gulland, J. Hildebrand, D. Houser, T. Hullar, P.D. Jepson, D. Ketten, C.D. MacLeod, P. Miller, S. Moore, D.C. Mountain, D. Palka, P. Ponganis, S. Rommel, T. Rowles, B. Taylor, P. Tyack, D. Wartzok, R. Gisiner, J. Mead, and L. Benner. 2006. Understanding the impacts of anthropogenic sound on beaked whales. **J. Cetac. Res. Manage.** 7(3):177-187.

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

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

Davis, R.A. and C.R. Evans. 1982. Offshore distribution and numbers of white whales in the eastern Beaufort Sea and Amundsen Gulf, summer 1981. Rep. from LGL Ltd., Toronto, Ont., for Sohio Alaska Petrol. Co., Anchorage, AK, and Dome Petrol. Ltd., Calgary, Alb. (co-managers). 76 p.

DeMaster, D.P. and I. Stirling. 1981. *Ursus maritimus*. **Mamm. Species** 145. 7 p.

Derocher, A.E., G.W. Garner, N.J. Lunn and Ø Wiig. 1998. Polar bears: Proceedings of the 12th Working Meeting of the IUCN/SSC Polar Bear Specialist Group, 3–7 February 1997, Oslo, Norway. Occ. Pap. IUCN Species Survival Commission No. 19. IUCN, Gland.

Dunn, R.A. and O. Hernandez. 2009. Tracking blue whales in the eastern tropical Pacific with an ocean-bottom seismometer and hydrophone array. **J. Acoust. Soc. Am.** 126(3):1084-1094.

Durner, G.M. and S.C. Amstrup. 1995. Movements of polar bear from north Alaska to northern Greenland. **Arctic** 48(4):338-341.

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

Estes, J.A. and J.R. Gilbert. 1978. Evaluation of an aerial survey of Pacific walruses (*Odobenus rosmarus divergens*). **J. Fish. Res. Board Can.** 35:1130-1140.

Fay, F.H. 1981. Walrus *Odobenus rosmarus* (Linnaeus, 1758). p. 1-23 *In*: S.H. Ridgway and R.J. Harrison (eds.), Handbook of marine mammals: Vol. 1. The walrus, sea lions, fur seals and sea otter. Academic Press, London, U.K. 235 p.

Fay, F.H. 1982. Ecology and biology of the Pacific walrus, *Odobenus rosmarus divergens* Illiger. **North Am. Fauna** 74. 279 p.

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

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

Finley, K.J. 1982. The estuarine habitat of the beluga or white whale, *Delphinapterus leucas*. **Cetus** 4:4-5.

Finley, K.J., G.W. Miller, R.A. Davis, and W.R. Koski. 1983. A distinctive large breeding population of ringed seals (*Phoca hispida*) inhabiting the Baffin Bay pack ice. **Arctic** 36(2):162-173.

Finley, K.J., G.W. Miller, R.A. Davis, and C.R. Greene. 1990. Reactions of belugas, *Delphinapterus leucas*, and narwhals, *Monodon monoceros*, to ice-breaking ships in the Canadian High Arctic. **Can. Bull. Fish. Aquat. Sci.** 1123. 57 p.

Finneran, J.J. and C.E. Schlundt. 2004. Effects of intense pure tones on the behavior of trained odontocetes. Tech. Rep. 1913. Space and Naval Warfare (SPAWAR) Systems Center, San Diego, CA. 15 p.

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

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

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

Forney, K.A, and J. Barlow. 1998. Seasonal patterns in the abundance and distribution of California cetaceans, 1991–1992. **Mar. Mamm. Sci.** 14(3):460-489.

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

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

Frost, K.J. 1985. The ringed seal. Unpubl. Rep., Alaska Dep. Fish. and Game, Fairbanks, AK. 14 p.

Frost, K.J., L.F. Lowry, and J.J. Burns. 1988. Distribution, abundance, migration, harvest, and stock identity of belukha whales in the Beaufort Sea. p. 27-40 *In*: P.R. Becker (ed.), Beaufort Sea (Sale 97) information update. OCS Study MMS 86-0047. Nat. Oceanic & Atmos. Admin., Ocean Assess. Div., Anchorage, AK. 87 p.

Fuller, A.S. and J.C. George. 1999. Evaluation of subsistence harvest data from the North Slope Borough 1993 census for eight North Slope villages for the calendar year 1992. North Slope Borough, Dep. Wildl. Manage., Barrow, AK.

Funk, D.W., R. Rodrigues, D.S. Ireland, and W.R. Koski (eds.). 2010. Joint Monitoring Program in the Chukchi and Beaufort seas, open water seasons, 2006–2008. LGL Alaska Rep. P1050-2. Rep. from LGL Alaska Research Associates, Inc., LGL Ltd., Greeneridge Sciences, Inc., and JASCO Research, Ltd., for Shell Offshore, Inc. and other Industry contributors, National Marine Fisheries Service, and U.S. Fish and Wildlife Service. 506 p. + app.

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

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

Garner, G.W., S.T. Knick, and D.C. Douglas. 1990. Seasonal movements of adult female polar bears in the Bering and Chukchi Seas. **Int. Conf. Bear Res. Manage.** 8:219-226.

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

Gentry, R. (ed). 2002. Report of the workshop on acoustic resonance as a source of tissue trauma in cetaceans. April 24 and 25, 2002, Silver Spring, MD. 19 p. Accessed on 7 January 2011 at http://www.nmfs.noaa.gov/pr/pdfs/acoustics/cetaceans.pdf.

George, J.C., L.M. Philo, K. Hazard, D. Withrow, G.M. Carroll, and R. Suydam. 1994. Frequency of killer whale (*Orcincus orca*) attacks and ship collisions based on scarring on bowhead whales (*Balaena mysticetus*) of the Bering-Chukchi-Beaufort Seas stock. **Arctic** 47(3):247-255.

George, J.C., J. Zeh, R. Suydam, and C. Clark. 2004. Abundance and population trend (1978–2001) of western arctic bowhead whales surveyed near Barrow, Alaska. **Mar. Mamm. Sci.** 20(4):755-773.

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

Gilbert, J.R. 1989. Aerial census of Pacific walruses in the Chukchi Sea, 1985. **Mar. Mamm. Sci.** 5(1):17-28.

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

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

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

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

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

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

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

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

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

Greene, C.R., Jr., R.G. Norman, S.B. Blackwell, and A. Thode. 2007. Acoustics research for studying bowhead migration, 2006. Chapter 10 *In* D.S. Ireland, D.W. Funk, R. Rodrigues, and W.R. Koski (eds.), Joint monitoring program in the Chukchi and Beaufort seas, July–November 2006. LGL Rep. P891-2. Rep. by LGL Alaska Research Associates, Inc., Anchorage, AK, and LGL Ltd., King City, Ont., for Shell Offshore Inc., ConocoPhillips Alaska, Inc., GX Technology, the National Marine Fisheries Service, and the U.S. Fish and Wildlife Service.

Haley, B. 2006. Marine mammal monitoring during University of Texas at Austin's marine geophysical survey of the western Canada Basin, Chukchi Borderland and Mendeleev Ridge, Arctic Ocean, July–August 2006. Rep. from LGL Alaska Research Associates, Inc., Anchorage AK, and LGL Ltd., King City, Ont., for the University of Texas at Austin, the Nat. Mar. Fish. Serv., Silver Springs, MD, and the U.S. Fish and Wildl. Serv., Anchorage, AK.

Haley, B. and D. Ireland. 2006. Marine mammal monitoring during University of Alaska Fairbanks' marine geophysical survey across the Arctic Ocean, August–September 2005. LGL Rep. TA4122-3. Rep. from LGL Ltd., King City, Ont., for Univ. Alaska Fairbanks, Fairbanks, AK, and Nat. Mar. Fish. Serv., Silver Spring, MD. 80 p.

Haley, B., J. Beland, D.S. Ireland, R. Rodrigues, and D.M. Savarese. 2010. Chapter 3 *In*: D.W. Funk, D.S. Ireland, R. Rodrigues, and W.R. Koski (eds.), Joint monitoring program in the Chukchi and Beaufort seas, open water seasons, 2006–2008. LGL Alaska Report P1050-2. Rep. from LGL Alaska Research Associates, Inc., LGL Ltd., Greeneridge Sciences, Inc., and JASCO Research, Ltd., for Shell Offshore, Inc. and other Industry contributors, National Marine Fisheries Service, and U.S. Fish and Wildlife Service. 506 p. + app.

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

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

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

Harwood, L., S. Innes, P. Norton, and M. Kingsley. 1996. Distribution and abundance of beluga whales in the Mackenzie estuary, southeast Beaufort Sea, and the west Amundsen Gulf during late July 1992. **Can. J. Fish. Aquatic Sci.** 53(10):2262-2273.

Harwood, L.A., F. McLaughlin, R.M. Allen, J. Illasiak Jr., and J. Alikamik. 2005. First-ever marine mammal and bird observations in the deep Canada Basin and Beaufort/Chukchi seas: expeditions during 2002. **Polar Biol.** 28(3):250-253.

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

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

Hay, K.A and A.W. Mansfield. 1989. Narwhal—*Monodon monoceros* Linnaeus, 1758. p. 145-176 *In*: S.H. Ridgway and R Harrison (eds.), Handbook of marine mammals, Vol. 4: River dolphins and the larger toothed whales. Academic Press, London, UK. 442 p.

Hazard, K. 1988. Beluga whale, *Delphinapterus leucas*. p. 195-235 *In*: J.W. Lentfer (ed.), Selected marine mammals of Alaska. Mar. Mamm. Comm., Washington, DC. 275 p. NTIS PB88-178462.

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

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

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

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

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

Holst, M., W.J. Richardson, W.R. Koski, M.A. Smultea, B. Haley, M.W. Fitzgerald, and M. Rawson. 2006. Effects of large and small-source seismic surveys on marine mammals and sea turtles. Abstract. Presented at Am. Geophys. Union - Soc. Explor. Geophys. Joint Assembly on Environ. Impacts Mar. Geophys. Geol. Stud. – Rec. Adv. Acad. Indust. Res. Progr., Baltimore, MD, May 2006.

Huntington, H.P., and L.T. Quakenbush. 2009. Traditional knowledge of bowhead whale migratory patterns near Kaktovik and Barrow, Alaska. Rep. to the Alaska Eskimo Whaling Commission. 13 p.

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

Innes, S., M.P. Heide-Jørgensen, J. Laake, K. Laidre, H. Cleator and P. Richard. 2002. Surveys of belugas and narwhals in the Canadian high Arctic in 1996. **NAMMCO Sci. Publ.** 4:169-190.

IUCN (The World Conservation Union). 2010. The IUCN Red List of Threatened Species vs 10.4 Accessed on 2 December 2010 at http://www.iucnredlist.org.

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

Jefferson, T.A., M.A. Webber, and R.L. Pitman. 2008. Marine mammals of the world: a comprehensive guide to their identification. Academic Press, New York. 573 p.

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

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

Johnson, S.R. 1979. Fall observations of westward migrating white whales (*Delphinapterus leucas*) along the central Alaskan Beaufort Sea coast. **Arctic** 32(3):275-276.

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

Jones, M.L. and S.L. Swartz. 1984. Demography and phenology of gray whales and evaluation of whale-watching activities in Laguna San Ignacio, Baja California Sur, Mexico. p. 309-374 *In*: M. L. Jones et al. (eds.), The gray whale *Eschrichtius robustus*. Academic Press, Orlando, FL. 600 p.

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

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

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

Kelly, B.P. 1988. Bearded seal, *Erignathus barbatus*. p. 77-94 *In:* J.W. Lentfer (ed.), Selected marine mammals of Alaska/species accounts with research and management recommendations. Mar. Mamm. Comm., Washington, DC. 275 p.

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., 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.

King, J.E. 1983. Seals of the world, 2nd ed. Cornell Univ. Press, Ithaca, NY. 240 p.

Koski, W.R., J.C. George, G. Sheffield, and M.S. Galginaitis. 2005. Subsistence harvests of bowhead whales (*Balaena mysticetus*) at Kaktovik, Alaska (1973–2000). **J. Cetac. Res. Manage**. 7(1):33-37.

Koski, W.R., J. Mocklin, A.R. Davis, J. Zeh, D.J. Rugh, J.C. George, and R. Suydam. 2008. Preliminary estimates of 2003–2004 Bering-Chukchi-Beaufort bowhead whale (*Balaena mysticetus*) abundance from photo-identification data. Working pap. SC/60/BRG18. Int. Whal. Comm., Cambridge, U.K. 7 p.

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

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

Larsen, T. 1985. Polar bear denning and cub production in Svalbard, Norway. **J. Wildl. Manage.** 49(2):320-326.

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

Leatherwood, S., A.E. Bowles, and R. Reeves. 1986. Aerial surveys of marine mammals in the southeastern Bering Sea. U.S. Department of Commerce, NOAA, OCSEAP Final Report 42:147-490.

LGL Alaska Res. Assoc., Inc. 2004. Request for a Letter of Authorization pursuant to Section 101(a)(5) of the Marine Mammal Protection Act covering taking of marine mammals incidental to operation of the Northstar facility in the U.S. Beaufort Sea 50 C.F.R. Part 216, Subpart R), submitted by BP Explor. (Alaska) Inc. to U.S. Dep. Comm./Nat. Oceanic & Atmosph. Admin./Nat. Mar. Fish. Serv. 89 p.

LGL and Greeneridge. 1996. Northstar marine mammal monitoring program, 1995: Baseline surveys and retrospective analyses of marine mammal and ambient noise data from the Central Alaskan Beaufort Sea. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Explor. (Alaska) Inc., Anchorage, AK. 104 p.

Ljungblad, D.K., S.E. Moore, and D.R. Van Schoik. 1984. Aerial surveys of endangered whales in the Beaufort, eastern Chukchi, and northern Bering Seas, 1983: with a five year review, 1979–1983. NOSC Tech Rep. 955. Rep. from Naval Ocean Systems Center, San Diego, CA, for U.S. Minerals Manage. Serv., Anchorage, AK. 356 p. NTIS AD-A146 373/6.

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.

Lowry, L.F., R.R. Nelson, and K.J. Frost. 1987. Observations of killer whales, (*Orcincus orca*) in western Alaska: Sightings, strandings and predation on other marine mammals. **Can. Field-Nat.** 101:6-12.

Lowry, L.F., K.J. Frost, R. Davis, D.P. DeMaster, and R.S. Suydam. 1998. Movements and behavior of satellite-tagged spotted seals (*Phoca largha*) in the Bering and Chukchi Seas. **Polar Biol.** 19(4):221-230.

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

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

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

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

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.

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

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

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

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

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

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

Malme, C.I., B. Würsig, J.E. Bird, and P. Tyack. 1988. Observations of feeding gray whale responses to controlled industrial noise exposure. p. 55-73 *In*: 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.

Mate, B.R., G.K. Krutzikowski, and M.H. Winsor. 2000. Satellite-monitored movements of radio-tagged bowhead whales in the Beaufort and Chukchi seas during the late-summer feeding season and fall migration. **Can. J. Zool.** 78:1168-1181.

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

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

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

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

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

Miller, G.W., R.E. Elliot, T.A. Thomas, V.D. Moulton, and W.R. Koski. 2002. Distribution and numbers of bowhead whales in the eastern Alaskan Beaufort Sea during lat summer and autumn, 1979-2000. Chapter 9 *In*: W.J. Richardson and D.H. Thomson (eds), 2002. Bowhead whale feeding in the eastern Alaskan Beaufort Sea: update of scientific and traditional information. OCS Study MMS 2002-012; LGL Rep. TA2196-7. Rep. from LGL Ltd., King City, Ont., for U.S. Minerals Manage. Serv., Anchorage, AK, and Herndon, VA. xliv + 697 p. 2 vol. NTIS PB2004-101568.

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

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

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

MMS. 1996. Beaufort Sea Planning Area oil and gas lease sale 144/Final Environmental Impact Statement. OCS EIS/EA MMS 96-0012. U.S. Minerals Manage. Serv., Alaska OCS Reg., Anchorage, AK. Two Vol. Var. pag.

Monnett, C. and S.D. Treacy. 2005. Aerial surveys of endangered whales in the Beaufort Sea, fall 2002–2004. OCS Study MMS 2005-037. Minerals Manage. Serv., Anchorage, AK. xii + 153 p.

Moore, S.E. 2000. Variability in cetacean distribution and habitat selection in the Alaskan Arctic, autumn 1982–91. **Arctic** 53(4):448-460.

Moore, S.E. and R.R. Reeves. 1993. Distribution and movement. p. 313-386 *In*: J.J. Burns, J.J. Montague, and C.J. Cowles (eds.), The bowhead whale. Spec. Publ. 2. Soc. Mar. Mammal., Lawrence, KS. 787 p.

Moore, S.E., J.C. George, K.O. Coyle, and T.J. Weingartner. 1995. Bowhead whales along the Chukotka coast in autumn. **Arctic** 48(2):155-160.

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

Moore, S.E., D.P. DeMaster, and P.K. Dayton. 2000b. Cetacean habitat selection in the Alaskan Arctic during summer and autumn. **Arctic** 53(4):432-447.

Moore, S.E., J.M. Waite, N.A. Friday, and T. Honkalehto. 2002. Cetacean distribution and relative abundance on the central-eastern and the southeastern Bering Sea shelf with reference to oceanographic domains. **Prog. Oceanogr.** 55(1-2):249-261.

Moore, S.E., J.M. Grebmeier, and J.R. Davies. 2003. Gray whale distribution relative to forage habitat in the northern Bering Sea: current conditions and retrospective summary. **Can. J. Zool.** 81(4):734-742.

Mosher, D.C., J.W. Shimeld, and D.R. Hutchinson. 2009. 2009 Canada Basin seismic reflection and refraction survey, western Arctic Ocean: CCGS *Louis S. St. Laurent* expedition report. Geological Survey of Canada, Ottawa, Ontario.

Moulton, V.D. and M. Holst. 2010. Effects of seismic survey sound on cetaceans in the Northwest Atlantic. Environmental Studies Research Funds Report No. 182. St. John's, Newfoundland. 28 p.

Moulton, V.D. and J.W. Lawson. 2002. Seals, 2001. p. 3-1 to 3-46 *In*: W.J. Richardson and J.W. Lawson (eds.), Marine mammal monitoring of WesternGeco's open-water seismic program in the Alaskan Beaufort Sea, 2001. LGL Rep. TA2564-4. Rep. from LGL Ltd., King City, Ont., for WesternGeco LLC, Anchorage, AK; BP Explor. (Alaska) Inc., Anchorage, AK; and Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 95 p.

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

Nerini, M. 1984. A review of gray whale feeding ecology. p. 423-450 *In*: M.L. Jones, S.L. Swartz, and S. Leatherwood (eds.), The gray whale, *Eschrichtius robustus*. Academic Press, Inc., Orlando, FL. 600 p.

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

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

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

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

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

NMFS (National Marine Fisheries Service). 2008a. Endangered and threatened wildlife; notice of 90-Day finding on a petition to list the three ice seal species as a threatened or endangered species. **Fed. Regist.** 73(172, 4 Sept.):51615-51617.

NMFS (National Marine Fisheries Service). 2008b. Endangered and threatened wildlife and plants; proposed threatened and not warranted status for distinct population segments of the spotted seal. **Fed. Regist.** 743(201, 20 Oct.):53683-53696.

NMFS (National Marine Fisheries Service). 2008c. Endangered and threatened wildlife; notice of 12-month finding on a petition to list the ribbon seal as a threatened or endangered species. **Fed. Regist.** 73(250, 30 Dec.):79822-79828.

NMFS (National Marine Fisheries Service). 2008d. Final Environmental Impact Statemenmt for issuing annual quotas to the Alaska Exkimo Whaling Commission for a subsistence hunt on bowhead whales for the years 2008 through 2012. January 2008. National Marine Fisheries Service, Alaska Region, Juneau, AK, and Seattle, WA. 255 p. Accessed in February 2010 at http://www.fakr.noaa.gov/protectedresources/whales/bowhead/eis0108/.

NMML (National Marine Mammal Labrotory). 2009. Polar ecosystems project. Telemetry of ice seals captured guring a research cruise aboard the *McArthur II* in the eastern Bering Sea. Accessed in February 2010 at http://www.afsc.noaa.gov/Quarterly/amj2009/divrptsNMML3.htm.

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

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

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

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. **Molec. Ecol.** 6(10):955-970.

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

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

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

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

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

Quakenbush, L.T. 2007. Preliminary satellite telemetry results for Bering-Chukchi-Beaufort bowhead whales. Working paper SC/59/BRG12. Int. Whal. Comm., Cambridge, U.K.

Quakenbush, L.T. and H.P. Huntington. 2010. Traditional knowledge regarding bowhead whales in the Chukchi Sea near Wainwright, Alaska. OCS Study MMS 2009-063. Minerals Manage. Serv., Anchorage, AK. 35 p.

Quakenbush, L.T., J.J. Citta, J.C. George, R.J. Small, and M.P. Heide-Jørgensen. 2010a. Fall and winter movements of bowhead whales (*Balaena mysticetus*) in the Chukchi Sea and within a potential petroleum development area. **Arctic** 63:289-307.

Quakenbush, L.T., R.J. Small, and J.J. Citta. 2010b. Satellite tracking of western Arctic bowhead whale. OCS Study BOEMRE 2010-033. Minerals Manage. Serv., Anchorage, AK. 118 p.

Ray, C.E. 1971. Polar bear and mammoth on the Pribilof Islands. **Arctic** 24(1):9-19.

Read, A.J. 1999. Harbour porpoise *Phocoena phocoena* (Linnaeus, 1758). p. 323-355 *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.

Reeves, R.R. 1980. Spitsbergen bowhead stock: a short review. **Mar. Fish. Rev.** 42(9/10):65-69.

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

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

Rice, D.W. and A.A. Wolman. 1971. The life history and ecology of the gray whale (*Eschrichtius robustus*). **Am. Soc. Mamm. Spec. Publ.** 3. 142 p.

Richard, P.R., A.R. Martin, and J.R. Orr. 1997. Study of summer and fall movements and dive behaviour of Beaufort Sea belugas, using satellite telemetry: 1992–1995. ESRF Rep. 134. Environ. Stud. Res. Funds, Calgary, Alb. 38 p.

Richard, P.R., A.R. Martin, and J.R. Orr. 2001. Summer and autumn movements of belugas of the eastern Beaufort Sea stock. **Arctic** 54(3):223-236.

Richardson, W.J. and C.I. Malme. 1993. Man-made noise and behavioral responses. p. 631-700 *In*: J.J. Burns, J.J. Montague, and C.J. Cowles (eds.), The bowhead whale. Spec. Publ. 2. Soc. Mar. Mammal., Lawrence, KS. 787 p.

Richardson, W.J. and Williams, M.T. (eds). 2004. Monitoring of industrial sounds, seals, and bowhead whales near BP's Northstar Oil Development, Alaskan Beaufort Sea, 1999-2003. Rep. from LGL Ltd., King City, Ont., Greeneridge Sciences Inc., Santa Barbara, CA, and WEST Inc., Cheyenne, WY, for BP Explor. (Alaska) Inc., Anchorage, AK.

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

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

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

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

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

Riedman, M. 1990. The pinnipeds: seals, sea lions, and walruses. Univ. Calif. Press, Berkeley and Los Angeles, CA. 439 p.

Rugh, D.J. and M.A. Fraker. 1981. Gray whale (*Eschrichtius robustus*) sightings in eastern Beaufort Sea. **Arctic** 34(2):186-187.

Rugh, D.J., K.E.W. Shelden, and D.E. Withrow. 1997. Spotted seals, *Phoca largha*, in Alaska. **Mar. Fish. Rev.** 59(1):1-18.

Savarese, D.M., C.R. Reiser, D.S. Ireland, and R. Rodrigues. 2010. Beaufort Sea vessel-based monitoring program. Chapter 6 *In*: D.W. Funk, D.S. Ireland, R. Rodrigues, and W.R. Koski (eds.), 2009. Joint monitoring program in the Chukchi and Beaufort seas, open water seasons, 2006–2008. LGL Alaska Report P1050-2. Rep. from LGL Alaska Research Associates, Inc., LGL Ltd., Greeneridge Sciences, Inc., and JASCO Research, Ltd., for Shell Offshore, Inc. and other Industry contributors, National Marine Fisheries Service, and U.S. Fish and Wildlife Service. 506 p. + app.

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.

Sease, J.L. and D.G. Chapman. 1988. Pacific walrus (*Odobenus rosmarus divergens*). p. 17-38 *In* J.W. Lentfer (eds) Selected marine mammals of Alaska: species accounts with research and management recommendations. Mar. Mamm. Comm., Washington, D.C. NTIS PB88-178462.

Sekiguchi, K., T. Uyama, and K. Yamshiro. 2008. Cetacean sighting survey during T/S *Oshoro Maru* Bering and Chukchi Sea cruise, 1 July–28 August 2007.

Shaughnessy, P.D. and F.H. Fay. 1977. A review of the taxonomy and nomenclature of North Pacific harbor seals. **J. Zool. (Lond.)** 182:385-419.

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

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

Smith, T.G. and I. Stirling. 1975. The breeding habitat of the ringed seal (*Phoca hispida*): the birth lair and associated structures. **Can. J. Zool.** 53(9):1297-1305.

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

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

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.

Stirling, I. and E.H. McEwan. 1975. The caloric value of whole ringed seals (*Phoca hispida*) in relation to polar bear (*Ursus maritimus*) ecology and hunting behavior. **Can. J. Zool.** 53(8):1021-1027.

Stirling, I., M. Kingsley, and W. Calvert. 1982. The distribution and abundance of seals in the eastern Beaufort Sea, 1974–79. **Can. Wildl. Serv. Occas. Pap.** 47. 25 p.

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

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

Suydam, R.S. and J.C. George. 1992. Recent sightings of harbor porpoises, *Phocoena phocoena*, near Point Barrow, Alaska. **Can. Field-Nat**. 106(4):489-492.

Suydam, R.S., L.F. Lowry, K.J. Frost, G.M. O'Corry-Crowe, and D. Pikok Jr. 2001. Satellite tracking of eastern Chukchi Sea beluga whales into the Arctic Ocean. **Arctic** 54(3):237-243.

Suydam, R.S., L.F. Lowry, and K.T. Frost. 2005. Distribution and movements of beluga whales from the eastern Chukchi Sea Stock during summer and early autumn. Rep. for the North Slope Borough Dep. Wildl. Manage., Barrow, Alaska.

Swartz, S.L. and M.L. Jones. 1981. Demographic studies and habitat assessment of gray whales, *Eschrichtius robustus,* in Laguna San Ignacio, Baja California, Mexico. U.S. Mar. Mamm. Comm. Rep. MMC-78/03. 34 p. NTIS PB-289737.

Thomas, T.A., W.R. Koski, and W.J. Richardson. 2002. Correction factors to calculate bowhead whale numbers from aerial surveys of the Beaufort Sea. p. 15-1 to 15-28 (Chap. 15) *In:* W.J. Richardson and D.H. Thomson (eds.), Bowhead whale feeding in the eastern Alaskan Beaufort Sea: update of scientific and traditional information, Vol. 1. OCS Study MMS 2002-012; LGL Rep. TA2196-7. Rep. from LGL Ltd., King City, Ont., for U.S. Minerals Manage. Serv., Anchorage, AK, and Herndon, VA. 420 p.

Thomas, T., W.R. Koski, and D.S. Ireland. 2010. Chukchi Sea nearshore aerial surveys. Chapter 4 *In*: D.W. Funk, D.S. Ireland, R. Rodrigues, and W.R. Koski (eds.), Joint monitoring program in the Chukchi and Beaufort seas, open water seasons, 2006–2008. LGL Alaska Rep. P1050-2. Rep. from LGL Alaska Research Associates, Inc., LGL Ltd., Greeneridge Sciences, Inc., and JASCO Research, Ltd., for Shell Offshore, Inc. and other Industry contributors, National Marine Fisheries Service, and U.S. Fish and Wildlife Service. 506 p. + app.

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 Mar. Mamm. Sci. Conf. Abstr. Vol., Monaco. 160 p.

Tomilin, A.G. 1957. Mammals of the U.S.S.R. and adjacent countries. Vol, 9: Cetaceans. Israel Progr. Sci. Transl. (1967), Jerusalem. 717 p. NTIS TT 65-50086.

Treacy, S.D. 1993. Aerial surveys of endangered whales in the Beaufort Sea, fall 1992. OCS Study MMS 93-0023. U.S. Minerals Manage. Serv., Anchorage, AK. 136 p.

Treacy, S.D. 1997. Aerial surveys of endangered whales in the Beaufort Sea, fall 1996. OCS Study MMS 97-0016. U.S. Minerals Manage. Serv., Anchorage, AK. 115 p. NTIS PB97-194690

Treacy, S.D. 2002a. Aerial surveys of endangered whales in the Beaufort Sea, fall 2000. OCS Study MMS 2002-014. U.S. Minerals Manage. Serv., Anchorage, AK. 111 p.

Treacy, S.D. 2002b. Aerial surveys of endangered whales in the Beaufort Sea, fall 2001. OCS Study MMS 2002-061. U.S. Minerals Manage. Serv., Anchorage, AK. 117 p.

Treacy, S.D., J.S. Gleason, and C.J. Cowles. 2006. Offshore distances of bowhead whales (*Balaena mysticetus*) observed during fall in the Beaufort Sea, 1982–2000: an alternative interpretation. **Arctic** 59(1):83-90.

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

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

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

UNEP-WCMC. 2011. UNEP-WCMC Species Database: CITES-Listed Species. Appendices I, II and III. Accessed on 16 February 2011 at http://www.cites.org/eng/app/appendices.shtml.

USDI/BLM (U.S. Department of the Interior/Bureau of Land Management). 2005. Northwest National Petroleum Reserve, Alaska; Final Amended Integrated Activity Plan/Environmental Impact Statement.

USFWS (U.S. Fish and Wildlife Service). 2008. Endangered and threatened wildlife and plants; designation of threatened status for the polar bear (*Ursus maritimus*) throughout its range; Final Rule. **Fed. Regist.** 73(95, 15 May):28212-28303.

USFWS (U.S. Fish and Wildlife Service). 2009a. Pacific walrus *Odobenus rosmarus divergens*. August 2009. U.S. Fish and Wildlife Service, Alaska. Accessed in February 2010 at http://alaska.fws.gov/fisheries/mmm/walrus/pdf/Walrus_FS.pdf.

USFWS (U.S. Fish and Wildlife Service). 2010. Endangered and threatened wildlife and plants; designation of critical habitat for the polar bear (*Ursus maritimus*) in the United States; Final Rule. **Fed. Regist**. 75(234, 7 Dec.):76086-76137.

van Meurs, R. and J.F. Splettstoesser. 2003. Letter to the editor–farthest north polar bear. **Arctic** 56(3):309.

Vibe, C. 1950. The marine mammals and the marine fauna in the Thule District (northwest Greenland) with observations on ice conditions in 1939–41. **Medd. Grønl.** 150:1-115.

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

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

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

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

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

Wieting, D. 2004. Background on development and intended use of criteria. p. 20 *In:* S. Orenstein, L. Langstaff, L. Manning, and R. Maund (eds.), Advisory Committee on Acoustic Impacts on Marine Mammals, Final Meet. Summary. Second Meet., April 28-30, 2004, Arlington, VA. Sponsored by the Mar. Mamm. Comm., 10 Aug.

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

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

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

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

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

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

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

Zeh, J.E. and A.E. Punt. 2005. Updated 1978–2001 abundance estimates and their correlations for the Bering-Chukchi-Beaufort Seas stock of bowhead whales. **J. Cetac. Res. Manage.** 7(2):169-175.

Zingarelli, R. and D. King. 2005. Software design document for the Split-Step Fourier/RAM Parabolic Equation Model Version 5.4. Naval Oceanographic Office.

Fish, Invertebrates, and Other

ADF&G (Alaska Department of Fish and Game). 2005. Alaska Subsistence Fisheries 2003 Annual Report. Division of Subsistence, Juneau. 234 p.

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

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

Boeger, W.A., M.R. Pie, A. Ostrensky, and M.F. Cardoso. 2006. The effect of exposure to seismic prospecting on coral reef fishes. **Braz. J. Oceanog.** 54(4):235-239.

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

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

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

Christian, J.R., A. Mathieu, D.H. Thomson, D. White, and R.A. Buchanan. 2003. Effect of seismic energy on snow crab (*Chionoecetes opilio*). Environ. Stud. Res. Funds Rep. 144. Calgary, Alberta.

Christian, J.R., A. Mathieu, and R.A. Buchanan. 2004. Chronic effects of seismic energy on snow crab (*Chionoecetes opilio*). Environ. Stud. Res. Funds Rep. 158, Calgary, Alberta.

Dalen, J. and G.M. Knutsen. 1986. Scaring effects in fish and harmful effects on eggs, larvae and fry by offshore seismic explorations. Symposium on Underwater Acoustics, Halifax.

Dalen, J. and A. Raknes. 1985. Scaring effects on fish from three dimensional seismic surveys. Inst. Mar. Res. Rep. FO 8504/8505, Bergen, Norway. (In Norwegian, with an English summary).

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

DFO (Fisheries and Oceans Canada). 2004. Potential impacts of seismic energy on snow crab. Canadian Science Advisory Secretariat Habitat Status Report 2004/003.

Engås, A, S. Løkkeborg, E. Ona, and A.V. Soldal. 1996. Effects of seismic shooting on local abundance and catch rates of cod (*G. morhua*) and haddock (*M. aeglefinus*). **Can. J. Fish. Aquat. Sci.** 53(10):2238-2249.

Falk, M.R. and M.J. Lawrence. 1973. Seismic exploration: its nature and effects on fish. Tech. Rep. Ser. CEN/T-73-9. Can. Dep. Environ., Fisheries & Marine Serv., Resource Manage. Br., Fisheries Operations Directorate, Central Region (Environment), Winnipeg, Man.

Guerra, A., A.F. González, and F. Rocha. 2004. A review of the records of giant squid in the north-eastern Atlantic and severe injuries in *Architeuthis dux* stranded after acoustic explorations. Paper presented at the International Council for the Exploration of the Sea (ICES) Annual Science Conference, 22–25 Sept. 2004, Vigo, Spain. ICES CM 2004/CC:29.

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

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

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

Jakobsson, M., A. Grantz, Y. Kristoffersen, and R. Macnab. 2003. Physiographic provinces of the Arctic Ocean seafloor. **Geol. Soc. Amer. Bull.** 115(12)**:**1443-1455.

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

La Bella, G., S. Cannata, C. Froglia, A. Modica, S. Ratti, and G. Rivas. 1996. First assessment of effects of air-gun seismic shooting on marine resources in the Central Adriatic Sea. p. 227-238 *In*: Society of Petroleum Engineers, Intern. Conf. on Health, Safety and Environ., New Orleans, LA, 9-12 June.

Løkkeborg, S. 1991. Effects of geophysical survey on catching success in longline fishing. Paper presented at Intern. Council for the Exploration of the Sea (ICES) Annual Science Conf. **ICES CM B** 40:1-9.

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 University, Perth, WA, for Australian Petroleum Production Association, Sydney, NSW.

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. 2000b. Marine seismic surveys – a study of environmental implications. **APPEA J.** 40:692-706.

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.

MMS (Minerals Management Service). 1996. Beaufort Sea Planning Area oil and gas lease sale 144/Final Environmental Impact Statement. OCS EIS/EA MMS 96-0012. U.S. Minerals Manage. Serv., Alaska OCS Reg., Anchorage, AK. Two Vol. Var. pag.

Moriyasu, M., R. Allain, K. Benhalima, and R. Claytor. 2004. Effects of seismic and marine noise on invertebrates: A literature review. Fisheries and Oceans Canada, Science. Canadian Science Advisory Secretariat Research Document 2004/126.

Parry, G.D. and A. Gason. 2006. The effect of seismic surveys on catch rates of rock lobsters in western Victoria, Australia. **Fish. Res.** 79:272-284.

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

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

Payne, J.F., J. Coady, and D. White. 2009. Potential effects of seismic airgun discharges on monkfish eggs (*Lophius americanus*) and larvae. Environ. Stud. Res. Funds Rep. 170. St. John's, NL. 35 p.

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

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

Pickett, G.D., D.R. Eaton, R.M.H. Seaby, and G.P. Arnold. 1994. Results of bass tagging in Poole Bay during 1992. Laboratory Leaflet Number 74. Ministry of Agriculture, Fisheries and Food, Directorate of Fisheries Research, Lowestoft, UK.

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

Popper, A.N. 2009. Are we drowning out fish in a sea of noise? **Marine Scientist** 27:18-20.

Popper, A.N. and M.C. Hastings. 2009a. The effects of human-generated sound on fish. **Integr. Zool.** 4(1):43-52.

Popper, A.N. and M.C. Hastings. 2009b. The effects of anthropogenic sources of sound on fishes. **J. Fish Biol.** 75(3):455-489.

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

Popper, A.N., M.E. Smith, P.A. Cott, B.W. Hanna, A.O. MacGillivray, M.E. Austin, and D.A. Mann. 2005. Effects of exposure to seismic airgun use on hearing of three fish species. **J. Acoust. Soc. Am.** 117(6):3958-3971.

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

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

Santulli, A., C. Messina, L. Ceffa, A. Curatolo, G. Rivas, G. Fabi, and V. Damelio. 1999. Biochemical responses of European sea bass (*Dicentrachus labrax*) to the stress induced by offshore experimental seismic prospecting. **Mar. Poll. Bull.** 38(12):1105-1114.

Skalski, J.R., W.H. Pearson, and C.I. Malme. 1992. Effects of sounds from a geophysical survey device on catch-per-unit-effort in a hook-and-line fishery for rockfish (*Sebastes* spp.). **Can. J. Fish. Aquat. Sci.** 49(7):1357-1365.

Slotte, A., K. Hansen, J. Dalen, and E. Ona. 2004. Acoustic mapping of pelagic fish distribution and abundance in relation to a seismic shooting area off the Norwegian west coast. **Fish. Res.** 67(2):143-150.

Thomsen, B. 2002. An experiment on how seismic shooting affects caged fish. Thesis, Faroese Fisheries Laboratory, University of Aberdeen, Aberdeen, Scotland. 16 August.

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

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

Wolfe, R. 2000. Subsistence in Alaska: a year 2000 update. Alaska Department of Fish and Game, Division of Subsistence, Juneau, AK.