Request by U.S. Geological Survey 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 Central Gulf of Alaska, June 2011

submitted by

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to

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SUMMARY

The U.S. Geological Survey (USGS) plans to conduct a marine seismic survey in the central Gulf of Alaska (GOA) during June 2011. The survey will take place in the U.S. Exclusive Economic Zone (EEZ) and adjacent International Waters in water depths from ~2000 m to >4500 m. The airgun array will consist of a towed array of 36 airguns with a total volume of ~6600 in^3. USGS requests that it be issued an Incidental Harassment Authorization (IHA) allowing non-lethal takes of marine mammals incidental to the planned seismic survey. This request is submitted pursuant to Section 101 (a) (5) (D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371 (a) (5).

Numerous species of cetaceans and pinnipeds inhabit the GOA. Several of these species are listed as ***endangered*** under the ESA, including the North Pacific right, humpback, sei, fin, blue, and sperm whales. Other ESA-listed species that could occur in the study area include the ***endangered*** leatherback turtle, the ***threatened*** green turtle, the ***endangered*** short-tailed albatross, the ***threatened*** Steller's eider.

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

USGS plans to conduct a seismic survey in the central GOA between ~200 and 650 km offshore, in the area 53–57°N, 135–148°W (Fig. 1). Water depths in the survey area range from ~2000 to >6000 m. The project is scheduled to occur ~5–25 June 2011. Some minor deviation from these dates is possible, depending on logistics and weather.

The proposed seismic survey will collect seismic reflection and refraction profiles to be used to delineate the U.S. extended continental shelf (ECS) in the Gulf of Alaska. The ECS is that region beyond 200 nautical miles (n.mi.) where a nation can show that it satisfies the conditions of Article 76 of the United Nations Convention on the Law of the Sea. One of the conditions in Article 76 is a function of sediment thickness. The seismic profiles are designed to identify the stratigraphic "basement" and to map the thickness of the overlying sediments. Acoustic velocities (required to convert measured travel times to true depth) will be measured directly using sonobuoys and ocean-bottom seismometers (OBSs), as well as by analysis of hydrophone streamer data.

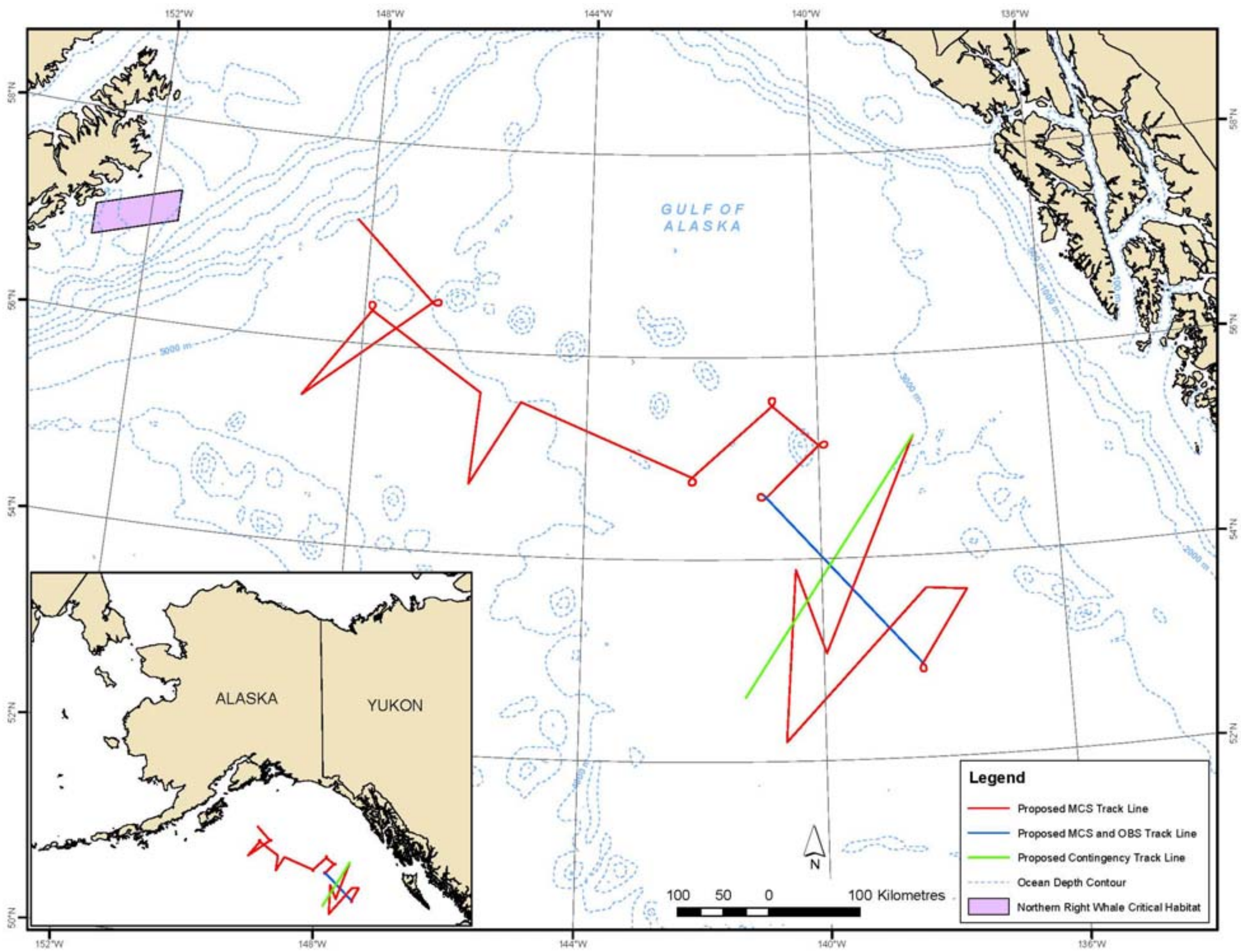

FIGURE 1. Proposed seismic transect lines for the central GOA survey planned by USGS for 5–25 June 2011. Also shown on the map is critical habitat for North Pacific right whales.

The survey will involve one source vessel, the R/V *Marcus G. Langseth*. The *Langseth* will deploy an array of 36 airguns as an energy source. The receiving system will consist of one 8-km long hydrophone streamer and/or five OBSs. As the airgun array is towed along the survey lines, the hydrophone streamer will receive the returning acoustic signals and transfer the data to the on-board processing system. The OBSs record the returning acoustic signals internally for later analysis.

The planned seismic survey will consist of ~2840 km of transect lines in the central GOA survey area (Fig. 1), with an additional 140 km of turns. The array will be powered down to one 40-in^3 airgun during turns. All of the survey will take place in water deeper than 1000 m. A multichannel seismic (MCS) survey using the hydrophone streamer will take place along 11 lines. Following the MCS survey, five OBSs will be deployed and a refraction survey will take place along of 1 of the 11 lines. If time permits, an additional 340-km contingency line will added to the MCS survey (Fig. 1). There will be additional seismic operations associated with equipment testing, startup, and possible line changes or repeat coverage of any areas where initial data quality is sub-standard. In our calculations (see § IV(3)), 25% has been added for those additional operations.

All planned geophysical data acquisition activities will be conducted by Lamont-Doherty Earth Observatory (L-DEO), the *Langseth*'s operator, with on-board assistance by the scientists who have proposed the study. The Principal Investigators are Drs. Jonathan R. Childs and Ginger Barth of the USGS. The vessel will be self-contained, and the crew will live aboard the vessel for the entire cruise.

Vessel Specifications

The R/V *Marcus G. Langseth* will be used as the source vessel. The *Langseth* will tow the 36-airgun array, as well as the hydrophone streamer, along predetermined lines (Fig. 1). The *Langseth* will also deploy and retrieve the OBSs. When the *Langseth* is towing the airgun array and the hydrophone streamer, the turning rate of the vessel is limited to five degrees per minute. Thus, the maneuverability of the vessel is limited during operations with the streamer.

The *Langseth* has a length of 71.5 m, a beam of 17.0 m, and a maximum draft of 5.9 m. The *Langseth* was designed as a seismic research vessel, with a propulsion system designed to be as quiet as possible to avoid interference with the seismic signals. The ship is powered by two Bergen BRG-6 diesel engines, each producing 3550 horsepower (hp), which drive the two propellers directly. Each propeller has four blades, and the shaft typically rotates at 750 revolutions per minute (rpm). The vessel also has an 800 hp 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 vessel-based protected species observers (PSOs) will watch for marine mammals and sea turtles before and during airgun operations, as described in § XIII, below.

Other details of the *Langseth* include the following:

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

Airgun Description

During the survey, the airgun array to be used will consist of 36 airguns[1], with a total volume of ~6600 in^3. The airgun array will consist of a mixture of Bolt 1500LL and Bolt 1900LLX airguns. The airguns will be configured as four identical linear arrays or "strings" (Fig. 2). Each string will have ten airguns; the first and last airguns in the strings are spaced 16 m apart. Nine airguns in each string will be fired simultaneously, whereas the tenth is kept in reserve as a spare, to be turned on in case of failure of another airgun. The four airgun strings will be distributed across an area of ~24×16 m behind the *Langseth* and will be towed ~100 m behind the vessel. The shot interval will be 50 m or ~22 s for the MCS survey and 150 m or ~66 s for the OBS refraction survey. The firing pressure of the array is 1900 psi. During firing, a brief (~0.1 s) pulse of sound is emitted. The airguns will be silent during the intervening periods.

The tow depth of the array will be 9 m during OBS refraction and MCS surveys. Because the actual source is a distributed sound source (36 airguns) rather than a single point source, the highest sound

[1] A two-string, 3300-in^3 array will be used if field trials show that it will accomplish the geophysical objectives, but calculations are based on the eventuality that the full array is required; see further in § II(3).

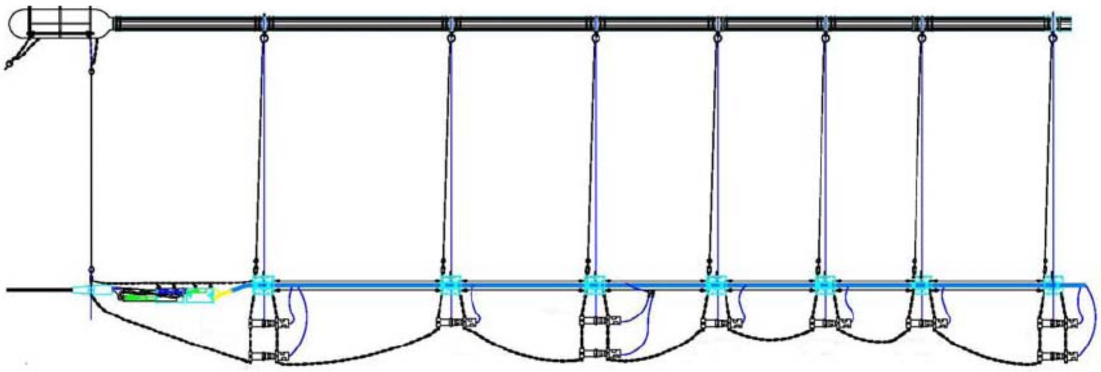

FIGURE 2. One linear airgun array or string with ten airguns, nine of which would be operating.

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.

36-Airgun Array Specifications

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

Acoustic Measurement Units

Received sound levels have been predicted by L-DEO, in relation to distance and direction from the airguns, for the 36-airgun array and for a single 1900LL 40-in^3 airgun, which will be used during power downs. Results were recently reported for propagation measurements of pulses from the 36-airgun array in two water depths (~1600 m and 50 m) in the Gulf of Mexico in 2007–2008 (Tolstoy et al. 2009). It would be prudent to use the empirical values that resulted to determine exclusion zones for the airgun array. Results of the propagation measurements (Tolstoy et al. 2009) showed that radii around the airguns for various received levels varied with water depth. During the proposed study, all survey effort will take place in deep (>1000 m) water, so propagation in shallow water is not relevant here. The depth of the array was different in the Gulf of Mexico calibration study (6 m) than in the proposed survey (9 m); thus, correction factors have been applied to the distances reported by Tolstoy et al. (2009). The correction factors used were the ratios of the 160-, 170-, 180-, and 190-dB distances from the modeled results for the 6600-in^3 airgun array towed at 6 m vs. 9 m.

Measurements were not reported for a single airgun, so model results will be used. 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. A detailed description of the modeling effort is provided in Appendix A 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 μPa^2·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

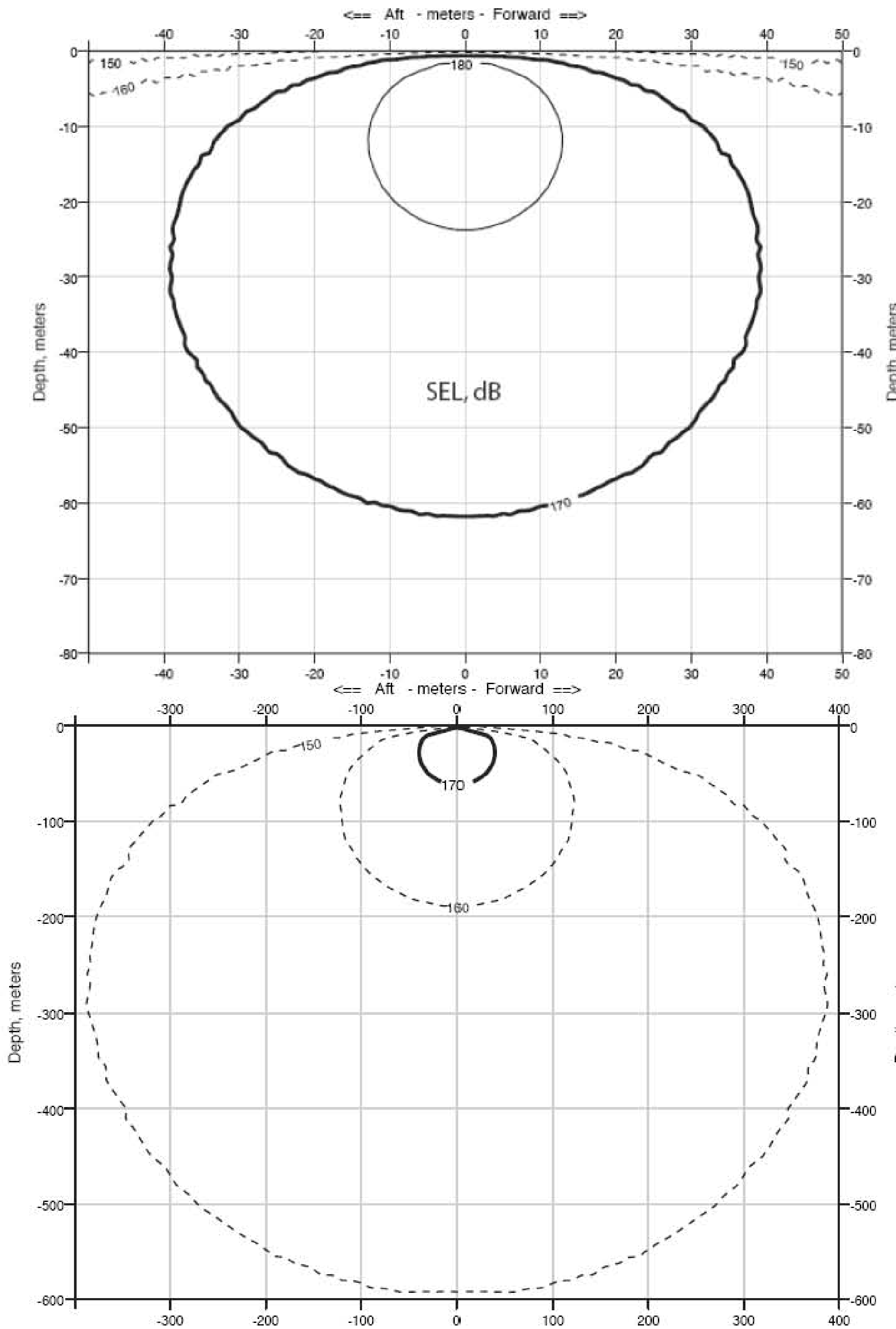

FIGURE 3. Modeled received sound levels (SELs) from a single 40-in^3 airgun operating in deep water, which is planned for use as a mitigation airgun during the central GOA survey. Received rms levels (SPLs) are expected to be ~10 dB higher.

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) is the same.

Although SEL is now believed to be a better measure than SPL when dealing with biological effects of pulsed sound, SPL is the measure that has been most commonly used in studies of marine mammal reactions to airgun sounds and in NMFS guidelines concerning levels above which "taking" might occur. SPL is often referred to as rms or "root mean square" pressure, averaged over the pulse duration. As noted above, the rms received levels that are used as impact criteria for marine mammals are not directly comparable to pulse energy (SEL). At the distances where rms levels are 160–190 dB re 1 μPa, the difference between the SEL and SPL values for the same pulse measured at the same location usually average ~10–15 dB, depending on the propagation characteristics of the location (Greene 1997; McCauley et al. 1998, 2000a; Appendix B of the EA). In this EA, 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

Using the corrected measurements (array) or model (single airgun), Table 1 shows the distances at which four rms sound levels are expected to be received from the 36-airgun array and a single airgun. The 180- and 190-dB re 1 μPa_{rms} distances are the safety criteria as specified by NMFS (2000) and are applicable to cetaceans and pinnipeds, respectively. The 180-dB distance will also be used as the exclusion zone for sea turtles, as required by NMFS in most other recent seismic projects (e.g., Smultea et al. 2004; Holst et al. 2005b; Holst and Beland 2008; Holst and Smultea 2008; Hauser et al. 2008). If marine mammals or turtles are detected within or about to enter the appropriate exclusion zone, the airguns will be powered down (or shut down if necessary) immediately.

Southall et al. (2007) made detailed recommendations for new science-based noise exposure criteria. USGS will be prepared to revise its 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.

TABLE 1. Measured (array) or predicted (single airgun) distances to which sound levels ≥190, 180, 170, and 160 dB re 1 μPa$_{rms}$ could be received in water depths >1000 m during the proposed central GOA survey, 5–25 June 2011. Measured radii for the array are based on Tolstoy at al. (2009), corrected for deployment depth, and predicted radii for a single airgun are based on Figure 3, assuming that received levels on an RMS basis are, numerically, 10 dB higher than the SEL values shown in Figure 3.

	Predicted RMS Distances (m) in deep (>1000 m) water			
Source and Volume	**190 dB**	**180 dB**	**170 dB**	**160 dB**
Single Bolt airgun, 40 in^3	12	40	120	385
4 strings, 36 airguns, 6600 in^3, 9 m depth	400	940	2200	3850

Description of Operations

The source vessel, the R/V *Marcus G. Langseth*, will deploy an array of 36 airguns with a discharge volume of 6600 in^3 as an energy source at a tow depth of ~9 m. The receiving system will consist of one 8-km long hydrophone streamer and/or five OBSs. As the airgun array is towed along the survey lines, the hydrophone streamer will receive the returning acoustic signals and transfer the data to the on-board processing system. The OBSs record the returning acoustic signals internally for later analysis.

The planned seismic survey will consist of ~2840 km of transect lines in the central GOA survey area (Fig. 1), with an additional 140 km of turns. The array will be powered down to one 40-in^3 airgun during turns. All of the survey will take place in water deeper than 1000 m. A multichannel seismic (MCS) survey using the hydrophone streamer will take place along 11 lines. Following the MCS survey, five OBSs will be deployed and a refraction survey will take place along of 1 of the 11 lines. If time permits, an additional 340-km contingency line will added to the MCS survey. In addition to the operations of the airgun array, a Kongsberg EM 122 multibeam echosounder (MBES) and a Knudsen 320B sub-bottom profiler (SBP) will also be operated from the *Langseth* continuously throughout the cruise.

Multibeam Echosounder and Sub-bottom Profiler

Along with the airgun operations, two additional acoustical data acquisition systems will be operated during the survey. 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.

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 or 2° fore–aft and 150° athwartship. The maximum source level is 242 dB re 1 μPa · m$_{rms}$. Each "ping" consists of eight (in water >1000 m deep) or four (<1000 m) successive fan-shaped transmissions, each ensonifying a sector that extends 1° fore–aft. Continuous-wave (CW) pulses increase from 2 to 15 ms long in water depths up to 2600 m, and FM chirp pulses up to 100 ms long are used in water >2600 m. The successive transmissions span an overall cross-track angular extent of about 150°, with 2-ms gaps between the pulses for successive sectors.

The Knudsen 320B SBP is normally operated to provide information about the sedimentary features and the bottom topography that is being mapped simultaneously by the MBES. 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 maximum output is 1000 watts (204 dB), but in practice, the output varies with water depth. The pulse interval is 1 s, but a common mode of operation is to broadcast five pulses at 1-s intervals followed by a 5-s pause.

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

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

II. Dates, Duration, and Region of Activity

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

The survey will occur in the central GOA, between ~200 and 650 km offshore, in the area 53–57°N, 135–148°W (Fig. 1). The seismic survey will take place in water depths of ~2000 to >6000 m. The exact dates of the activities depend on logistics and weather conditions. The Langseth will depart from Dutch Harbor on 5 June and return there on 25 June 2011. Seismic operations will be carried out for an estimated 12–14 days.

III. Species and Numbers of Marine Mammals in Area

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

Eighteen cetacean species, six pinniped species, and the sea otter are known to or could occur in the GOA (Table 2). Information on the occurrence, population size, and conservation status for each of these 25 marine mammal species is presented in Table 2. The status of these species is based on the ESA, the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species, and the Convention on International Trade in Endangered Species (CITES). Several of these species are listed under the ESA as ***endangered***, including the North Pacific right, sperm, humpback, fin, sei, and blue whales, as well as the Cook Inlet distinct population segment (DPS) of beluga whales and the western stock of Steller sea lions. The eastern stock of Steller sea lions is listed as ***threatened***, as is the southwest Alaska DPS of the sea otter.

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.

TABLE 2. The habitat, abundance, and conservation status of marine mammals that could occur in or near the proposed seismic survey area in the Gulf of Alaska.

Species	Habitat	Occurrence in/near Study Area	Abundance (Alaska)	Regional Abundance	ESA[1]	IUCN[2]	CITES[3]
Mysticetes							
North Pacific right whale (*Eubalaena japonica)*	Coastal, shelf	Rare	28–31[4]	Low hundreds[5]	EN	EN	I
Gray whale (*Eschrichtius robustus*)	Coastal	Uncommon	N.A.	19,126[6]	DL	LC	I
Humpback whale (*Megaptera novaeangliae*)	Coastal, banks	Common	3000–5000[7]	20,800[8]	EN	LC	I
Minke whale (*Balaenoptera acutorostrata*)	Coastal, shelf	Uncommon	1233[9]	25,000[10]	NL	LC	I
Sei whale (*Balaenoptera borealis*)	Pelagic	Rare	N.A.	7260-12,620[11]	EN	EN	I
Fin whale (*Balaenoptera physalus*)	Pelagic	Common	1652 [9]	13,620-18,680[12]	EN	EN	I
Blue whale (*Balaenoptera musculus*)	Pelagic, shelf, coastal	Rare	N.A.	3500[13]	EN	EN	I
Odontocetes							
Sperm whale (*Physeter macrocephalus*)	Pelagic	Uncommon	159[14]	24,000[15]	EN	VU	I
Cuvier's beaked whale (*Ziphius cavirostris*)	Pelagic	Common	N.A.	20,000[16]	NL	LC	II
Baird's beaked whale (*Berardius bairdii*)	Pelagic	Rare	N.A.	6000[17]	NL	DD	I
Stejneger's beaked whale (*Mesoplodon stejnegeri*)	Likely pelagic	Common	N.A	N.A	NL	DD	II
Beluga whale (*Delphinapterus leucas*)	Coastal & ice edges	Extralimital	340[18]	N.A.	EN*	NT	II
Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)	Pelagic, shelf, coastal	Common	26,880[19]	988,000[20]	NL	LC	II
Risso's dolphin (*Grampus griseus*)	Pelagic, shelf, coastal	Extralimital	N.A.	838,000[21]	NL	LC	II
Killer whale (*Orcinus orca*)	Pelagic, shelf, coastal	Common	2636[22]	8500[23]	NL[†]	DD	II
Short-finned pilot whale (*Globicephala macrorhynchus*)	Pelagic, shelf, coastal	Extralimital	N.A.	53,000 [21]	NL	DD	II
Harbor porpoise (*Phocoena phocoena*)	Coastal	Uncommon	11,146[24] 31,046[25]	168,387[26]	NL	LC	II
Dall's porpoise (*Phocoenoides dalli*)	Pelagic, shelf	Common	83,400[19]	1,186,000[27]	NL	LC	II
Pinnipeds							
Northern fur seal (*Callorhinus ursinus*)	Pelagic, breeds coastally	Uncommon	653,171[6]	1.1 million[28]	NL	VU	NL
Steller sea lion (*Eumetopias jubatus*)	Coastal, offshore	Common	58,334–72,223[29] 42,366[30]	N.A.	T/EN[‡]	EN	NL
California sea lion (*Zalophus c. californianus*)	Coastal	Uncommon	N.A.	238,000[32]	NL	LC	NL
Harbor seal (*Phoca vitulina richardsi*)	Coastal	Uncommon	45,975[25]	180,017[31]	NL	LC	NL
Northern elephant seal (*Mirounga angustirostris*)	Coastal, offshore	Uncommon	N.A.	124,000[32]	NL	LC	NL

Species	Habitat	Occurrence in/near Study Area	Abundance (Alaska)	Regional Abundance	ESA[1]	IUCN[2]	CITES[3]
Pacific walrus (*Odobenus rosmarus divergens*)	Ice	Extralimital	201,039[33]	N.A.	NL	DD	III
Mustelids Northern sea otter (*Enhydra lutris*)	Coastal	Very rare	10,563[34] 15,090[35] 47,676[36]	N.A.	T	EN	II

N.A. means data not available.
[1] U.S. Endangered Species Act. EN = Endangered; T = Threatened; DL = Delisted; NL = Not listed.
[2] Codes for IUCN (2010) classifications: 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 (CITES-UNEP 2010): Appendix I = threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled; Appendix III = trade of species regulated but cooperation from other countries needed to prevent unsustainable or illegal exploitation.
[4] Bering Sea and Aleutian Islands (Wade et al. 2010).
[5] Western population (Brownell et al. 2001).
[6] Eastern North Pacific (Allen and Angliss 2010).
[7] GOA (Calambokidis et al. 2008).
[8] North Pacific Ocean (Barlow et al. 2009).
[9] Western GOA and eastern Aleutians (Zerbini et al. 2006).
[10] Northwest Pacific (Buckland et al. 1992; IWC 2009).
[11] North Pacific (Tillman 1977).
[12] North Pacific (Ohsumi and Wada 1974).
[13] Eastern North Pacific (NMFS 1998).
[14] Western GOA and eastern Aleutians (Zerbini et al. 2004).
[15] Eastern temperate North Pacific (Whitehead 2002b).
[16] Eastern Tropical Pacific (Wade and Gerrodette 1993).
[17] Western North Pacific (Reeves and Leatherwood 1994; Kasuya 2002).
[18] Cook Inlet stock (Shelden et al. 2010).
[19] Alaska stock (Allen and Angliss 2010).
[20] North Pacific Ocean (Miyashita 1993b).
[21] Western North Pacific Ocean (Miyashita 1993a).
[22] Minimum abundance in Alaska, includes 2,084 resident and 552 GOA, Bering Sea, Aleutian Islands transients (Allen and Angliss 2010).
[23] Eastern Tropical Pacific (Ford 2002).
[24] SE Alaska stock (Allen and Angliss 2010).
[25] GOA stock (Allen and Angliss 2010).
[26] Eastern North Pacific (totals from Carretta et al. 2009 and Allen and Angliss 2010).
[27] North Pacific Ocean and Bering Sea (Houck and Jefferson 1999).
[28] North Pacific (Gelatt and Lowry 2008).
[29] Eastern U.S. Stock (Allen and Angliss 2010).
[30] Western U.S. Stock (Allen and Angliss 2010).
[31] Alaska statewide (Allen and Angliss 2010).
[32] Carretta et al. 2009.
[33] Speckman 2010.
[34] SE Alaska stock (Allen and Angliss 2010).
[35] Southcentral Alaska stock (Allen and Angliss 2010).
[36] SW Alaska stock (Allen and Angliss 2010).
[*] The Cook Inlet DPS is listed as endangered; other stocks are not listed.
[†] Stocks in Alaska are not listed, but the southern resident DPS is listed as endangered. AT1 transient in Alaska is considered depleted and a strategic stock (NOAA 2004a).
[‡] The eastern stock is listed as threatened, and the western stock is listed as endangered.

The marine mammals that occur in the proposed survey area belong to four taxonomic groups: odontocetes (toothed cetaceans, such as dolphins), mysticetes (baleen whales), pinnipeds (seals, sea lions, and walrus), and fissipeds (sea otter). Cetaceans and pinnipeds are the subject of the IHA application to NMFS. The sea otter and Pacific walrus are two marine mammal species mentioned in this document that are managed by the U.S. Fish and Wildlife Service (USFWS); all others are managed by NMFS. Walrus sightings are rare in the GOA. Sea otters generally inhabit nearshore areas inside the 40-m depth contour (Riedman and Estes 1990) and likely would not be encountered in the deep, offshore waters of the study area. Coastal cetacean species (gray whale, beluga, and harbor porpoise) and pinniped species (California sea lion and harbor seal) likely would not be encountered in the deep, offhore waters of the survey area.

Mysticetes

North Pacific Right Whale

The North Pacific right whale is listed as ***Endangered*** under the ESA and on the 2010 IUCN Red List of Threatened Species (IUCN 2010), and it is listed in CITES Appendix I (CITES-UNEP 2010) (Table 2). It is considered by NMFS (1991) to be the most endangered baleen whale in the world. Although protected from commercial whaling since 1935, there has been little indication of recovery. The pre-exploitation stock may have exceeded 11,000 (NMFS 1991), but Jefferson et al. (2008) indicate that there are “no more than a few hundred right whales alive today”. Whaling records seem to indicate that right whales once ranged across the entire North Pacific Ocean north of 35ºN and occasionally occurred as far south as 20ºN (e.g., Scarff 1986, 1991). However, recent analysis showed a longitudinally bimodal distribution (Josephson et al. 2008). Right whales in the eastern and western North Pacific appear to be from discrete stocks (Brownell et al. 2001). The western North Pacific population “may number at least in the low hundreds” (Brownell et al. 2001), whereas the eastern population may number 28 animals based on genotyping or 31 animals based on photo-identification (Wade et al. 2010).

North Pacific right whales summer in the Sea of Okhotsk, the southeast Bering Sea, and the northern GOA. Wintering and breeding areas are unknown, but have been suggested to include the Hawaiian Islands, the Ryukyu Islands, and the Sea of Japan (Allen 1942; Banfield 1974; Gilmore 1978; Reeves et al. 1978; Herman et al. 1980; Omura 1986). In April 1996, a right whale was sighted off Maui, the first documented sighting of a right whale in Hawaiian waters since 1979 (Herman et al. 1980; Rowntree et al. 1980); this individual was also sighted in the Bering Sea in multiple years (Zerbini et al. 2009).

Since the 1960s, North Pacific right whale sightings have been relatively rare (e.g., Clapham et al. 2004; Shelden et al. 2005). In the eastern North Pacific, south of 50ºN, only 29 reliable sightings were recorded from 1900 to 1994 (Scarff 1986, 1991; Carretta et al. 1994). Starting in 1996, right whales have been sighted regularly in the southeast Bering Sea, including calves in some years (Goddard and Rugh 1998; LeDuc et al. 2001; Moore et al. 2000, 2002b; Wade et al. 2006; Zerbini et al. 2009); they have also been detected acoustically when sonobuoys were deployed (McDonald and Moore 2002; Munger et al. 2003; 2005, 2008; Berchok et al. 2009). Right whales are known to occur in the southeast Bering Sea from May to December (e.g., Tynan et al. 2001; Hildebrand and Munger 2005; Munger et al. 2005, 2008). Call frequencies tended to be higher in July–October than from May–June or November–December (Munger et al. 2008). Right whales seem to pass through the middle-shelf areas, without remaining there longer than a few days (Munger et al. 2008).

Shelden et al. (2005) reported that the slope and abyssal plain in the western GOA were important areas for right whales until the late 1960s. In March 1979, a group of four right whales was seen in Yakutat Bay (Waite et al. 2003). However, there were no further reports of right whale sightings in the GOA until July 1998, when a single whale was seen southeast of Kodiak Island (Waite et al. 2003) and additional solitary animals were observed in the Barnabas Canyon area from U.S. National Oceanic and Atmospheric Administration (NOAA) surveys in August 2004, 2005, and 2006 (NOAA unpublished data *in* Allen and Angliss 2010). Right whale acoustic detections were made south of the Alaska Peninsula and to the east of Kodiak Island in 2000 during August and September (see Waite et al. 2003; Mellinger et al. 2004b), but no acoustic detections were made from April to August 2003 (Munger et al. 2008) or in

April 2009 (Rone et al. 2010). One right whale was sighted in the Aleutian Islands south of Umiak Pass in September 2004 (Wade et al. 2010).

Critical feeding-season habitat was recently designated by NMFS for the North Pacific right whale: one area in the western GOA and one in the southeast Bering Sea (NMFS 2006). The critical habitat in the GOA is located south of Kodiak Island; none of the proposed transect lines enter the critical habitat. In addition, the survey will occur far enough away from the critical habitat area that received sound levels within the habitat will not exceed 160 dB re 1 μPa_{rms}. Considering the rarity of right whale sightings in the area, it is unlikely that any right whales will be seen during the proposed survey.

Gray Whale

Gray whales are found primarily in shallow water and usually remain closer to shore than any other large cetacean. Two stocks of gray whales are recognized in the Pacific: the Eastern North Pacific stock and the Western North Pacific or “Korean” stock (Rice et al. 1984; Swartz et al. 2006). The eastern gray whale population ranges from the Chukchi and Beaufort seas to the Gulf of California (Rice 1998). Most of the eastern Pacific population makes a round-trip annual migration of more than 18,000 km. From late May to early October, the majority of the population concentrates in the northern and western Bering Sea and in the Chukchi Sea. However, some individuals spend the summer months scattered along the coasts of southeast Alaska, B.C., Washington, Oregon, and northern California (Rice and Wolman 1971; Nerini 1984; Darling et al. 1998; Dunham and Duffus 2001, 2002; Calambokidis et al. 2002). The current best population estimate is 19,126 for 2006/2007 (Allen and Anglis 2010).

It is difficult to determine precisely when the southbound migration begins; whales near Barrow were moving predominantly south in August (Maher 1960; Braham 1984). Gray whales leave the Bering Sea through Unimak Pass from late October through January (Braham 1984). From October to January, the main part of the population moves down the west coast of North America. Rugh et al. (2001) analyzed data collected from two sites in California to estimate the timing of the gray whale southward migration. They estimated that the median date for the migration past various sites was 1 December in the central Bering Sea (a nominal starting point), 12 December at Unimak Pass, 18 December at Kodiak Island, and 5 January for Washington.

By January and February, most of the whales are concentrated in the lagoons along the Pacific coast of the Baja Peninsula, Mexico. From late-February to June, the population migrates northward to arctic and subarctic seas (Rice and Wolman 1971). The peak of northward migration in the GOA occurs in mid-April (Braham 1984). Most gray whales follow the coast during migration and stay within 2 km of the shoreline, except when crossing major bays, straits, and inlets from southeast Alaska to the eastern Bering Sea (Braham 1984). Gray whales use the nearshore areas of the Alaska Peninsula during the spring and fall migrations, and are often found within the bays and lagoons, primarily north of the peninsula, during the summer (Brueggeman et al. 1989 *in* Waite et al. 1999). However, gray whales are known to move further offshore between the entrance to Prince William Sound (PWS) and Kodiak Island and between Kodiak Island and the southern part of the Alaska Peninsula (Consiglieri et al. 1982). During May–October, primary occurrence extends seaward 28 km from the shoreline. This is the main migratory corridor for gray whales.

In the summer, gray whales are seen in the southeast Bering Sea (Moore et al. 2002b) and in the GOA, including around Kodiak Island (e.g., Wade et al. 2003; Calambokidis et al. 2004; Calambokidis 2007; Moore et al. 2007). In fact, gray whales have been seen feeding off southeast Kodiak Island, in particular near Ugak Bay, year-round (Moore et al. 2007). Moore et al. (2007) noted that sighting rates were highest from September to November (exceeding 100 sightings/h) and lowest from June to August. Whales were clustered in groups of 10–20 near Ugak Bay (Moore et al. 2007). Wade et al. (2003)

reported a group size of 5.6 in the western GOA. No gray whales were seen during surveys in the eastern GOA during August–September 2004 (MacLean and Koski 2005) or September–October 2008 (Hauser and Holst 2009). Gray whales likely would not be encountered during the proposed seismic survey in the offshore waters of the GOA.

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 and ***Least concern*** on the 2010 IUCN Red List of Threatened Species (IUCN 2010), and it is listed in CITES Appendix I (CITES-UNEP 2010) (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 (e.g., Baker et al. 1993; Caballero et al. 2001). Based on a collaborative study involving numerous jurisdictions, the entire 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.

Although considered to be mainly a coastal species, humpback whales often traverse deep pelagic areas while migrating (Clapham and Mattila 1990; Norris et al. 1999; Calambokidis et al. 2001). Humpback whales spend spring through fall on mid- or high-latitude feeding grounds, and winter on low-latitude breeding grounds, with limited interchange between regions (Baker et al. 1998; Clapham 2002; Garrigue et al. 2002). On winter breeding grounds, humpback dives have been recorded at depths >100 m (Baird et al. 2000). In summer feeding areas, humpbacks typically forage in the upper 120 m of the water column, with a maximum recorded dive depth of 500 m (Dolphin 1987; Dietz et al. 2002). Humpback whales are often sighted singly or in groups of 2–3; although while on their breeding and feeding ranges, groups can include up to 15 (Leatherwood and Reeves 1983; Donoghue 1996). Wade et al. (2003) and Waite (2003) reported average group sizes for Alaska of 1.9 and 2.7, respectively.

North Pacific humpback whales migrate between summer feeding grounds along the Pacific Rim and the Bering and Okhotsk seas and winter calving and breeding areas in subtropical and tropical waters (Pike and MacAskie 1969; Rice 1978; Winn and Reichley 1985; Calambokidis et al. 2000, 2001). North Pacific humpback whales are known to assemble in three different winter breeding areas: (1) the eastern North Pacific along the coast of Mexico and central America, and near the Revillagigedo Islands; (2) around the main Hawaiian Islands; and (3) in the west Pacific, particularly around the Ogasawara and Ryukyu islands in southern Japan and the northern Philippines (Perry et al. 1999a; Calambokidis et al. 2008). There is a low level of interchange of whales among the three main wintering areas (e.g., Darling and Cerchio 1993; Salden et al. 1999; Calambokidis et al. 2001, 2008).

Two stocks of humpback whales mainly occur in Alaska—the Central and Western North Pacific stocks—although individuals of the Eastern North Pacific or California/Oregon/Washington stocks can also be found there during summer. Whales of the Central North Pacific Stock generally winter in Hawaii and the Revillagigedos, and migrate to southeast Alaska, PWS, the GOA, and northern B.C. to feed (Fiscus et al. 1976; Brueggeman et al. 1988; Calambokidis et al. 1997, 2009; Waite et al. 1999). The Western North Pacific Stock winters in Asia and is thought to primarily feed in Russia (Calambokidis et al. 2008), although some feed in the Bering Sea and Aleutians (Darling et al. 1996; Calambokidis et al. 2009). Research indicates that the Central, Western, and Eastern North Pacific stocks mix on the summer feeding grounds at the Kodiak Archipelago and the Shumagin Islands (Urbán et al. 2000; Calambokidis et al. 2001, 2009; Witteveen et al. 2004). However, there appears to be a very low level of interchange between wintering and feeding areas in Asia and those in the eastern and central Pacific (Calambokidis et al. 2008). Peak abundance in southeast Alaska is late August–early September (Baker et al. 1985; Dahlheim et al. 2008a), but humpback whales occur in the GOA year-round (Straley 1990; Stafford et al. 2007). Whales present in fall, winter, and early spring apparently are irregular migrants (Straley 1990).

Waite (2003) reported that 117 humpbacks were seen in 41 groups during their surveys in the western GOA in 2003, and Rone et al. (2010) reported 11 humpback sightings totaling 20 individuals in the GOA during April 2009. During summer surveys from the Kenai Fjord to the central Aleutian Islands in 2001–2003, humpbacks were most abundant near Kodiak Island, the Shumagin Islands, and north of Unimak Pass (Zerbini et al. 2006). During surveys of the western GOA, aggregations of humpbacks were also seen off northeastern Kodiak Island (Waite 2003). Waite et al. (1999) noted another aggregation area north of Unalaska Island. Rone et al. (2010) estimated humpback whale densities of 4/1000 km^2 and 0.5/1000 km^2 for inshore and offshore waters of the U.S. Navy training area east of Kodiak Island during spring. The density for the central GOA was reported as 0.0019/km^2 (DoN 2009).

Waite et al. (1999) identified 127 individuals in the Kodiak area from 1991 to 1994, and calculated a total abundance estimate of 651 for the Kodiak and PWS area. Although some interchange occurs between individuals at Kodiak Island and PWS, these two areas are generally considered different feeding grounds (Waite et al. 1999). Witteveen et al. (2005) provided an abundance estimate of 157 humpbacks for eastern Kodiak Island. Witteveen et al. (2004) reported an estimate of 410 humpbacks in the Shumagin Islands, which may belong to the same feeding group as the whales near Kodiak Island. Sightings of humpbacks around Kodiak Islands were made most frequently in the fall, and aggregations were seen off Shuyak and Sitkalidak islands (Wynne and Witteveen 2005), as well as Marmot and Chiniak bays (Baraff et al. 2005). For the western GOA and eastern Aleutian Islands, Zerbini et al. (2006) estimated an abundance of 2644. Calambokidis et al. (2008) reported updated abundance estimates of 6000–14,000 for the Bering Sea and Aleutians, 3000–5000 for the GOA, and 3000–5000 for southeast Alaska and northern B.C. The annual rate of increase of this population is thought to be ~4.9% (Calambokidis et al. 2008). Offshore sightings of humpbacks have also been made south of the Alaska Peninsula, including ~280 km south of the Shumagin Islands (e.g., Forney and Brownell 1996; Waite et al. 1999).

Minke Whale

The minke whale has a cosmopolitan distribution that spans polar, temperate, and tropical regions (Jefferson et al. 2008). In the Northern Hemisphere, the minke whale is 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). In the North Pacific, the summer range of the minke whale extends to the Chukchi Sea; in the winter, the whales move farther south to within 2º of the equator (Perrin and Brownell 2002). The International Whaling Commission (IWC) recognizes three stocks of minke whales in the North Pacific: the Sea of Japan/East China Sea, the rest of the western Pacific west of 180ºN, and the remainder of the Pacific (Donovan 1991). For management purposes in Pacific U.S. waters, three stocks of minke whales are recognized: the Alaska, Hawaii, and California/Oregon/Washington stocks (Carretta et al. 2009).

The minke whale tends to be solitary or in groups of 2–3, but can occur in much larger aggregations around prey resources (Jefferson et al. 2008). Predominantly solitary animals were seen during surveys in Alaska (Wade et al. 2003; Waite 2003; Zerbini et al. 2006). The small size, inconspicuous blows, and brief surfacing times of minke whales mean that they are easily overlooked in heavy sea states, although they are known to approach vessels in some circumstances (Stewart and Leatherwood 1985). Little is known about the diving behavior of minke whales, but they are not known to make prolonged deep dives (Leatherwood and Reeves 1983).

Minke whales are relatively common in the Bering and Chukchi seas and in the inshore waters of the GOA (Mizroch 1992), but they are not considered abundant in any other part of the eastern Pacific

(Brueggeman et al. 1990). Minke whales are seen regularly around Glacier Bay in southeast Alaska and in central Icy Strait (Gabriele and Lewis 2000). None were seen during seismic surveys in the eastern GOA and southeast Alaska in 2004 or 2008 (MacLean and Koski 2005; Hauser and Holst 2009). Waite (2003) sighted four minke whales in three groups during surveys in the western GOA in 2003, south of the Kenai Peninsula and south of PWS. Moore et al. (2002b) reported a minke whale sighting south of the Sanak Islands. Rone et al. (2010) reported two sightings of three minke whales in slope waters of the GOA in April 2009, and Baraff et al. (2005) reported a single sighting near Kodiak Island in July 2002. During surveys in the western GOA and eastern Aleutians, minke whales occurred primarily in the Aleutians; a few were seen south of the Alaska Peninsula and near Kodiak Island (Zerbini et al. 2006).

Sei Whale

The sei whale is listed as ***Endangered*** under the U.S. ESA and on the 2010 IUCN Red List of Threatened Species (IUCN 2010); it is listed in CITES Appendix I (CITES-UNEP 2010) (Table 2). Sei whale populations were depleted by whaling, and the current status of this species is generally uncertain (Horwood 1987). The global population is thought to be ~80,000 (Horwood 2002), with up to ~12,620 in the North Pacific (Tillman 1977). The sei whale is poorly known because of confusion with Bryde's whale and unpredictable distribution patterns, such that it can be common in an area for several years and then seemingly disappears (Schilling et al. 1992; Jefferson et al. 2008).

The sei whale is generally not found in coastal waters (Harwood and Wilson 2001). It is found in deeper waters characteristic of the continental shelf edge region (Hain et al. 1985) and in other areas of steep bathymetric relief such as seamounts and canyons (Kenney and Winn 1987; Gregr and Trites 2001). On feeding grounds, sei whales associate with oceanic frontal systems (Horwood 1987) such as the cold eastern currents in the North Pacific (Perry et al. 1999a). Sei whales are frequently seen in groups of 2–5 (Jefferson et al. 2008), although larger groups sometimes form on feeding grounds (Gambell 1985a). Sei whales generally do not dive deeply, with dive durations >15 min (Gambell 1985a).

The distribution of the sei whale is not well known, but this whale is found in all oceans and appears to prefer mid-latitude temperate waters (Jefferson et al. 2008). Sei whales migrate from temperate zones occupied in winter to higher latitudes in the summer, where most feeding takes place (Gambell 1985a). During summer in the North Pacific, the sei whale can be found from the Bering Sea to the northern GOA and south to southern California, and in the western Pacific from Japan to Korea. Its winter distribution is concentrated at about 20°N, and sightings have been made between southern Baja California and the Islas Revilla Gigedo (Rice 1998). No breeding grounds have been identified for sei whales; however, calving is thought to occur from September to March. Moore et al. (2002b) made four sightings of six sei whales during summer surveys in the eastern Bering Sea, and one sighting south of the Alaska Peninsula between Kodiak and the Shumagin islands. No sei whales were seen during surveys of the GOA by Wade et al. (2003), Waite (2003), Zerbini et al. (2006), or Rone et al. (2010). It is unlikely that sei whales will be encountered during the proposed survey.

Fin Whale

The fin whale is widely distributed in all the world's oceans (Gambell 1985b), but typically occurs in temperate and polar regions from 20° to 70° north and south of the equator (Perry et al. 1999b). It is listed as ***Endangered*** under the U.S. ESA and on the 2010 IUCN Red List of Threatened Species (IUCN 2010), and is listed in CITES Appendix I (CITES-UNEP 2010) (Table 2). Probably at least in part because of its initially high abundance, wide distribution, and diverse feeding habits, the fin whale does not seem to have been as badly depleted as the other large whales in the North Pacific. Northern and southern fin whale populations are distinct and are sometimes recognized as different subspecies (Aguilar 2002). Abundance estimates for the North Pacific are 13,620–18,680 (Ohsumi and Wada 1974).

Fin whales occur in coastal, shelf, and oceanic waters. Moore et al. (2002b) reported that in the eastern Bering Sea, sighting rates were more than twice as high in water >100 m deep than in water 50–100 m deep; no sightings occurred in water <50 m deep. Sergeant (1977) suggested that fin whales tend to follow steep slope contours, either because they detect them readily or because biological productivity is high along steep contours because of tidal mixing and perhaps current mixing.

Fin whales can be found as individuals or groups of 2–7, but can form much larger feeding aggregations, sometimes with humpback and minke whales (e.g., Waite 2003; Jefferson et al. 2008). Average group sizes in Alaska have been reported as 2.1 for the western GOA and Aleutians (Wade et al. 2003), 2.9 for the western GOA (Waite 2003), and 1.8–3.2 for the Bering Sea (Moore et al. 2002b). Foraging fin whales reach mean dive depths and times of 98 m and 6.3 min, and non-foraging fin whales reach mean dive depths and times of 59 m and 4.2 min (Croll et al. 2001). Dive depths of >150 m coinciding with the diel migration of krill were reported by Panigada et al. (1999).

Fin whales appear to have complex seasonal movements and are likely seasonal migrants (Gambell 1985b). They mate and calve in temperate waters during winter and migrate to northern latitudes during summer to feed (Mackintosh 1965 *in* Gambell 1985b). The North Pacific population summers from the Chukchi Sea to California and winters from California southwards (Gambell 1985b). Recent information about the seasonal distribution of fin whales in the North Pacific has been obtained from the reception of fin whale calls by bottom-mounted, offshore hydrophone arrays along the U.S. Pacific coast, in the central North Pacific, and in the western Aleutian Islands (Moore et al. 1998, 2006; Watkins et al. 2000a,b; Stafford et al. 2007, 2009). Fin whale calls are detected year-round in the Northern Pacific, including the GOA (Moore et al. 2006; Stafford et al. 2007, 2009). Near the Alaska Peninsula in the western GOA, the number of calls received peaked in May–August, with few calls during the rest of the year (Moore et al. 1998). In the central North Pacific, the GOA, and the Aleutian Islands, call rates peak during fall and winter (Moore et al. 1998, 2006; Watkins et al. 2000a,b; Stafford et al. 2009). A recent review of fin whale distribution in the North Pacific noted the lack of sightings across the pelagic waters between eastern and western winter areas (Mizroch et al. 2009).

Rice and Wolman (1982) encountered 19 fin whales during surveys in the GOA. Rone et al. (2010) reported 24 sightings of 64 whales in offshore and inshore waters during surveys in the GOA in April 2009. During surveys from the Kenai Peninsula to the central Aleutian Islands, fin whales were most abundant near the Semidi Islands and Kodiak Island (Zerbini et al. 2006). Numerous fin whales were also seen between the Semidi Islands and Kodiak Island during surveys by Waite (2003). Fin whale sightings around Kodiak Island were most numerous along the western part of the island in Uyak Bay and Kupreanof Straits, and in Marmot Bay (Wynne and Witteveen 2005; Baraff et al. 2005). Fin whales were sighted around Kodiak Island year-round, but most sightings were made in the spring and summer (Wynne and Witteveeen 2005). The density for fin whales has been reported as 0.01 km^2 for the central GOA (DoN 2009). Rone et al. (2010) estimated fin whale densities of 11/1000 km^2 and 9/1000 km^2 for inshore and offshore waters, respectively, of the U.S. Navy training area south of PWS and east of Kodiak Island.

Blue Whale

The blue whale has a cosmopolitan distribution and tends to be pelagic, only coming nearshore to feed and possibly to breed (Jefferson et al. 2008). It is listed as ***Endangered*** under the U.S. ESA and on the 2010 IUCN Red List of Threatened Species (IUCN 2010), and is listed in CITES Appendix I (CITES-UNEP 2010) (Table 2). All blue whale populations have been exploited commercially, and many have been severely depleted as a result. Blue whale abundance has been estimated at 2300 for the Southern

Hemisphere (IWC 2009), up to 1000 in the central and northeast Atlantic (Pike et al. 2009), and ~3500 in the eastern North Pacific (NMFS 1998).

Blue whales are typically found singly or in groups of 2–3 (Yochem and Leatherwood 1985; Jefferson et al. 2008). Matsuoka et al. (2009) reported a mean group size of 1.4 for the western North Pacific, and Wade and Gerrodette (1993) reported a mean group size of 1.5 for the Eastern Tropical Pacific (ETP). Croll et al. (2001) reported mean dive depths and times of 140 m and 7.8 min for foraging blue whales, and 68 m and 4.9 min for non-foraging whales. Dives of up to 300 m were recorded for tagged blue whales (Calambokidis et al. 2003).

Generally, blue whales are seasonal migrants between high latitudes in summer, where they feed, and low latitudes in winter, where they mate and give birth (Lockyer and Brown 1981). Little information is available on wintering areas (Perry et al. 1999a). Some individuals may stay in low or high latitudes throughout the year (Reilly and Thayer 1990; Watkins et al. 2000b). In the North Pacific, blue whale calls are received year-round (Moore et al. 2002a, 2006).

Although it has been suggested that there are at least five subpopulations of blue whales in the North Pacific (NMFS 1998), analysis of blue whale calls monitored from the U.S. Navy Sound Surveillance System (SOSUS) and other offshore hydrophones (see Stafford et al. 1999, 2001, 2007; Watkins et al. 2000a; Stafford 2003) suggest that there are two separate populations—one in the eastern and one in the western North Pacific (Sears 2002). Broad-scale acoustic monitoring indicates that blue whales of the Northeast Pacific stock may range from the ETP along the coast of North America to Canada, and offshore at least 500 km (Stafford et al. 1999, 2001).

One population of blue whales feeds in the eastern North Pacific from June to November and migrates south in winter/spring (Calambokidis et al. 1990; Mate et al. 1999). In the GOA, no detections of blue whales had been made since the late 1960s (NOAA 2004b; Calambokidis et al. 2009), until blue whale calls were recorded in the area during 1999–2002 (Stafford 2003; Stafford and Moore 2005; Moore et al. 2006; Stafford et al. 2007). Call types from both northeastern and northwestern Pacific blue whales were recorded from July through December in the GOA, suggesting that two stocks use the area at that time (Stafford 2003; Stafford et al. 2007). Call rates peaked during August–November (Moore et al. 2006). In July 2004, three blue whales were sighted in the GOA, one on 14 July ~185 km southeast of PWS and two ~275 km southeast of PWS (NOAA 2004b; Calambokidis et al. 2009). These whales were thought to be part of the California feeding population (Calambokidis et al. 2009). Western blue whales are more likely to occur in the western portion of the GOA, southwest of Kodiak, where their calls have been detected (see Stafford 2003). Two blue whale sightings were also made in the Aleutians in August 2004 (Calambokidis et al. 2009). No blue whales were seen during surveys of the western GOA by Zerbini et al. (2006), or during surveys in the U.S. Navy training area east of Kodiak Island in April 2009 (Rone et al. 2010). It is unlikely that blue whales will be encountered during the proposed survey.

Odontocetes

Sperm Whale

The sperm whale is the largest of the toothed whales, with an extensive worldwide distribution (Rice 1989). The species is listed as ***Endangered*** under the U.S. ESA, but on a worldwide basis it is abundant and not biologically endangered. It is listed as ***Vulnerable*** on the 2010 IUCN Red List of Threatened Species (IUCN 2010), and is listed in CITES Appendix I (CITES-UNEP 2010) (Table 2). There currently is no accurate estimate for the size of any sperm whale population (Whitehead 2002a). The best estimate probably is that of Whitehead (2002b), 24,000 for the eastern temperate North Pacific.

Sperm whale distribution is linked to social structure—mixed groups of adult females and juvenile animals of both sexes generally occur in tropical and subtropical waters, whereas adult males are commonly found alone or in same-sex aggregations, often occurring in higher latitudes outside the breeding season (Best 1979; Watkins and Moore 1982; Arnbom and Whitehead 1989; Whitehead and Waters 1990). Males may migrate north in the summer to feed in the GOA, Bering Sea, and waters around the Aleutian Islands (Kasuya and Miyashita 1988 *in* Allen and Angliss 2010). Mature male sperm whales migrate to warmer waters to breed when they are in their late twenties (Best 1979). They spend periods of at least months on the breeding grounds, moving between mixed groups of ~20–30 animals (Whitehead 1993, 2003). Mean group sizes were reported as 3.5 for the western North Pacific (Kato and Miyashita 1998), 1.2 for the GOA (Wade et al. 2003; Waite 2003), and 7.9 for the ETP (Wade and Gerrodette 1993). An acoustic survey of sperm whales in the GOA showed that they occur there year-round, although more common in the summer than winter (Mellinger et al. 2004a; Moore et al. 2006).

Sperm whales generally are distributed over large areas that have high secondary productivity and steep underwater topography, in waters at least 1000 m deep (Jaquet and Whitehead 1996; Whitehead 2002a). They are often found far from shore, but can be found closer to oceanic islands that rise steeply from deep ocean waters (Whitehead 2002a). They can dive as deep as ~2 km and possibly deeper on rare occasions for >1 h, although most of their foraging occurs at depths of ~300–800 m for 30–45 min (Whitehead 2003). During a foraging dive, sperm whales typically travel ~3 km horizontally and 0.5 km vertically (Whitehead 2003). Whales in the Galápagos Islands typically dove for ~40 min and then spent 10 min at the surface (Papastavrou et al. 1989).

In the North Pacific, sperm whales are distributed widely, with the northernmost occurrences at Cape Navarin (62ºN) and the Pribilof Islands (Omura 1955 *in* Allen and Angliss 2010). Sperm whales are commonly sighted during surveys in the Aleutians and the central and western GOA (e.g., Forney and Brownell 1996; Moore 2001; Waite 2003; Wade et al. 2003; Zerbini et al. 2004; Barlow and Henry 2005; Ireland et al. 2005; Staley et al. 2005; Allen and Angliss 2010). Waite (2003) and Wade et al. (2003) noted an average group size of 1.2 in the western GOA. In contrast, there are fewer reports on the occurrence of sperm whales in the eastern GOA (e.g., Rice and Wolman 1982; Mellinger et al. 2004a; MacLean and Koski 2005; Rone et al. 2009).

Most of the information regarding sperm whale distribution in the GOA (especially the eastern GOA) and southeast Alaska has come from anecdotal observations from fishermen and reports from fisheries observers aboard commercial fishing vessels (e.g., Dahlheim 1988). Fishery observers have identified interactions between longline vessels and sperm whales in the GOA and southeast Alaska since at least the mid 1970s (e.g., Hill et al. 1999; Straley et al. 2005; Sigler et al. 2008), with most interactions occurring in the West Yakutat and East Yakutat/Southeast regions (Perez 2006; Hanselman et al. 2008). Sigler et al. (2008) noted high depredation rates in West Yakutat, East Yakutat/Southeast region, as well as the central GOA. Hill et al. (1999) found that most interactions in the GOA occurred to the east of Kodiak Island, even though there was substantial longline effort in waters to the west of Kodiak. Mellinger et al. (2004a) also noted that sperm whales occurred less often west of Kodiak Island.

Cuvier's Beaked Whale

Cuvier's beaked whale is probably the most widespread of the beaked whales, although it is not found in polar waters (Heyning 1989). It is rarely observed at sea and is mostly known from strandings. It strands more commonly than any other beaked whale (Heyning 1989). Its inconspicuous blows, deep-diving behavior, and tendency to avoid vessels all help to explain the infrequent sightings (Barlow and Gisner 2006). Adult males of this species usually travel alone, but these whales can be seen in groups of up to 15 (Heyning 2002), with a mean group size of 2.3 (MacLeod and D'Amico 2006). Cuvier's beaked whale is an offshore species (Heyning 2002). Its dives generally last 30–60 min, but dives of 85 min have been recorded (Tyack et al. 2006).

Cuvier's beaked whale ranges north to the GOA, including southeast Alaska, the Aleutian Islands, and the Commander Islands (Rice 1986, 1998). Most reported sightings have been in the Aleutian Islands (e.g., Leatherwood et al. 1983; Forney and Brownell 1996; Brueggeman et al. 1987). Waite (2003) reported a single sighting of four Cuvier's beaked whales at the shelf break east of Kodiak Island during summer 2003, and one individual stranded on Kodiak Island in January 1987 (Foster and Hare 1990).

Baird's Beaked Whale

Baird's beaked whale has a fairly extensive range across the North Pacific north of 30˚N, and strandings have occurred as far north as the Pribilof Islands (Rice 1986). This species is divided into three distinct stocks: Sea of Japan, Okhotsk Sea, and Bering Sea/Eastern North Pacific (Balcomb 1989; Reyes 1991). Concentrations are thought to occur in the Sea of Okhotsk and Bering Sea (Rice 1998; Kasuya 2002).

Baird's beaked whales sometimes are seen close to shore, but their primary habitat is over or near the continental slope and oceanic seamounts in waters 1000–3000 m deep (Jefferson et al. 1993; Kasuya and Ohsumi 1984; Kasuya 2002). Baird's beaked whales can stay submerged for up to 67 min, although most (66%) dives are <20 min long, and time at the surface is 1–14 min (Kasuya 2002). They travel in groups of a few to several dozen (Balcomb 1989). Off Japan, they form groups of up to 30, although groups of 2–9 are seen most often (Kasuya 2002). Wade et al. (2003) reported a mean group size of 10.8 for the ETP.

Baird's beaked whale is migratory, arriving in the Bering Sea in the spring, and remaining there throughout the summer; the winter distribution is unknown (Kasuya 2002). There are numerous sighting records from the central GOA to the Aleutian Islands and the southern Bering Sea (Leatherwood et al. 1983; Kasuya and Ohsumi 1984; Forney and Brownell 1996; Brueggeman et al. 1987; Moore et al. 2002b; Waite 2003; Wade et al. 2003).

Stejneger's Beaked Whale

Stejneger's beaked whale is endemic to the cold waters of the North Pacific, Sea of Japan, and Bering Sea (Allen and Angliss 2010). It is the only mesoplodont species known to occur in Alaskan waters, ranging from southeast Alaska through the Aleutians and the central Bering Sea. Most sightings have been reported in the Aleutian Islands (Leatherwood et al. 1983; Rice 1986; Wade et al. 2003). There have been no confirmed sightings of Stejneger's beaked whale in the GOA since 1986 (Wade et al. 2003). Small groups have been known to strand at the Aleutian Islands (Mead 1989) and in B.C. (Willis and Baird 1998). This species occurs in groups of 3–4, ranging up to ~15 (Reeves et al. 2002).

Beluga Whale

The beluga whale is distributed in seasonally ice-covered seas throughout the Northern Hemisphere (Gurevich 1980). In Alaska, beluga whales comprise five distinct stocks: Beaufort Sea, Eastern Chukchi Sea, Eastern Bering Sea, Bristol Bay, and Cook Inlet (O'Corry-Crowe et al. 1997). The Cook Inlet DPS of belugas is listed as ***endangered*** under the ESA, and critical habitat has been proposed (NMFS 2009). The species is listed as ***vulnerable*** on the 2010 IUCN Red List of Threatened Species (IUCN 2010), and it is listed in CITES Appendix I (CITES-UNEP 2010) (Table 2).

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

It has been suggested that all of the beluga whale populations in Alaska, other than the Cook Inlet DPS, overwinter in the Bering Sea and are segregated only during the summer (Shelden 1994). The Cook Inlet stock is isolated from other stocks throughout the year and is considered to be the most genetically isolated of the five Alaskan sub-populations (O'Corry-Crowe et al. 1997). Estimates of the size of the Cook Inlet beluga population over the last several decades have ranged from 300 to 1300. The most recent abundance estimate from aerial surveys in 2010 of beluga whales in Cook Inlet is 340 (Shelden et al. 2010). It is likely that an uncontrolled and excessive Native hunt to supply the Anchorage market for traditional foods caused the most recent decline (Hobbs and Shelden 2008; NOAA 2008). Recent studies indicate that the population may still be declining (Hobbs and Shelden 2008; Allen and Angliss 2010). Thus, the allowable harvest for 2008–2012 is zero (NMFS 2008); belugas were last harvested in 2005 (Allen and Angliss 2010). In addition, mass strandings, some involving mortalities, occur in Cook Inlet nearly annually (Vos and Shelden 2005; Hobbs and Shelden 2008; Allen and Angliss 2010).

Outside of Cook Inlet, beluga sightings in the GOA are rare (Laidre et al. 2000). From 1936 through 2000, only 28 sightings of belugas had been reported for the GOA: 9 near Kodiak Island, 10 in or near PWS, 8 in Yakutat Bay, and 1 anomalous sighting south of the GOA.

Pacific White-sided Dolphin

The Pacific white-sided dolphin is found throughout the temperate North Pacific, in a relatively narrow distribution between 38°N and 47°N (Brownell et al. 1999). Recently it has been suggested that the species could be experiencing a poleward shift in occurrence at both the northern and southern limits of its range associated with increases in water temperature (Salvadeo et al. 2010). From surveys conducted in the North Pacific, Buckland et al. (1993a) estimated that there were a total of 931,000 Pacific white-sided dolphins, and Miyashita (1993b) estimated an abundance of 988,000. Two stocks are identified in the U.S: the North Pacific and the California/Oregon/Washington stocks (Allen and Angliss 2010). As there have been no comprehensive surveys for Pacific white-sided dolphins in Alaska, the portion of the Buckland et al. (1993a) estimate derived from sightings north of 45ºN in GOA waters (26,880) is used as the minimum population estimate of the North Pacific stock (Allen and Angliss 2010).

The species is common both on the high seas and along the continental margins, and animals are known to enter the inshore passes of southeast Alaska, B.C., and Washington (Leatherwood et al. 1984; Dahlheim and Towell 1994; Ferrero and Walker 1996). Pacific white-sided dolphins form large groups, averaging 90, with groups of more than 3000 known (Van Waerebeek and Würsig 2002). Pacific white-sided dolphins often associate with other species, including cetaceans, pinnipeds, and seabirds. In particular, they are frequently seen in mixed-species schools with Risso's and northern right whale dolphins (Green et al. 1993). Pacific white-sided dolphins are very inquisitive and are known to approach stationary boats (Carwardine 1995). They are highly acrobatic, commonly bowriding, and often leaping, flipping, or somersaulting (Jefferson et al. 1993).

During winter, this species is most abundant in California slope and offshore areas; as northern marine waters begin to warm in the spring, it appears to move north to slope and offshore waters off Oregon/Washington (Green et al. 1992, 1993; Forney 1994; Forney et al. 1995; Buchanan et al. 2001; Barlow 2003). During summer, Pacific white-sided dolphins occur north into the GOA and west to Amchitka in the Aleutian Islands, but rarely in the southern Bering Sea (Allen and Angliss 2010). Sightings in the GOA and Aleutian Islands have been documented in the summer by Waite (2003) and Wade et al. (2003), and in the spring in shelf waters southeast of Kodiak Island by Rone et al. (2010). Dahlheim and Towell (1994) reported sightings for southeast Alaska.

Risso's Dolphin

Risso's dolphin is primarily a tropical and mid-temperate species distributed worldwide. It occurs between 60ºN and 60ºS, where surface water temperatures are at least 10ºC (Kruse et al. 1999). Risso's dolphin is pelagic, mostly occurring on the upper continental slope shelf edge in waters 350–1000 m deep (Baumgartner 1997; Davis et al. 1998). Risso's dolphin occurs individually or in small to moderate-sized groups, normally 2–250, although groups as large as 4000 have been sighted (Baird 2002). The majority of groups consist of <50 (Kruse et al. 1999; Miyashita 1993a). In the western North Pacific, Miyashita (1993a) reported a mean group size of 32.6, and in the ETP, Wade and Gerrodette (1993) reported a mean group size of 12.

Like the Pacific white-sided dolphin, Risso's dolphin is believed to make seasonal north-south movements related to water temperature, spending colder winter months off California and moving north to waters off Oregon/Washington during the spring and summer as northern waters begin to warm (Green et al. 1992, 1993; Buchanan et al. 2001; Barlow 2003; Becker 2007). Risso's dolphins are uncommon to rare in the GOA. Risso's dolphins have been sighted near Chirikof Island (southwest of Kodiak Island) and offshore in the GOA (Consiglieri et al. 1980; Braham 1983).

Killer Whale

The killer whale is cosmopolitan and globally fairly abundant; it has been observed in all oceans of the world (Ford 2002). It is very common in temperate waters and also frequents tropical waters, at least seasonally (Heyning and Dahlheim 1988). High densities of the species occur in high latitudes, especially in areas where prey is abundant. Although resident in some parts of its range, the killer whale can also be transient. Killer whales are segregated socially, genetically, and ecologically into three distinct groups: residents, transients, and offshore animals. Resident groups feed exclusively on fish (e.g., mainly coho salmon in PWS; Saulitis et al. 2000). Transients feed almost exclusively on marine mammals. Offshore killer whales are less known, and their feeding habits are uncertain, but it has been suggested that they are fish-eaters (Ford et al. 2000; Jones 2006; Dahlheim et al. 2008b).

Killer whale movements generally appear to follow the distribution of their prey. Killer whales are large and conspicuous, often traveling in close-knit matrilineal groups of a few to tens of individuals (Dahlheim and Heyning 1999). For Alaska, Waite (2003) and Wade et al. (2003) reported mean group sizes of 14.8 and 17.6, respectively. Zerbini et al. (2007) noted that average group size was greater for offshore and resident whales compared to transient killer whales; mean group sizes were 40–50 for offshore, 16–21.7 for resident, and 3.9–4.6 for transient killer whales.

Of eight killer whale stocks currently recognized in the Pacific U.S., six occur in Alaskan waters: (1) Alaska Residents, from southeast Alaska to the Aleutians and Bering Sea, (2) Northern Residents, from B.C. through parts of southeast Alaska, (3) GOA, Aleutians, and Bering Sea Transients, from PWS through to the Aleutians and Bering Sea, (4) AT1 Transients, from PWS through the Kenai Fjords, (5) West Coast Transients, from California through southeast Alaska, and (6) the Offshore Stock, from California through Alaska. Movements of resident groups between different geographic areas have also been documented (Leatherwood et al. 1990; Dahlheim et al. 1997). In the proposed study area, individuals from the Offshore Stock and the GOA, Aleutians, and Bering Sea Transient Stock could be encountered during the survey.

During surveys of the western GOA and Aleutian Islands, transient killer whale densities were higher south of the Alaska Peninsula between the Shumagin Islands and the eastern Aleutians than in other areas (Wade et al. 2003; Zerbini et al. 2007). They were not seen between the Shumagin Islands and the eastern side of Kodiak Island during surveys in 2001–2003, but they were sighted there during earlier surveys (e.g., Dahlheim 1997 *in* Zerbini et al. 2007). Resident killer whales were most abundant near Kodiak Island, around Umnak and Unalaska Islands in the eastern Aleutians, and in Seguam Pass in the central Aleutians (Wade et al. 2003; Zerbini et al. 2007). No residents were seen between 156ºW and 164ºW, south of the Alaska Peninsula (Zerbini et al. 2007).

Little is known about offshore killer whales in the GOA, but they could be encountered during the proposed survey. Rone et al. (2010) reported six sightings of 119 killer whales in offshore and inshore waters during spring surveys east of Kodiak Island in 2009. During summer surveys of the western GOA and Aleutian Islands in 2001–2003, two sightings of offshore killer whales were made, one northeast of Unalaska Island and another one south of Kodiak Island near the Trinity Islands (Wade et al. 2003; Zerbini et al. 2007). As the groups sighted were large, it suggests the number of offshore killer whales in the area is relatively high (Zerbini et al. 2007). Dahlheim et al. (2008b) encountered groups of 20–60 killer whales in western Alaska; offshore killer whales encountered near Kodiak Island and the eastern Aleutians were also sighted in southeast Alaska and California. A group of at least 54 offshore killer whales was sighted in July 2003 during a survey in the eastern Aleutian Islands (Matkin et al. 2007).

Short-finned Pilot Whale

The short-finned pilot whale is found in tropical and warm temperate waters (Olson and Reilly 2002); it is seen as far south as ~40ºS, but is more common north of ~35ºS (Olson and Reilly 2002). It is generally nomadic, but may be resident in certain locations, including California and Hawaii (Olson and Reilly 2002). It is an occasional visitor as far north as the Alaska Peninsula. Pilot whales occur on the shelf break, over the slope and in areas with prominent topographic features (Olson and Reilly 2002).

Pilot whales are very social and are usually seen in groups of 20–90 with matrilineal associations (Olson and Reilly 2002). In the western North Pacific, Miyashita (1993a) reported sightings of 10–300, although most sightings were of groups with <100. Mean group sizes have been reported as 49.8 for the western North Pacific (Miyashita 1993a) and 18.3 for the ETP (Wade and Gerrodette 1993). Both species (short-finned and long-finned) are known for single and mass strandings. Long-finned pilot whales outfitted with time-depth recorders dove to depths up to 828 m, although most of their time was spent above depths of 7 m (Heide-Jørgensen et al. 2002). The species' maximum recorded dive depth is 971 m (Baird pers. comm. *in* DoN 2005).

Harbor Porpoise

The harbor porpoise inhabits temporal, subarctic, and arctic waters. In the eastern North Pacific, harbor porpoises range from Point Barrow, Alaska, to Point Conception, California. The harbor porpoise primarily inhabits coastal waters, although sightings have been made over deeper waters between land masses (Bjørge and Tolley 2002). Harbor porpoises are normally found in small groups of up to 3 that often contain at least one mother-calf pair. Larger groups of 6–8 are not uncommon, and rarely much larger aggregations are seen. Mean group sizes of 1.0–2.0 have been reported for Alaska (Dahlheim et al. 2000; Moore et al. 2002b; Wade et al. 2003; Waite 2003).

In Alaska, there are three separate stocks of harbor porpoise: Southeast Alaska, GOA, and Bering Sea. The Southeast Alaska Stock occurs from northern B.C. to Cape Suckling, and the GOA Stock ranges from Cape Suckling to Unimak Pass. The population estimates for the Southeast Alaska, GOA, and Bering Sea stocks are 11,146, 31,046, and 48,215, respectively (Allen and Angliss 2010).

Harbor porpoises are seen regularly in the western GOA and Aleutian Islands (e.g., Wade et al. 2003; Waite 2003; Baraff et al. 2005; Ireland et al. 2005) and Bering Sea (Moore et al. 2002b). Harbor porpoises are also sighted in the eastern and central GOA and southeast Alaska (Dahlheim et al. 2000, 2008a; MacLean and Koski 2005; Rone et al. 2010).

Dall's Porpoise

Dall's porpoise is only found in the North Pacific and adjacent seas, and is widely distributed over the continental shelf and slope waters, and over deep (>2500 m) oceanic waters (Hall 1979), ranging from ~32ºN to 65ºN (Reeves et al. 2002). In general, this species is common throughout its range (Buckland et al. 1993a). Buckland et al. (1993a) provided an abundance estimate of 1.3 million Dall's porpoises for the North Pacific.

Dall's porpoises usually occur in small groups of 2–12, characterized by fluid associations (Reeves et al. 2002). In Alaska, average group size ranged from 2.7 to 3.7 (Wade et al. 2003; Waite 2003; Moore et al. 2002b). Dall's porpoises are fast-swimming and active porpoises, and readily approach vessels to ride the bow wave.

Dall's porpoise occurs throughout Alaska; the only apparent gaps in distribution in Alaskan waters south of the Bering Strait are for upper Cook Inlet and the Bering Sea shelf. Using a population estimate based on vessel surveys during 1987–1991, and correcting for the tendency of this species to approach vessels, which Turnock and Quinn (1991) suggested resulted in inflated abundance estimates perhaps by as much as five times, Allen and Angliss (2010) reported a minimum population estimate of 83,400 for the Alaska stock of Dall's porpoise.

Numerous studies have documented the occurrence of Dall's porpoise in the Aleutian Islands and western GOA (Forney and Brownell 1996; Moore 2001; Wade et al. 2003; Waite 2003; Baraff et al. 2005; Ireland et al. 2005) as well as in the Bering Sea (Moore et al. 2002b). Dall's porpoise was one of the most frequently sighted species during summer seismic surveys in the central and eastern GOA and southeast Alaska (MacLean and Koski 2005; Hauser and Holst 2009); it was also sighted during spring surveys of the central GOA in offshore and inshore waters (Rone et al. 2010).

Pinnipeds

Steller Sea Lion

The Steller sea lion is listed under the ESA as ***threatened*** in the eastern portion of its range and ***endangered*** in the western portion, west of Cape Suckling, Alaska, at 144ºW. The species is listed as ***endangered*** on the 2010 IUCN Red List of Threatened Species (IUCN 2010). The major anthropogenic factors that likely contributed to the decline of the western population are by-catch in fisheries, commercial hunting, and legal and illegal shooting (Atkinson et al. 2008). Minimum population sizes of the western stock and eastern stock, including animals in Alaska, B.C., Washington, Oregon, and California, are estimated at 42,366 and 58,334–72,223, respectively (Allen and Angliss 2010). Pitcher et al. (2007) estimated the eastern stock to number between 46,000 and 58,000. Data from aerial surveys showed that the non-pup counts of the western population of Steller sea lions was stable between 2004 and 2008 (Fritz et al. 2008a,b). The eastern stock is thought to be increasing at a rate of 3.1% annually (Pitcher et al. 2007).

Steller sea lions occur in the coastal and immediate offshore waters of the North Pacific. In the western Pacific, they are distributed from the Bering Strait along the Aleutian Islands, the Kuril Islands, and the Okhotsk Sea to Hokkaido, Japan. In the eastern Pacific, they occur along the coast of North America south to the Channel Islands off Southern California (Rice 1998). Steller sea lions are present in Alaska year-round, with centers of abundance in the GOA and Aleutian Islands.

Critical habitat for Steller sea lions is defined in detail in the Code of Federal Regulations (50 CFR 226.202). Designated critical habitat includes all rookeries and major haulouts, as well as the Shelikof Strait foraging area. Areas of critical habitat are more extensive for the endangered western stock of Steller sea lions than for the threatened eastern stock. In brief, critical habitat includes terrestrial, aquatic, and air zones that extend 3000 ft (0.9 km) landward, seaward, and above of each major rookery and major haulout in Alaska. The aquatic zone includes waters 3000 ft (0.9 km) seaward in state- and federally-managed waters east of 144ºW, and 20 n.mi. (37 km) seaward west of 144ºW (50 CFR 226.202). In addition, "no approach" buffer areas around rookery sites of the western stock of Steller sea lions are identified in the Code of Federal Regulations (50 CFR 223.202). "No approach" zones are restricted areas wherein no vessel may approach within 3 n.mi. (5.6 km) of listed rookeries. Neither critical habitat nor "no approach" zones are located within the proposed study area.

Breeding adults occupy rookeries from late May to early July (NMFS 1992). Females frequently return to the same pupping site within the rookery in successive years; females in the northern GOA showed 73% pupping site fidelity (Parker et al. 2005). Rookeries generally are found on gently sloping beaches that are protected from waves (NMFS 1992). Males arrive at rookeries in May to establish their territory and are soon followed by females, who pup within days of their arrival. Non-breeding males use haulouts or occupy sites at the periphery of rookeries during breeding season (NRC 2003). Pupping occurs from mid May to mid July (Pitcher and Calkins 1981) and peaks in June (Pitcher et al. 2002). Breeding typically occurs within 11–14 days postpartum (NMFS 1992).

Territorial males fast and remain on land during the breeding season (NMFS 1992). Andrews et al. (2001) estimated that females foraged for brief trips (7–26 h) around rookeries, spending 49–76% of their time at the rookeries. Females with pups feed principally at night during the breeding season, and generally stay within 30 km of the rookeries in shallow (30–120 m) water (NMFS 1992). Steller sea lion pups enter the water 2–4 weeks after birth (Sandegren 1970 *in* Raum-Suryan et al. 2002), but do not tend to move from their natal rookeries to haulouts with their mothers until they are 2–3 months old (Merrick et al. 1988 *in* Raum-Suryan et al. 2002). Tagged juvenile sea lions showed localized movements near shore (Briggs et al. 2005).

Steller sea lions haul out on beaches and rocky shorelines of remote islands, often in areas exposed to wind and waves (NMFS 1992). Haulouts are areas used at times other than the breeding season, although Coombs and Trites (2005) have reported breeding behavior at these sites. Steller sea lions spend more time at sea in the winter than during the breeding season (Sease and York 2003). During the non-breeding season, sea lions may disperse great distances from the rookeries (e.g., Mathews 1996; Raum-Suryan 2001).

Steller sea lion at-sea densities for the GOA have been calculated at ~4/1000 km^2 in August–September (MacLean and Koski 2005) and 9.8/1000 km^2 year-round (DoN 2009). However, the proposed survey is during the breeding season when males stay on land and females with pups generally stay close to the rookeries in shallow water.

Steller sea lions are an important subsistence resource for Alaska Natives from southeast Alaska to the Aleutian Islands. There are numerous communities along the shores of the GOA that participate in subsistence hunting. In 2008, 146 sea lions were harvested throughout Alaska (Wolfe et al. 2009).

California Sea Lion

The California sea lion is found from southern Mexico to Alaska. The breeding areas of the California sea lion are on islands located in southern California, western Baja California, and the Gulf of California. The present population is estimated at 238,000 (Carretta et al. 2009).

California sea lions are coastal animals that often haul out on shore throughout the year. King (1983) noted that sea lions are rarely found more than 16 km offshore. During fall and winter surveys off Oregon/Washington, mean distance from shore was ~13 km (Bonnell et al. 1992). During August and September, after the mating season, adult males migrate northward to feeding areas as far away as

Washington (Puget Sound) and B.C. (Lowry et al. 1992). They remain there until spring (March to May), when they migrate back to the breeding colonies. The distribution of immature California sea lions is less well known but some make northward migrations that are shorter in length than the migrations of adult males (Huber 1991). However, most immature sea lions are presumed to remain near the rookeries for most of the year (Lowry et al. 1992). Adult females remain near the rookeries throughout the year. The California sea lion appears to be extending its feeding range northward, with increasing sightings in Alaska waters (Maniscalco et al. 2004). California sea lions sighted in Alaska are typically seen at Steller sea lion rookeries or haulouts, with most sightings occurring between March and May, although they can be found in the GOA year-round (Maniscalco et al. 2004).

Northern Fur Seal

The northern fur seal is endemic to the North Pacific Ocean, and it occurs from southern California to the Bering Sea, the Okhotsk Sea, and Honshu Island, Japan (Allen and Angliss 2010). Two stocks are recognized in U.S. waters: the Eastern Pacific and the San Miguel Island stocks. The Eastern Pacific stock ranges from the Pribilof Islands and Bogoslof Island in the Bering Sea during summer to the Channel Islands in Southern California during winter. Despite differences in population dynamics and extensive separation of breeding islands, there is little evidence of population structure across the North Pacific range (Dickerson et al. 2010). The worldwide population of northern fur seals has declined from a peak of ~2.1 million in the 1950s to the present population estimate of ~653,171 (Allen and Angliss 2010). They were subjected to large-scale harvests on the Pribilof Islands to supply a lucrative fur trade, beginning with the discovery of the Pribilof Islands by Russian sealers in 1786.

During the breeding season (June–September), most of the world's population of northern fur seals occurs on the Pribilof and Bogoslof islands. In November, adult females and pups leave the Pribilof Islands and migrate into the North Pacific Ocean to areas including offshore Oregon and Washington (Ream et al. 2005). Males usually migrate only as far south as the GOA (Kajimura 1984). Some juveniles and non-pregnant females may remain in the GOA throughout the summer (Calkins 1986).

Lactating females from the same breeding site share a foraging area, whereas females from different sites tend to forage in different areas (Robson et al. 2004). Females from both islands traveled for similar durations and maximum distances; mean duration was 7.5–8.8 days and maximum distances were 226–263 km (Robson et al. 2004). In the Bering Sea, female northern fur seal dive patterns consisted of epipelagic and benthic dives that varied in depth and duration. Epipelagic dives were to average depths of 22 m and averaged 1.6 min in duration, and occurred equally during the day and night. Benthic dives were to average depths of 85 m and averaged 3.1 min in duration, and occurred mostly (79%) during daytime hours (Kuhn et al. 2010).

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

A total of 42 northern fur seals were seen during 3767 km of shipboard surveys in the northwestern GOA during June–July 1987 (Brueggeman et al. 1988). Leatherwood et al. (1983) reported 14 sightings of 34 northern fur seals away from the breeding islands in the southeast Bering Sea during aerial surveys in 1982, mostly during July and August. No fur seals were seen during summer surveys in the GOA in 2004 or 2008 (MacLean and Koski 2005; Hauser and Holst 2009) or during spring surveys in 2009 (Rone et al. 2010). None of the 42 female northern fur seals tagged on St Paul Island during August–October 2007 and 2008 traveled south of the Aleutian Islands (Kuhn et al. 2010).

Harbor Seal

The harbor seal ranges from Baja California, north along the western coasts of the U.S., B.C., and southeast Alaska, west through the GOA, PWS, and the Aleutian Islands, and north in the Bering Sea to Cape Newenham and the Pribilof Islands. There are currently three stocks in Alaska: the Southeast Alaska Stock, from the Alaska/B.C. border to Cape Suckling, at 144ºW; the GOA Stock, from Cape Suckling to Unimak Pass, including animals throughout the Aleutian Islands; and the Bering Sea Stock, including all waters north of Unimak Pass (Allen and Angliss 2010). However, recent genetic data indicates that the harbor seal stock division in Alaska needs to be reassessed (Allen and Angliss 2010). There are an estimated 112,391 individuals in the southeast Alaska stock and 45,975 in the GOA stock (Allen and Angliss 2010). Based on surveys off southeast Alaska from ~134ºW to ~148ºW in August-September 2004, MacLean and Koski (2005) calculated at-sea density estimates of 2/1000 km^2, 20/1000 km^2, and 0 for water depths <100 m, 100–1000 m, and >1000 m, respectively.

Harbor seals inhabit estuarine and coastal waters, hauling out on rocks, reefs, beaches, and glacial ice flows. They are generally non-migratory, but move locally with the tides, weather, season, food availability, and reproduction (Scheffer and Slipp 1944; Fisher 1952; Bigg 1969, 1981). Juvenile harbor seals can travel significant distances (525 km) to forage or disperse, whereas adults were generally found within 190 km of the tagging location in PWS (Lowry et al. 2001). The smaller home range used by adults is suggestive of strong site fidelity (Pitcher and Calkins 1979; Pitcher and McAllister 1981; Lowry et al. 2001). Most (40 to 80%) dives in the GOA were to depths <20 m and less than 4 min in duration. Dives of 50–150 m were also recorded, as well as dives as deep as ~500 m (Hastings et al. 2004). Most diving activity occurs at night (Hastings et al. 2004).

Female harbor seals give birth to a single pup while hauled out on shore or on glacial ice flows; pups are born from May to mid July. The mother and pup remain together until weaning occurs at 3–6 weeks (Bishop 1967; Bigg 1969). Little is known about breeding behavior in harbor seals. When molting, which occurs primarily in late August, seals spend the majority of the time hauled out on shore, glacial ice, or other substrates. Harbor seals are an important subsistence resource for Alaska Natives in the northern GOA. In 2008, 1462 harbor seals were taken by communities throughout Alaska (Wolfe et al. 2009).

Northern Elephant Seal

Northern elephant seals breed in California and Baja California, primarily on offshore islands (Stewart et al. 1994), from December to March (Stewart and Huber 1993). Juvenile elephant seals typically leave the rookeries in April or May and head north, traveling an average of 900–1000 km. Most elephant seals return to their natal rookeries when they start breeding (Huber et al. 1991). When not at their breeding rookeries, elephant seals feed at sea far from the rookeries. Males may feed as far north as the eastern Aleutian Islands and the GOA; females feed farther south, south of 45ºN (Le Boeuf et al. 1993; Stewart and Huber 1993). Male elephant seals can occur in the GOA throughout the year (Calkins 1986).

Pacific Walrus

The walrus occurs in moving pack ice over shallow waters of the circumpolar arctic coast (King 1983). There are two subspecies, the Atlantic walrus (*O. r. rosmarus*) and the Pacific walrus (*O. r. divergens*). The Pacific walrus ranges from the Bering Sea to the Chukchi Sea, occasionally moving to 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 summer, most of the population of the Pacific walrus moves to the Chukchi Sea, but several thousand aggregate in the Gulf of Anadyr and in Bristol Bay (Allen and Angliss 2010). During the late winter breeding season, walrus concentrations occur from the Gulf of

Anadyr to southwest of St. Lawrence Island, and in the southeast Bering Sea, from south of Nunivak Island to northwestern Bristol Bay.

The walrus is vagrant to the GOA (Fay 1982). Two walruses were seen during surveys of the southern Alaska Peninsula in July 1979 at Spitz and Mitrofania islands (Bailey and Faust 1981). Walruses had also been reported that summer in Chignik Bay (Bailey and Faust 1981).

Marine Fissiped

Northern Sea Otter

There are three stocks of sea otter in Alaska: the Southeast Alaska Stock occurs from Dixon Entrance to Cape Yakataga; the Southcentral Alaska Stock extends from Cape Yakataga to Cook Inlet, including PWS, the Kenai Peninsula, and Kachemak Bay; and the Southwest Alaska Stock includes the Alaska Peninsula and Bristol Bay coasts, and the Aleutian, Barren, Kodiak, and Pribilof Islands (Allen and Angliss 2010). The Southwest Alaska DPS of the sea otter is listed as ***threatened***. In 2002, USFWS estimated population sizes for the Southeast, Southcentral, and Southwest Alaska stocks were 10,563, 15,090, and 47,676, respectively (Allen and Angliss 2010).

Sea otters generally occur in shallow (<35 m), nearshore waters in areas with sandy or rocky bottoms, where they feed on a wide variety of sessile and slow moving benthic invertebrates (Rotterman and Simon-Jackson 1988). Sea otters in Alaska are generally not migratory and do not disperse over long distances. However, individual sea otters are capable of long-distance movements of >100 km (Garshelis and Garshelis 1984), although movements are likely limited by geographic barriers, high energy requirements, and social behavior. Critical habitat for the Southwest Alaska DPS of the northern sea otter was designated in October 2009 (USFWS 2009a). The critical habitat primarily consists of shallow-water areas <20 m deep and nearshore water within 100 m of the mean tide line.

Sea otters are harvested by Alaska Native hunters from southeast Alaska to the Aleutian Islands. Sea otters harvested by Alaska Natives must be tagged by the USFWS, and the USFWS keeps records of the number of tags issued, by each community. The mean annual subsistence takes from 2002 to 2006 were 91, 322, and 346 animals from the Southwest, Southeast Alaska, and Southcentral sea otter stocks, respectively (Allen and Angliss 2010).

Sea otters will almost certainly not be encountered in the deep, offshore waters of 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.

USGS 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 central GOA during June 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, by echosounders, and by general vessel operations. “Takes” by harassment will potentially result when marine mammals near the activities are exposed to the pulsed sounds generated by the airguns or echosounders. The effects will depend on the species of 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.
- Finally, we estimate the numbers of marine mammals that could be affected by the proposed survey in the GOA during June 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) in the EA. That is often true even in cases when the pulsed sounds must be readily audible to the animals based on measured received levels and the hearing sensitivity of that mammal group. Although various baleen whales, toothed whales, and (less frequently) pinnipeds have been shown to react behaviorally to airgun pulses under some conditions, at other times mammals of all three types have shown no overt reactions.

In general, pinnipeds usually seem to be more tolerant of exposure to airgun pulses than are cetaceans, with the relative responsiveness of baleen and toothed whales being variable.

Masking

Masking effects of pulsed sounds (even from large arrays of airguns) on marine mammal calls and other natural sounds are expected to be limited, although there are very few specific data on this. Because of the intermittent nature and low duty cycle of seismic pulses, animals can emit and receive sounds in the relatively quiet intervals between pulses. However, in exceptional situations, reverberation occurs for much or all of the interval between pulses (e.g., Simard et al. 2005; Clark and Gagnon 2006) which could mask calls. Some baleen and toothed whales are known to continue calling in the presence of seismic pulses, and their calls usually can be heard between the seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999a,b; Nieukirk et al. 2004; Smultea et al. 2004; Holst et al. 2005a,b, 2006; Dunn and Hernandez 2009). However, Clark and Gagnon (2006) reported that fin whales in the northeast Pacific Ocean went silent for an extended period starting soon after the onset of a seismic survey in the area. Similarly, there has been one report that sperm whales ceased calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994). However, more recent studies found that 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}.

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

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

There are no data on reactions of *right whales* to seismic surveys, but results from the closely-related *bowhead whale* show that their responsiveness can be quite variable depending on their activity (migrating vs. feeding). Bowhead whales migrating west across the Alaskan Beaufort Sea in autumn, in particular, are unusually responsive, with substantial avoidance occurring out to distances of 20–30 km from a medium-sized airgun source at received sound levels of around 120–130 dB re 1 μPa_{rms} [Miller et al. 1999; Richardson et al. 1999; see Appendix B (5) 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 analysis (Richardson et al. 1986). In summer, bowheads typically begin to show avoidance reactions at received levels of about 152–178 dB re 1 μPa_{rms} (Richardson et al. 1986, 1995; Ljungblad et al. 1988; Miller et al. 2005).

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

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

Data on short-term reactions by cetaceans to impulsive noises are not necessarily indicative of long-term or biologically significant effects. It is not known whether impulsive sounds affect reproductive rate or distribution and habitat use in subsequent days or years. However, gray whales have continued to migrate annually along the west coast of North America with substantial increases in the population over recent years, despite intermittent seismic exploration (and much ship traffic) in that area for decades (Appendix A *in* Malme et al. 1984; Richardson et al. 1995; 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).

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

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

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

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

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

Odontocete reactions to large arrays of airguns are variable and, at least for delphinids and Dall's porpoises, seem to be confined to a smaller radius than has been observed for the more responsive of the mysticetes, belugas, and harbor porpoises (Appendix 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).

Fissipeds.—Behavior of sea otters along the California coast was monitored by Riedman (1983, 1984) while they were exposed to a single 100-in^3 airgun and a 4089-in^3 airgun array. No disturbance reactions were evident when the airgun array was as close as 0.9 km. Otters also did not respond noticeably to the single airgun. The results suggest that sea otters are less responsive to marine seismic pulses than are baleen whales. Also, sea otters spend a great deal of time at the surface feeding and grooming. While at the surface, the potential noise exposure of sea otters would be much reduced by the pressure release effect at the surface.

Additional details on the behavioral reactions (or the lack thereof) by all types of marine mammals to seismic vessels can be found in Appendix B (5) of the EA.

Hearing Impairment and Other Physical Effects

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds. 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 by Southall et al. (2007). Those recommendations have not, 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, the deep water in the study area, and the planned monitoring and mitigation measures (see below). The following subsections discuss in somewhat more detail the possibilities of TTS, PTS, and non-auditory physical effects.

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

For toothed whales exposed to single short pulses, the TTS threshold appears to be, to a first approximation, a function of the energy content of the pulse (Finneran et al. 2002, 2005). Given the available data, the received energy level of a single seismic pulse (with no frequency weighting) might need to be ~186 dB re 1 $\mu Pa^2 \cdot s$ (i.e., 186 dB SEL or ~196–201 dB re 1 μPa_{rms}) in order to produce brief, mild TTS[2]. Exposure to several strong seismic pulses that each have received levels near 190 dB re 1 μPa_{rms} might result in cumulative exposure of ~186 dB SEL and thus slight TTS in a small odontocete assuming the TTS threshold is (to a first approximation) a function of the total received pulse energy; 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 400 m (Table 1). For an odontocete closer to the surface, the maximum radius with ≥190 dB re 1 μPa_{rms} would be smaller.

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

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

In pinnipeds, TTS thresholds associated with exposure to brief pulses (single or multiple) of underwater sound have not been measured. Initial evidence from more prolonged (non-pulse) exposures suggested that some pinnipeds (harbor seals in particular) incur TTS at somewhat lower received levels than do small odontocetes exposed for similar durations (Kastak et al. 1999, 2005; Ketten et al. 2001). The TTS threshold for pulsed sounds has been indirectly estimated as being an SEL of ~171 dB re 1

[2] 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).

$\mu Pa^2 \cdot s$ (Southall et al. 2007), which would be equivalent to a single pulse with received level ~181–186 dB re 1 $\mu Pa_{rms,}$ 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}. Those sound levels are ***not*** considered to be the levels above which TTS might occur. Rather, they were the received levels above which, in the view of a panel of bioacoustics specialists convened by NMFS before TTS measurements for marine mammals started to become available, one could not be certain that there would be no injurious effects, auditory or otherwise, to marine mammals. As summarized above and in Southall et al. (2007), data that are now available imply that TTS is unlikely to occur in most odontocetes (and probably mysticetes as well) unless they are exposed to a sequence of several airgun pulses stronger than 190 dB re 1 μPa_{rms}. 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 $\mu Pa^2 \cdot s$ (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 $\mu Pa^2 \cdot s$ in the harbor seal exposed to impulse sound. The PTS threshold for the California sea lion and northern elephant seal would probably be higher, given the higher TTS thresholds in those species.

Southall et al. (2007) also noted that, regardless of the SEL, there is concern about the possibility of PTS if a cetacean received one or more pulses with peak pressure exceeding 230 or 218 dB re 1 μPa (peak), respectively. Thus, PTS might be expected upon exposure of cetaceans to *either* SEL ≥198 dB re 1 $\mu Pa^2 \cdot s$ *or* peak pressure ≥ 230 dB re 1 μPa. Corresponding proposed dual criteria for pinnipeds (at least harbor seals) are ≥ 186 dB SEL and ≥ 218 dB peak pressure (Southall et al. 2007). These estimates are all first approximations, given the limited underlying data, assumptions, species differences, and evidence that the "equal energy" model 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. The planned monitoring and mitigation measures, including visual monitoring, PAM, 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. However, the evidence for this remains circumstantial and associated with exposure to naval mid-frequency sonar, not seismic surveys (Cox et al. 2006; Southall et al. 2007).

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

2001; Jepson et al. 2003; Fernández et al. 2004, 2005; Hildebrand 2005; Cox et al. 2006) suggests that caution is warranted when dealing with exposure of marine mammals to any high-intensity pulsed sound.

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

Non-auditory Physiological Effects.—Non-auditory physiological effects or injuries that theoretically might occur in marine mammals exposed to strong underwater sound include stress, neurological effects, bubble formation, resonance, and other types of organ or tissue damage (Cox et al. 2006; Southall et al. 2007). Studies examining such effects are limited. However, resonance 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 § II. 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 μPa · m_{rms}. The beam is narrow (1–2º) in the 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 USGS' operations, the individual pings 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 µPa·m, gray whales reacted by orienting slightly away from the source and being deflected from their course by ~200 m (Frankel 2005). When a 38-kHz echosounder and a 150-kHz acoustic Doppler current profiler were transmitting during studies in the ETP, baleen whales showed no significant responses, whereas 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 USGS, 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 by USGS 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 μPa·m_{rms} (see § I), the received level for an animal within the MBES beam 100 m below the ship would be ~202 dB re 1 μPa_{rms}, assuming 40 dB of spreading loss over 100 m (circular spreading). Given the narrow beam, only one 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 EM 122. That animal might incur some TTS (which would be fully recoverable), but the exposure would still be below the anticipated PTS threshold for cetaceans. As noted by Burkhardt et al. (2007, 2008), cetaceans are very unlikely to incur PTS from operation of scientific sonars on a ship that is underway.

In the harbor seal, the TTS threshold for non-impulse sounds is about 183 dB re 1 $\mu Pa^2 \cdot s$, as compared with ~195 dB re 1 $\mu Pa^2 \cdot s$ in odontocetes (Kastak et al. 2005; Southall et al. 2007). TTS onset occurs at higher received energy levels in the California sea lion and northern elephant seal than in the harbor seal. A harbor seal as much as 100 m below the *Langseth* could receive a single MBES 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 signals, occurring for 1–4 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 204 dB re 1 μPa · m (see § I). Kremser et al. (2005) noted that the probability of a cetacean swimming through the area of exposure when a bottom profiler emits a 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 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 Release Signals

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

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

All anticipated takes would be "takes by harassment", involving temporary changes in behavior. The mitigation measures to be applied will minimize the possibility of injurious takes. (However, as noted earlier, there is no specific information demonstrating that injurious "takes" would occur even in the absence of the planned mitigation measures.) In the sections below, we describe methods to estimate the number of potential exposures to various received sound levels and present estimates of the numbers of marine mammals that could be affected during the proposed seismic program. The estimates are based on a consideration of the number of marine mammals that could be disturbed appreciably by operations with the 18-airgun subarray to be used during ~3300 km of seismic surveys in the central GOA. The sources of distributional and numerical data used in deriving the estimates are described in the next subsection.

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

Basis for Estimating "Take by Harassment"

There are several sources of systematic data on the numbers and distributions of marine mammals in the coastal and nearshore areas of the GOA, but there are fewer data for offshore areas. Vessel-based surveys in the northern and western GOA from the Kenai Peninsula to the central Aleutian Islands during July–August 2001–2003 (Zerbini et al. 2003, 2006, 2007) and in the northern and western GOA from PWS to ~160ºW off the Alaska Peninsula during 26 June–15 July 2003 (Waite 2003) were confined to waters <1000 m deep, and most effort was in depths <100 m. Similarly, Dahlheim et al. (2000)

conducted aerial surveys of the nearshore waters from Bristol Bay to Dixon Entrance for harbor porpoises during 1993, and Dahlheim and Towell (1994) conducted vessel-based surveys of Pacific white-sided dolphins in the inland waterways of southeast Alaska during April–May, June or July, and September–early October of 1991–1993.

Deeper water was included in several surveys. In a report on a seismic cruise in southeast Alaska from Dixon Entrance to Kodiak Island during August–September 2004, MacLean and Koski (2005) included density estimates of cetaceans and pinnipeds for each of three depth ranges (<100 m, 100–1000 m, and >1000 m) during non-seismic periods. Hauser and Holst (2009) reported density estimates during non-seismic periods for all marine mammals sighted during a September–early October geophysical cruise in southeast Alaska for each of the same three depth ranges as MacLean and Koski (2005). Rone et al. (2010) conducted surveys of nearshore and offshore strata in the GOA during April 2009, with much of their survey effort in water depths >1000 m. DoN (2009) estimated densities of several species of marine mammals in the offshore GOA based on surveys by other researchers.

Table 3 gives the estimated average and maximum densities of marine mammals expected to occur in the deep, offshore waters of the proposed survey area. We used the densities reported by MacLean and Koski (2005) and Hauser and Holst (2009) for >1000 m, which were corrected for both detectability and availability biases[3] We calculated density estimates from effort and sightings in water depths >1000 m in Rone et al. (2010) for humpback, fin, and killer whales and Dall's porpoise, and in 500–1000 m depths of Waite (2003) for Cuvier's and Baird's beaked whales, using values for *f*(0) and *g*(0) from Barlow and Forney (2007). Finally, we used seasonal densities for pinnipeds from DoN (2009), which were based on counts at haulout sites and biological (mostly breeding) information to estimate in-water densities.

There is some uncertainty about the representativeness of the data and the assumptions used in the calculations below for two main reasons: (1) the surveys from which densities were derived were at different times of year: April (Rone et al. 2010), June–July (Waite 2003), August–September (MacLean and Koski 2005), and September–October (Hauser and Holst 2009); and (2) the MacLean and Koski (2005) and Hauser and Holst (2009) surveys were conducted primarily in southeast Alaska (east of the proposed study area). However, the approach used here is believed to be the best available approach.

Also, to provide some allowance for these uncertainties, "maximum estimates" as well as "best estimates" of the densities present and numbers potentially affected have been derived. Best estimates of cetacean density are effort-weighted mean densities from the various surveys, whereas maximum estimates of density come from the individual survey that provided the highest density. For marine mammals where only one density estimate was available, the maximum is 1.5× the best estimate.

For one species, the Dall's porpoise, density estimates in the original reports are much higher than densities expected during the proposed survey, because this porpoise is attracted to vessels. Our estimates for Dall's porpoise are from vessel-based surveys without seismic survey activity; they are overestimates, possibly by a factor of 5×, given the tendency of this species to approach vessels (Turnock and Quinn 1991). Noise from the airgun array during the proposed survey is expected to at least reduce and possibly eliminate the tendency of this porpoise to approach the vessel. Dall's porpoises are tolerant of small airgun sources (MacLean and Koski 2005) and tolerated higher sound levels than other species during a large-array survey (Bain and Williams 2006); however, they did respond to that and another large airgun array by moving away (Calambokidis and Osmek 1998; Bain and Williams 2006). Because of the

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

TABLE 3. Densities of marine mammals sighted during various surveys in the Gulf of Alaska in deep water. Densities are from various sources (see text); they are corrected for *f*(0) and *g*(0). Species listed as *endangered* or *threatened* under the ESA are in italics.

	Density in the central GOA (#/1000 km^2)	
Species[1]	**Average**	**Maximum**
Mysticetes		
North Pacific right whale	*0*	*0*
Humpback whale	*2.15*	*6.53*
Minke whale	0	0
Sei whale	*0*	*0*
Fin whale	*2.40*	*5.93*
Blue whale	*0*	*0*
Odontocetes		
Sperm whale	*0.31*	*1.69*
Cuvier's beaked whale	1.29	1.81
Baird's beaked whale	0.40	0.60
Stejneger's beaked whale	0	0
Killer whale	3.13	7.73
Dall's porpoise	19.97	62.50
Pinnipeds		
Steller sea lion	*9.80*	*14.70*
Northern fur seal	105.90	158.85
Northern elephant seal	0	0

[1] Does not include other species listed in Table 2 that are extralimital in the GOA or coastal.

probable overestimates, the best and maximum estimates for Dall's porpoises shown in Table 3 are one-quarter of the reported densities. In fact, actual densities are probably slightly lower than that.

The estimated numbers of individuals potentially exposed are presented below based on the 160-dB re 1 μPa_{rms} criterion for all marine mammals, and the 170-dB re 1 μPa_{rms} criterion for delphinids, Dall's porpoise, and pinnipeds. 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 including the contingency line; in fact, the ensonified areas calculated using the planned number of line-kilometers ***have been increased by 25%*** to accommodate lines that may need to be repeated, equipment testing, etc. As is typical during offshore ship surveys, inclement weather and equipment malfunctions are likely to cause delays and may limit the number of useful line-kilometers of seismic operations that can be undertaken. Furthermore, any marine mammal sightings within or near the designated exclusion 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- or 170-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 weather, equipment, or mitigation delays, which is highly unlikely.

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

Number of Cetaceans that could be Exposed to ≥160 dB.— The number of different individuals that could be exposed to 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 1.13× the area excluding overlap. Moreover, it is unlikely that a particular animal would stay in the area during the entire survey.

For each depth stratum, the numbers of different individuals potentially exposed to ≥160 dB re 1 μPa_{rms} were calculated by multiplying

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

The area expected to be ensonified was determined by entering the planned survey lines into a MapInfo GIS, using the GIS to identify the relevant areas by "drawing" the applicable 160-dB (or, in the next subsection, 170-dB) buffer (see Table 1) around each seismic line, and then calculating the total area within the buffers. Areas 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. Before calculating numbers of individuals exposed, the areas were increased by 25% as a precautionary measure.

Table 4 shows the best and maximum estimates of the number of different individual marine mammals that potentially could be exposed to ≥160 dB re 1 μPa_{rms} during the seismic survey if no animals moved away from the survey vessel. The ***Requested Take Authorization***, given in the far right column of Table 4, is based on the maximum estimates rather than the best estimates of the numbers exposed, because of the uncertainty about the representativeness of the density data discussed in the previous section.

Applying the approach described above, ~20,933 km^2 (~26,166 km^2 including the 25% contingency) would be within the 160-dB isopleth on one or more occasions during the survey, assuming that the contingency line is completed. Because this approach does not allow for turnover in the mammal populations in the study area during the course of the survey, the actual number of individuals exposed could be underestimated. However, the approach assumes that no cetaceans will move away from or toward the trackline as the *Langseth* approaches in response to increasing sound levels prior to the time the levels reach 160 dB, which will result in overestimates for those species known to avoid seismic vessels (see § VII).

The 'best estimate' of the number of individual cetaceans that could be exposed to seismic sounds with received levels ≥160 dB re 1 μPa_{rms} during the proposed survey is 776 (Table 4). That total includes 127 ***endangered*** whales (8 sperm, 56 humpback, and 63 fin whales), which (if realistic) would represent <0.1%, 0.3%, and 0.4%, respectively, of the regional populations (Table 4). Dall's porpoise is expected to be the most common species in the study area; the best estimate of the number of Dall's porpoises that could be exposed is 522 or <0.1% of the regional population (Table 4). This may be a slight overestimate because the estimated densities are slight overestimates (see previous section). Estimates for other species are lower (Table 4). The 'maximum estimate' column in Table 4 shows estimates totaling 1882 cetaceans.

Number of Delphinids and Dall's Porpoise that could be Exposed to ≥170 dB.—The 160-dB criterion, on which the preceding estimates are based, was derived from studies of baleen whales. Odontocete hearing at low frequencies is relatively insensitive, and delphinids and Dall's porpoise generally appear to be more tolerant of strong low-frequency sounds than are many baleen whales. As summarized in Appendix B (5) of the EA, delphinids commonly occur within distances where received levels would

TABLE 4. Estimates of the possible numbers of marine mammals exposed to sound levels ≥160 and ≥170 dB during USGS' proposed seismic survey in the central Gulf of Alaska in June 2011. The proposed sound source consists of a 36-airgun, 6600-in^3 array. Received levels of airgun sounds are expressed in dB re 1 µPa$_{rms}$ (averaged over pulse duration), consistent with NMFS' practice. Not all marine mammals will change their behavior when exposed to these sound levels, but some may alter their behavior when levels are lower (see text). Delphinids, Dall's porpoise, and pinnipeds are unlikely to react to levels below 170 dB. Species in italics are listed under the ESA as *endangered* or *threatened*. The column of numbers in boldface shows the numbers of "takes" for which authorization is requested.

	Number of Individuals Exposed to Sound Levels ≥160 dB (≥170 dB, Delphinids, Porpoise, and Pinnipeds)					
	Best Estimate[1]					
Species	**Number**		**% of Regional Pop'n[2]**	**Maximum Estimate[1]**		**Requested Take Authorization**
Balaenopteridae						
North Pacific right whale	*0*		*0*	*0*		***0***
Humpback whale	*56*		*0.3*	*171*		***171***
Minke whale	0		0	0		**0**
Sei whale	*0*		*0*	*0*		***0***
Fin whale	*63*		*0.4*	*155*		***155***
Blue whale	*0*		*0*	*0*		***0***
Physeteridae						
Sperm whale	*8*		*<0.1*	*35*		***35***
Ziphiidae						
Cuvier's beaked whale	34		0.2	38		**38**
Baird's beaked whale	11		0.2	13		**13**
Stejneger's beaked whale	0		0	0		**0**
Delphinidae						
Killer whale	82	(48)	1.0	162	(119)	**162**
Phocoenidae						
Dall's porpoise	522	(307)	<0.1	1308	(961)	**1308**
Pinnipeds						
Northern fur seal	2771	(1628)	<0.1	3325	(2442)	**3325**
Northern elephant seal	0		0	0		**0**
Steller sea lion	*256*	*(151)*	*0.6*	*308*	*(226)*	***308***

[1] Best and maximum estimates are based on densities from Table 3 and ensonified areas (including 25% contingency) of 26,166.25 km^2 for 160 dB and 15,372.5 km^2 for 170 dB (identified in parentheses).

[2] Regional population size estimates are from Table 2.

be expected to exceed 160 dB re 1 µPa$_{rms}$. There is no generally accepted alternative "take" criterion for delphinids exposed to airgun sounds. However, the estimates in this subsection assume that only those delphinids and Dall's porpoises exposed to ≥170 dB re 1 µPa$_{rms}$, on average, would be affected sufficiently to be considered "taken by harassment". ("On average" means that some individuals might react significantly upon exposure to levels somewhat <170 dB, but others would not do so even upon exposure to levels somewhat >170 dB.)

The area ensonified by levels ≥170 dB was estimated to be ~12,298 km^2 (15,372.5 km^2 including the 25% contingency). The best and maximum estimates of the numbers of individuals exposed to ≥170 dB for the killer whale, the only delphinid expected to be encountered during the survey, are 48 and 119, respectively, and the corresponding estimates for Dall's porpoise are 307 and 961 (Table 4). These values are based on the predicted 170-dB radii around the array to be used during the study and are considered to be more realistic estimates of the number of individual delphinids and Dall's porpoises that could be affected. However, the number of Dall's porpoises that might be exposed to ≥170 dB is probably slightly overestimated because of the (presumed) overestimated density as noted earlier.

Number of Pinnipeds that might be Exposed to ≥160 dB and ≥170 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}. As summarized in § VII and Appendix B of the EA, most pinnipeds, like delphinids, seem to be less responsive to airgun sounds than are some mysticetes. Thus, the numbers of pinnipeds that could be exposed to received levels ≥170 dB re 1 μPa_{rms} were also calculated, based on the estimated 170-dB radii (Table 1). Based on the "best" densities, 256 ***endangered Steller sea lions and 2771 northern fur seals could be exposed to airgun sounds ≥160 dB re 1 μPa_{rms}; the corresponding numbers that could be exposed to airgun sounds ≥170 dB re 1 μPa_{rms} are 151 Steller sea lions and 1628 northern fur seals. The 'maximum estimate' column in Table 4 shows an estimated 308 or 226 Steller sea lions that could be exposed to airgun sounds ≥160 dB or ≥170 dB re 1 $\mu Pa_{rms,}$ respectively. The corresponding numbers for northern fur seals are 3325 and 2442.

Conclusions

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

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

Odontocete reactions to seismic pulses, or at least the reactions of delphinids and Dall's porpoise, are expected to extend to lesser distances than are those of mysticetes. Odontocete low-frequency hearing is less sensitive than that of mysticetes, and dolphins are often seen from seismic vessels. In fact, there are documented instances of dolphins approaching active seismic vessels. However, delphinids (along with other cetaceans) sometimes show avoidance responses and/or other changes in behavior when near operating seismic vessels.

Taking into account the mitigation measures that are planned (see § XI), effects on cetaceans are generally expected to be limited to avoidance of the area around the seismic operation and short-term changes in behavior, falling within the MMPA definition of "Level B harassment".

Killer, humpback, and fin whales are expected to be common in the survey area. For these three species, 0.3–1.0% of the regional populations is likely to be exposed (Table 4) unless additional mitigation measures are implemented. Thus, if concentrations of these species are sighted, the airgun array will be powered down until the animals move away or disperse from the area, or the vessel will move its operations to a different area.

Varying estimates of the numbers of marine mammals that might be exposed to strong airgun sounds during the proposed program have been presented, depending on the specific exposure criteria (≥160 or ≥170 dB) and density criterion used. The requested "take authorization" for each species is based on the maximum estimate of the number of individuals that could be exposed to ≥160 dB re 1 μPa_{rms}. Those figures likely overestimate the actual number of animals that will be exposed to and 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.—Three pinniped species—the Steller sea lion, the northern fur seal, and the northern elephant seal—could occur in the study area. Best estimates of 256 Steller sea lions and 2771 northern fur seals could be exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms}. These estimates represent 0.6% of the Steller sea lion regional population and <0.1% of the northern fur seal regional population. As for cetaceans, the estimated numbers of pinnipeds that could be exposed to received levels ≥160 dB are probably overestimates of the actual numbers that will be affected. During the June survey period, the Steller sea lion is in its breeding season, with males staying on land and females with pups generally staying close to the rookeries in shallow water. Male northern fur seals are at their rookeries in June, and adult females are either there or migrating there, possibly through the survey area.

VIII. ANTICIPATED IMPACT ON SUBSISTENCE

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

There is no subsistence hunting in the deep, offshore waters of the central GOA, so the proposed activities will not have any impact on the availability of the species or stocks for subsistence users.

IX. ANTICIPATED IMPACT ON HABITAT

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

The proposed seismic 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 D of the EA). There are three types of potential effects of exposure to seismic surveys: (1) pathological, (2) physiological, and (3) behavioral. Pathological effects involve lethal and temporary or permanent sub-lethal injury. Physiological effects involve temporary and permanent primary and secondary stress responses, such as changes in levels of enzymes and proteins. Behavioral effects refer to temporary and (if they occur) permanent changes in exhibited behavior (e.g., startle and avoidance behavior). The three categories are interrelated in complex ways. For example, it is possible that certain physiological and behavioral changes could potentially lead to an ultimate pathological effect on individuals (i.e., mortality).

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

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

Little is known about the mechanisms and characteristics of damage to fish that may be inflicted by exposure to seismic survey sounds. Few data have been presented in the peer-reviewed scientific literature. As far as we know, there are only two papers with proper experimental methods, controls, and careful pathological investigation implicating sounds produced by actual seismic survey airguns in causing adverse anatomical effects. One such study indicated anatomical damage, and the second indicated TTS in fish hearing. The anatomical case is McCauley et al. (2003), who found that exposure to airgun sound caused observable anatomical damage to the auditory maculae of "pink snapper" (*Pagrus auratus*). This damage in the ears had not been repaired in fish sacrificed and examined almost two months after exposure. On the other hand, Popper et al. (2005) documented only TTS (as determined by auditory brainstem response) in two of three fish species from the Mackenzie River Delta. This study found that broad whitefish (*Coregonus nasus*) that received a sound exposure level of 177 dB re 1 $\mu Pa^2 \cdot s$ showed no hearing loss. During both studies, the repetitive exposure to sound was greater than would have occurred during a typical seismic survey. However, the substantial low-frequency energy produced by the 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 D of the EA).

Behavioral Effects

Behavioral effects include changes in the distribution, migration, mating, and catchability of fish populations. Studies investigating the possible effects of sound (including seismic survey sound) on fish behavior have been conducted on both uncaged and caged individuals (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.

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

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

Effects on Invertebrates

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

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

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 E 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 will be limited in duration.

XI. Mitigation Measures

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

Marine mammals and sea turtles are known to occur in the proposed study area. To minimize the likelihood that impacts will occur to the species and stocks, 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 the U.S. EEZ and in International Waters.

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 USGS and L-DEO seismic research cruises as approved by NMFS, and on best practices recommended in Richardson et al (1995), Pierson et al. (1998), and Weir and Dolman (2007).

Planning Phase

In designing this proposed seismic survey, USGS has considered potential environmental impacts including seasonal, biological, and weather factors; ship schedules; and equipment availability. Part of the considerations was whether the research objectives could be met with a smaller source; tests will be conducted to determine whether the 2-string subarray (3300 in^3) will be satisfactory to accomplish the geophysical objectives. If so, the smaller array will be used to minimize environmental impact. Also, the array will be powered down to a single gun during turns, and the array will be shut down during OBS deployment and retrieval.

Proposed Exclusion Zones

Received sound levels have been predicted by L-DEO, in relation to distance and direction from the airguns, for the 36-airgun array and for a single 1900LL 40-in^3 airgun, which will be used during power downs. Results were recently reported for propagation measurements of pulses from the 36-airgun array in two water depths (~1600 m and 50 m) in the Gulf of Mexico in 2007–2008 (Tolstoy et al. 2009). It would be prudent to use the empirical values that resulted to determine exclusion zones for the airgun array. Results of the propagation measurements (Tolstoy et al. 2009) showed that radii around the airguns for various received levels varied with water depth. During the proposed study, all survey effort will take place in deep (>1000 m) water, so propagation in shallow water is not relevant here. The depth of the array was different in the Gulf of Mexico calibration study (6 m) than in the proposed survey (9 m); thus, correction factors have been applied to the distances reported by Tolstoy et al. (2009). The correction factors used were the ratios of the 160-, 170-, 180-, and 190-dB distances from the modeled results for the 6600-in^3 airgun array towed at 6 m vs. 9 m. Based on the propagation measurements and modeling, the distances from the source where sound levels are predicted to be 190, 180, 170, and 160 dB re 1 μPa_{rms} were determined (see Table 1 in § I). The 180- and 190-dB radii are to 940 m and 400 m, respectively. The 180- and 190-dB levels are shut-down criteria applicable to cetaceans and pinnipeds, respectively, as specified by NMFS (2000); these levels were used to establish the exclusion zones (EZs). If the protected species observer (PSO) detects marine mammal(s) or turtle(s) within or about to enter the appropriate EZ, the airguns will be powered down (or shut down if necessary) immediately (see below).

Detailed recommendations for new science-based noise exposure criteria were published in early 2008 (Southall et al. 2007). USGS 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 of early 2011, NMFS has not specified a new procedure for determining EZs.

Mitigation During Operations

Mitigation measures that will be adopted during the survey in the central GOA include (1) power-down procedures, (2) shut-down procedures, (3) ramp-up procedures, and (4) special mitigation measures for situations or species of particular concern.

Power-down Procedures

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

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

Following a power down, airgun activity will not resume until the marine mammal or turtle has cleared the 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, or
- the vessel has moved outside the EZ for turtles, e.g., if a turtle is sighted close to the vessel and the ship speed is 7.4 km/h, it would take the vessel ~8 min to leave the turtle behind.

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

Shut-down Procedures

The operating airgun(s) will be shut down if a marine mammal or turtle is seen within or approaching the 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 or turtle 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. This period is based on the 180-dB radius for the 36-airgun array (940 m) in relation to the minimum planned speed of the *Langseth* while shooting (7.4 km/h). Similar periods (~8–10 min) were used during previous 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 ~35 min. During ramp up, the PSOs will monitor the exclusion zone, and if marine mammals or turtles 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 and turtles 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 sea turtle or marine mammal is sighted within or near the applicable EZs during the day or at night.

Special Procedures for Situations and Species of Particular Concern

Special mitigation procedures will be implemented as follows:

- The airguns will be shut down immediately if ESA-listed species for which no takes are being requested (North Pacific right, sei, blue, beluga whale — see § VII) are sighted at any distance from the vessel. Ramp up will only begin if the whale has not been seen for 30 min.
- Concentrations of humpback whales, fin whales, and killer whales will be avoided if possible, and the array will be powered down if necessary.

XII. PLAN OF COOPERATION

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

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

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

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

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

Not applicable. The proposed activity will take place in the deep, offshore waters of the central GOA, and no activities will take place in or near a traditional Arctic subsistence hunting area.

XIII. MONITORING AND REPORTING PLAN

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

USGS 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.

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

During seismic operations in the central GOA, at least four PSOs will be based aboard the *Langseth*. PSOs will be appointed by USGS with NMFS concurrence. Observations will take place during ongoing daytime operations and nighttime start ups of the airguns. During the majority of seismic operations, two PSOs will monitor marine mammals and turtles near the seismic vessel. Use of two simultaneous observers will increase the effectiveness of detecting animals near 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 turtles 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 and turtle 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 or turtles 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 cetaceans. The acoustic monitoring will serve to alert visual observers (if on duty) when vocalizing cetaceans are detected. It is only useful when marine mammals call, but it can be effective either by day or by night, and does not depend on good visibility. It will be monitored in real time so that the visual observers can be advised when cetaceans are detected.

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 cable. The array will be deployed from a winch located on the back deck. A deck cable will connect from the winch to the main computer lab where the acoustic station and signal conditioning and processing system will be located. The lead-in from the hydrophone array is ~400 m long, and the active part of the hydrophone array is ~56 m long. The hydrophone array is typically towed at depths <20 m.

The towed hydrophones will ideally be monitored 24 h per day while at the seismic survey area during airgun operations, and during most periods when the *Langseth* is underway while the airguns are not operating. However, PAM may not be possible if damage occurs to the array 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. The PSO 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

PSOs will record data to estimate the numbers of marine mammals and turtles exposed to various received sound levels and to document apparent disturbance reactions or lack thereof. Data will be used to estimate numbers of animals potentially 'taken' by harassment (as defined in the MMPA). They will also provide information needed to order a power down or shut down of the airguns when a marine mammal or sea turtle is within or near the EZ. Observations will also be made during daytime periods when the *Langseth* is underway without seismic operations. In addition to the transits to, from, and through the study area, there will also be opportunities to collect baseline biological data during the deployment and recovery of OBSs.

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 and turtles in the area where the seismic study is conducted.
4. Information to compare the distance and distribution of marine mammals and turtles relative to the source vessel at times with and without seismic activity.
5. Data on the behavior and movement patterns of marine mammals and turtles seen at times with and without seismic activity.

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

XIV. Coordinating Research to Reduce and Evaluate Incidental Take

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

USGS will coordinate the planned marine mammal monitoring program associated with the seismic survey in the central GOA (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. USGS will coordinate with applicable U.S. agencies (e.g., NMFS), and will comply with their requirements.

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