Request by Lamont-Doherty Earth Observatory for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during a Marine Geophysical Survey by the R/V *Marcus G. Langseth* on the Shatsky Rise in the Northwest Pacific Ocean, March–April 2012

submitted by

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SUMMARY

Lamont-Doherty Earth Observatory (L-DEO), with research funding from the National Science Foundation (NSF), plans to conduct a marine seismic survey on the Shatsky Rise in the Northwest Pacific Ocean during March–April 2012. The survey will take place in International Waters ~3000–5000 m deep. The airgun array will consist of 36 airguns with a total volume of ~6600 in^3. L-DEO requests that it be issued an Incidental Harassment Authorization (IHA) allowing non-lethal takes of marine mammals incidental to the planned seismic survey. This request is submitted pursuant to Section 101 (a)(5)(D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371 (a) (5).

Numerous species of cetaceans and pinnipeds inhabit the proposed survey area in the Northwest Pacific Ocean. Several of these species are listed as ***Endangered*** under the U.S. Endangered Species Act (ESA), including the Western North Pacific gray, North Pacific right, sperm, humpback, sei, fin, and blue whales. The Western North Pacific gray whale is listed as ***Critically Endangered*** by the International Union for Conservation of Nature and Natural Resources (IUCN) 2011 Red List of Threatened species, but is unlikely to occur in the offshore study area as it prefers coastal waters. With the exception of humpback and sperm whales, the other ESA-listed whale species are also considered ***Endangered*** by the IUCN (2011). Northern fur seals may also be present, and are listed as ***Vulnerable*** under the ESA and by the IUCN. Other ESA-listed species that could occur in the study area include the ***Endangered*** hawksbill turtle, leatherback turtle, and short-tailed albatross, and the ***Threatened*** green, loggerhead, and olive ridley turtles.

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

I. OPERATIONS TO BE CONDUCTED

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

Overview of the Activity

L-DEO plans to conduct a seismic survey on the Shatsky Rise in the Northwest Pacific Ocean. The survey will encompass the area ~33.5–36°N, 156–161°E (Fig. 1). Water depths in the survey area are ~3000–5000 m. The project is scheduled to occur ~24 March–16 April 2012. Some minor deviation from these dates is possible, depending on logistics and weather.

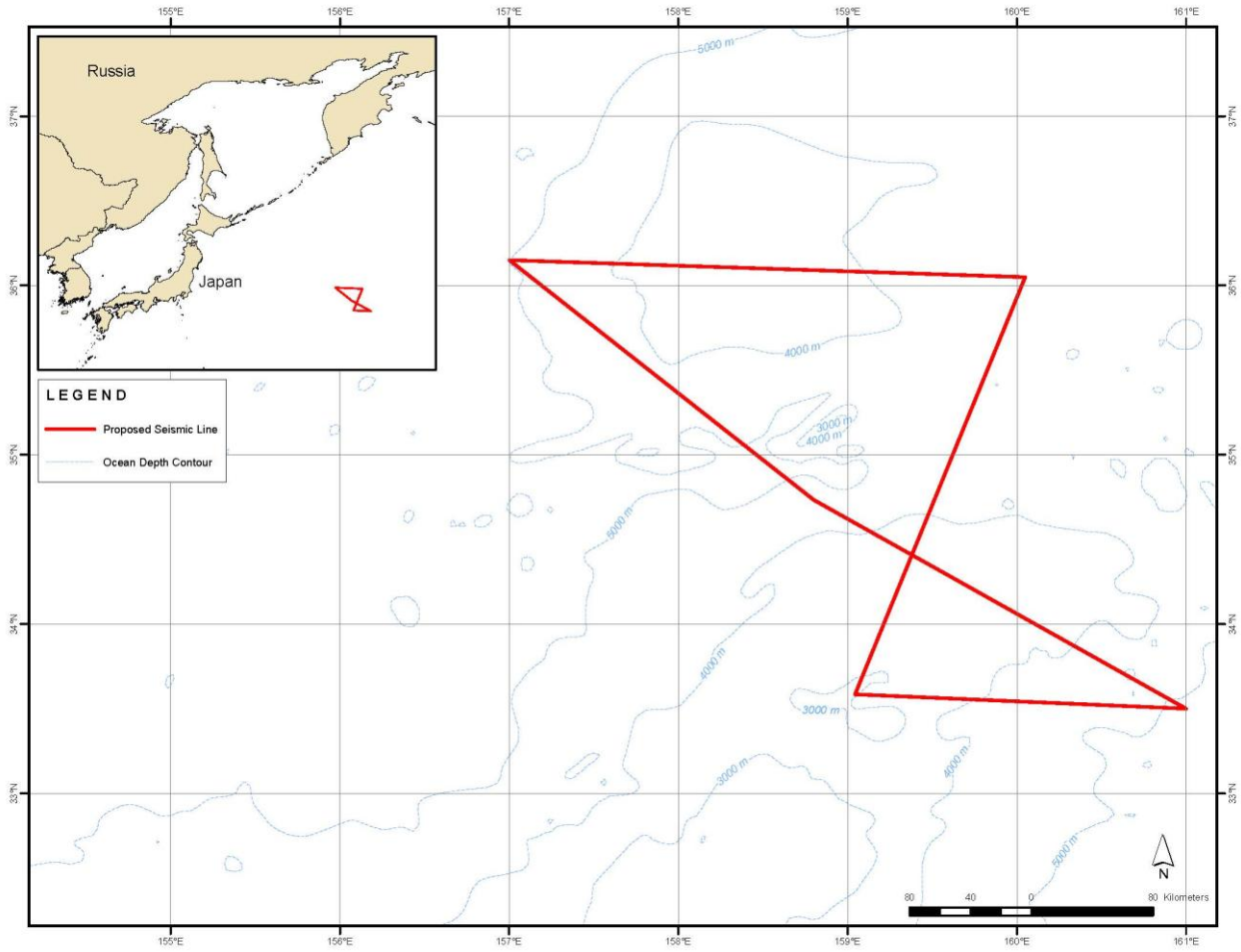

FIGURE 1. Study area and proposed survey design for the seismic survey in the northwestern Pacific Ocean planned for 24 March–16 April 2012 with seismic tracklines.

L-DEO plans to complete the seismic survey over the Shatsky Rise, a large igneous plateau in the Northwest Pacific Ocean, that was started in 2010. (The survey could not be completed in 2010 because the survey was disrupted twice by medical diversions to Japan.) The proposed survey will provide data necessary to decipher the crustal structure of the Shatsky Rise. The sheer scale of plateau formation implies a potential role in environmental crises such as oceanic anoxia and mass extinctions. Likewise, oceanic plateaus may be important for the growth of continental crust. Hence, the information provided by this survey will address major questions of Earth history, geodynamics, and tectonics, and could have a profound impact on our understanding of terrestrial magmatism and mantle convection. The survey may also obtain data that could be used to improve estimates of regional earthquake occurrence and distribution.

The survey will involve one source vessel, the R/V *Marcus G. Langseth*. The *Langseth* will deploy a 36-airgun array as an energy source. The receiving system will consist of one 6-km long hydrophone streamer. As the airgun array is towed along the survey lines, the hydrophone streamer will receive the returning acoustic signals and transfer the data to the on-board processing system.

The planned seismic survey will consist of ~1216 km of transect lines in the Shatsky Rise survey area (Fig. 1). A multichannel seismic (MCS) survey will be conducted with shot intervals of ~20 s. There will be additional seismic operations in the survey area associated with turns, airgun testing, and

repeat coverage of any areas where initial data quality is sub-standard. In our calculations (see § IV(3)), 25% has been added for those additional operations.

In addition to the operations of the airgun array, a multibeam echosounder (MBES) and a sub-bottom profiler (SBP) will also be operated from the *Langseth* continuously throughout the cruise. All planned geophysical data acquisition activities will be conducted by L-DEO with on-board assistance by the scientists who have proposed the study. The Principal Investigators are Drs. Jun Korenaga (Yale University, New Haven, CT) and William Sager (Texas A&M University, College Station, TX). 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 and streamer along predetermined lines (Fig. 1). When the *Langseth* is towing the airgun array as well as the hydrophone streamer, the turning rate of the vessel while the gear is deployed is limited to five degrees per minute. Thus, the maneuverability of the vessel is limited during operations with the streamer.

The *Langseth* has a length of 71.5 m, a beam of 17.0 m, and a maximum draft of 5.9 m. The *Langseth* was designed as a seismic research vessel, with a propulsion system designed to be as quiet as possible to avoid interference with the seismic signals. The ship is powered by two Bergen BRG-6 diesel engines, each producing 3550 hp, which drive the two propellers directly. Each propeller has four blades, and the shaft typically rotates at 600 or 750 revolutions per minute (rpm). The vessel also has an 800 hp bowthruster, which is not used during seismic acquisition. The operation speed during seismic acquisition will be 8.5 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 *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, 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 towed ~100 m behind the *Langseth* and will distributed across an area of ~24×16 m. The shot interval will be relatively short (~20 s or 50 m) for the multichannel seismic (MCS) 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.

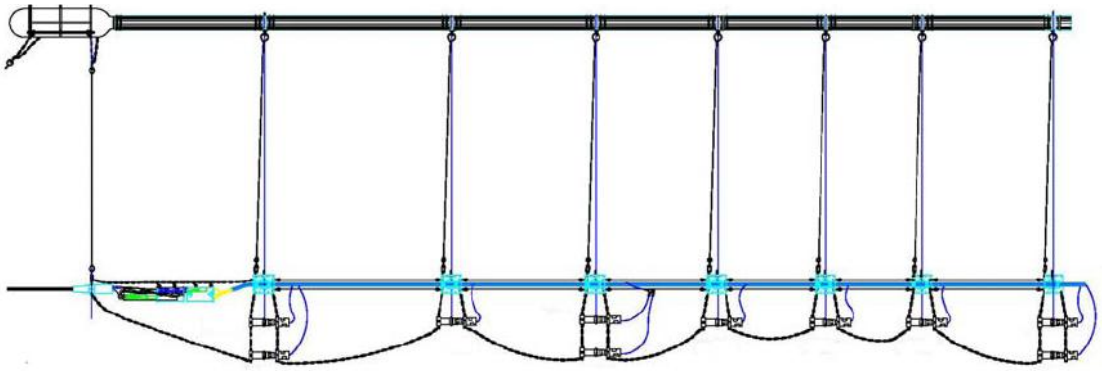

FIGURE 2. One linear airgun array or string with ten airguns, nine of which would be operating.

The tow depth of the array will be 9 m. Because the actual source is a distributed sound source (36 airguns) rather than a single point source, the highest sound levels measurable at any location in the water will be less than the nominal source level. In addition, the effective source level for sound propagating in near-horizontal directions will be substantially lower than the nominal source level applicable to downward propagation because of the directional nature of the sound from the airgun array.

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 Measurements

Received sound levels have been predicted by L-DEO's model, 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 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). However, measurements were not reported for a single airgun, although the sound levels in deep water have been modeled (Fig. 3). A detailed description of the modeling effort is provided in Appendix A of the Environmental Assessment (EA).

The predicted sound contours for the 40-in^3 mitigation airgun are shown in Figure 3 as sound exposure levels (SEL) in decibels (dB) re 1 $\mu Pa^2 \cdot s$. SEL is a measure of the received energy in the pulse and represents the sound pressure level (SPL) that would be measured if the pulse energy were spread evenly across a 1-s period. Because actual seismic pulses are less than 1 s in duration in most situations, this means that the SEL value for a given pulse is usually lower than the SPL calculated for the actual duration of the pulse (see Appendix B). The advantage of working with SEL is that the SEL measure accounts for the total received energy in the pulse, and biological effects of pulsed sounds are believed to depend mainly on pulse energy (Southall et al. 2007). In contrast, SPL for a given pulse depends greatly on pulse duration. A pulse with a given SEL can be long or short depending on the extent to which propagation effects have "stretched" the pulse duration. The SPL will be low if the duration is long and higher if the duration is short, even though the pulse energy (and presumably the biological effects) are the same.

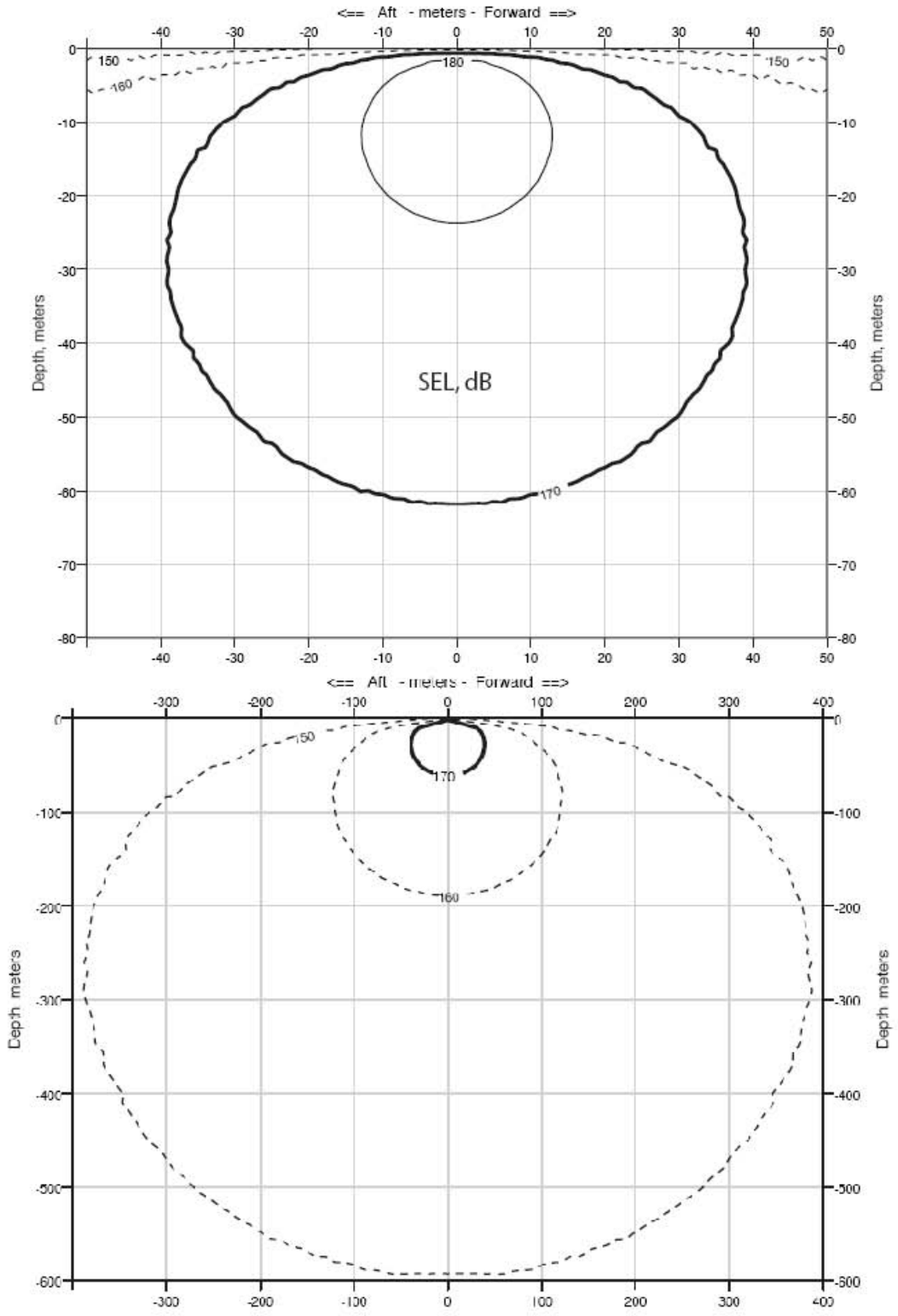

FIGURE 3. Modeled received sound levels (SELs) from a single 40-in^3 airgun operating in deep water, which is planned for use during the survey in the in the northwestern Pacific Ocean in March–April 2012. Received rms levels (SPLs) are expected to be ~10 dB higher.

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

Results of the propagation measurements showed that radii around the airguns for various received levels varied with water depth (Tolstoy et al. 2009). In addition, propagation varies with array tow depth. The empirical values that resulted from Tolstoy et al. (2009) are used here to determine exclusion zones for the 36-airgun array. However, 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-, 180-, and 190-dB distances from the modeled results for the 6600-in^3 airgun array towed at 6 m vs. 9 m, from LGL (2008): 1.285; 1.338; and 1.364, respectively.

Using the corrected empirical measurements (array) or model (single airgun), Table 1 shows the distances at which three 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. 2005a,b; Holst and Beland 2008; Holst and Smultea 2008; Hauser et al. 2008; Holst 2009; Antochiw et al. n.d.). If marine mammals or sea 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. L-DEO will be prepared to revise its procedures for estimating numbers of mammals "taken", exclusion zones, etc., as may be required by any new guidelines 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, and 160 dB re 1 μPa_{rms} are expected to be received in deep water during the proposed survey in the northwestern Pacific Ocean, 24 March–16 April 2012. Radii for the array are based on empirical data in Tolstoy at al. (2009), corrected for tow depth using model results, and predicted radii for a single airgun are based on L-DEO's model, 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**	**160 dB**
Single Bolt airgun, 40 in^3	12	40	385
4 strings, 36 airguns, 6600 in^3, tow depth 9 m	400	940	3850

Description of Operations

The source vessel, the R/V *Marcus G. Langseth*, will deploy an array of 36 airguns as an energy source at a tow depth of 9 m. The receiving system will consist of one 6-km long hydrophone streamer. As the airgun array is towed along the survey lines, the hydrophone streamer will receive the returning acoustic signals and transfer the data to the on-board processing system.

The planned seismic survey will consist of ~1216 km of transect lines (Fig. 1). There will be additional seismic operations in the survey area associated with turns, airgun testing, and repeat coverage of any areas where initial data quality is sub-standard. In our calculations (see § VI), 25% has been added for those additional operations. In addition to the operations of the airgun array, a Kongsberg EM 122 multibeam echosounder (MBES) and a Knudsen Chirp 3260 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 Chirp 3260 SBP.

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 $\mu Pa \cdot m_{rms}$. Each "ping" consists of eight (in water >1000 m deep) or four (<1000 m) successive fan-shaped transmissions, each ensonifying a sector that extends 1° fore–aft. Continuous-wave (CW) pulses increase from 2 to 15 ms long in water depths up to 2600 m, and 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 Chirp 3260 SBP is normally operated to provide information about the sedimentary features and the bottom topography that is being mapped simultaneously by the MBES. The SBP is capable of reaching depths of 10,000 m. The beam is transmitted as a 27º cone, which is directed downward by a 3.5-kHz transducer in the hull of the *Langseth*. The nominal power output is 10 kW, but the actual maximum radiated power is 3 kW or 222 dB re 1 $\mu Pa \cdot m$. The ping duration is up to 64 ms, and the ping interval is 1 s. A common mode of operation is to broadcast five pulses at 1-s intervals followed by a 5-s pause.

II. DATES, DURATION, AND REGION OF ACTIVITY

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

The survey will encompass the area ~33.5–36°N, 156–161°E in International Waters in the northwestern Pacific Ocean at least 1200 km from Japan (Fig. 1). Water depths in the survey area are ~3000–5000 m. The exact dates of the activities depend on logistics and weather conditions. The R/V *Langseth* will depart Yokohama, Japan, on 24 March 2012 and arrive at Honolulu, HI, on 16 April 2012. Seismic operations will be carried out for an estimated 7 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

Thirty-four marine mammal species could occur in the northwestern Pacific survey area. To avoid redundancy, we have included the required information about the species and (insofar as it is known) numbers of these species in § IV, below.

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

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

Sections III and IV are integrated here to minimize repetition.

Thirty-three cetacean species, including 26 odontocete (dolphins and small- and large-toothed whales) species and seven mysticetes (baleen whales) may occur in the Shatsky Rise study area (Table 2). In addition, the southern extent of the pelagic range for the northern fur seal overlaps with the study area. Information on the occurrence, distribution, population size, and conservation status for each of the 34 marine mammal species that may occur in the proposed study area is presented in Table 2. The status of these species is based on the ESA, the IUCN Red List of Threatened Species, and the Convention on International Trade in Endangered Species (CITES). Several of these species are listed under the ESA as endangered, including the North Pacific right, sperm, humpback, fin, sei, and blue whales.

The Western North Pacific gray whale also occurs in the Northwest Pacific Ocean; it is listed as endangered under the ESA and as critically endangered by the IUCN. Its migration route is believed to include the Pacific coast of Japan (Reilly et al. 2008a). Although the offshore limit of this route is not well documented, gray whales are known to prefer nearshore coastal waters. Hence, it is extremely unlikely that this species would occur within the proposed study area. Therefore, the gray whale is not analyzed further and is not included in the density table (see below) or as take requests.

Mysticetes

North Pacific Right Whale (*Eubalaena japonica*)

The North Pacific right whale is listed as ***Endangered*** under the ESA and on the IUCN Red List of Threatened Species (IUCN 2011), and is listed in CITES Appendix I (UNEP-WCMC 2011) (Table 2). It is considered by NMFS (1991) to be the most endangered baleen whale in the world. Although protected from commercial whaling since 1935, there has been little indication of recovery. The pre-exploitation stock may have exceeded 11,000 animals (NMFS 1991). There are no reliable current population

TABLE 2. The habitat, regional population sizes, and conservation status of marine mammals that could occur in or near the proposed seismic survey area on the Shatsky Rise in the Northwest Pacific Ocean.

Species	Habitat	Regional pop. Size [a]	U.S. ESA [b]	IUCN [c]	CITES [d]
Mysticetes					
North Pacific right whale	Pelagic and coastal	few 100 [e]	EN	EN	I
Humpback whale	Mainly nearshore, banks	938–1107 [f]	EN	LC	I
Minke whale	Pelagic and coastal	25,000 [g]	NL	LC	I
Bryde's whale	Pelagic and coastal	20,501 [h]	NL	DD	I
Sei whale	Primarily offshore, pelagic	7260-12,620 [i]	EN	EN	I
Fin whale	Continental slope, mostly	13,620–18,680 [j]	EN	EN	I
Blue whale	Pelagic and coastal	3500 [k]	EN	EN	I
Odontocetes					
Sperm whale	Usually pelagic, deep sea	29,674 [l]	EN	VU	I
Pygmy sperm whale	Deep waters off the shelf	N.A.	NL	DD	II
Dwarf sperm whale	Deep waters off the shelf	11,200 [m]	NL	DD	II
Cuvier's beaked whale	Pelagic	20,000 [m]	NL	LC	II
Baird's beaked whale	Deep water	N.A.	NL	DD	II
Longman's beaked whale	Deep water	N.A.	NL	DD	II
Hubb's beaked whale	Deep water	25,300 [n]	NL	DD	II
Ginkgo-toothed beaked whale	Pelagic	25,300 [n]	NL	DD	II
Blainville's beaked whale	Pelagic	25,300 [n]	NL	DD	II
Stejneger's beaked whale	Deep water	25,300 [n]	NL	DD	II
Rough-toothed dolphin	Deep water	145,900 [m]	NL	LC	II
Common bottlenose dolphin	Coastal, oceanic, shelf break	168,000 [o]	NL	LC	II
Pantropical spotted dolphin	Coastal and pelagic	438,000 [o]	NL	LC	II
Spinner dolphin	Coastal and pelagic	801,000 [p]	NL	DD	II
Striped dolphin	Off continental shelf	570,000 [o]	NL	LC	II
Fraser's dolphin	Waters >1000 m	289,300 [m]	NL	LC	II
Short-beaked common dolphin	Shelf, pelagic, seamounts	2,963,000 [q]	NL	LC	II
Pacific white-sided dolphin	Continental slope, pelagic	988,000 [r]	NL	LC	II
Northern right whale dolphin	Deep water	307,000 [r]	NL	LC	II
Risso's dolphin	Deep water, seamounts	838,000 [o]	NL	LC	II
Melon-headed whale	Oceanic	45,400 [m]	NL	LC	II
Pygmy killer whale	Deep, pantropical waters	38,900 [m]	NL	DD	II
False killer whale	Pelagic	16,000 [o]	NL	DD	II
Killer whale	Widely distributed	8500 [m]	NL	DD	II
Short-finned pilot whale	Mostly pelagic, high-relief	53,000 [o]	NL	DD	II
Dall's porpoise	Deep water	1,337,224 [s]	NL	LC	II
Pinnipeds					
Northern fur seal	Coastal and pelagic	1.1 million [t]	NL	VU	-

N.A. - Data not available or species status was not assessed.

[a] Region for population size, in order of preference based on available data, is Western North Pacific, North Pacific, or Eastern Tropical Pacific; see footnotes below.

[b] U.S. Endangered Species Act; EN = Endangered, NL = Not listed.

[c] Codes for IUCN (2011) classifications; EN = Endangered; VU = Vulnerable; LC = Least Concern; DD = Data Deficient.

[d] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2011): Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled.

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

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

[g] Northwest Pacific and Okhotsk Sea (Buckland et al. 1992; IWC 2010a).

[h] Western North Pacific (Kitakado et al. 2008; IWC 2010a).

[i] North Pacific (Tillman 1977).

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

[k] North Pacific (NMFS 1998).

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

[m] Eastern Tropical Pacific (ETP) (Wade and Gerrodette 1993).
[n] ETP; all *Mesoplodon* spp. (Wade and Gerrodette 1993).
[o] Western North Pacific (Miyashita 1993a).
[p] Whitebelly spinner dolphin in the ETP in 2000 (Gerrodette et al. 2005 *in* Hammond et al 2008a).
[q] ETP (Gerrodette and Forcada 2002 *in* Hammond et al 2008b).
[r] North Pacific (Miyashita 1993b).
[s] North Pacific (Buckland et al 1993).
[t] North Pacific, 2004–2005 (Gelatt and Lowry 2008).

estimates for this species. Wada (1973; see also Braham and Rice 1984) provided an estimate of 100–200 right whales in the North Pacific. More recently, Miyashita and Kato (1998 *in* Kato et al. 2005) suggested an abundance of 420–2100 right whales for the Sea of Okhotsk, and Jefferson et al. (2008) indicate that there are "no more than a few hundred right whales alive today".

North Pacific right whales summer in the northern North Pacific and Bering Sea, apparently feeding off southern and western Alaska from May to September (e.g., Tynan et al. 2001). Wintering 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), as well as Guangdong province, southern China (Rudolph and Smeenk 2002).

The Hawaiian Islands were not a major calving ground for right whales in the last 200 years, but mid-ocean whaling records of right whales during winter suggest that right whales may have wintered and calved far offshore in the Pacific Ocean (Scarff 1986, 1991; Clapham et al. 2004). In April 1996, a right whale was sighted off Maui, the first documented sighting of a right whale in Hawaiian waters since 1979 (Herman et al. 1980; Rowntree et al. 1980).

Whaling records indicate that right whales once ranged across the entire North Pacific Ocean north of 35ºN and occasionally occurred as far south as 20ºN. In the western Pacific, most sightings in the 1900s were reported from Japanese waters, followed by the Kuril Islands, and the Okhotsk Sea (Brownell et al. 2001). However, since the 1960s sightings have been relatively rare (e.g., Clapham et al. 2004; Shelden et al. 2005). Nonetheless, in the western Pacific, significant numbers of right whales have been seen in the Okhotsk Sea during the 1990s, suggesting that the adjacent Kuril Islands and Kamchatka coast are a major feeding ground (Brownell et al. 2001). Right whales were also seen near Chichi-jima Island (Bonin Islands), Japan, in the 1990s (Mori et al. 1998). During 1994-2007, right whale sightings were also reported off northern Japan, the Kuril Islands, and Kamchatka (Matsuoka et al. 2009). Sightings were reported for the months of April through August, with highest densities occurring in May and August (Matsuoka et al. 2009). All sightings were north of 37ºN (Matsuoka et al. 2009). Right whale sightings were made directly north of the proposed Shatsky Rise study area during May (Matsuoka et al. 2009). However, given the relatively small number of whales in this population, it is unlikely that any right whales would be encountered in the study.

Humpback Whale (*Megaptera novaeangliae*)

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 IUCN Red List of Threatened Species (IUCN 2011), and it is listed in CITES Appendix I (UNEP-WCMC 2011) (Table 2). The worldwide population of humpback whales is divided into northern and southern ocean populations, but genetic analyses suggest some gene flow (either past or present) between the North and South Pacific oceans (e.g., Baker et al. 1993; Caballero et al. 2001). Based on a collaborative study involving numerous jurisdictions, the North Pacific stock has been recently estimated at 18,302 whales, excluding calves (Calambokidis et al. 2008; IUCN 2009). Overall, the North Pacific stock is considered to be increasing. The western Pacific stock is estimated at 938–1107 (Calambokidis et al. 2008). The low

population estimate for the western North Pacific subpopulation is a cause for concern for the IUCN (2009). Calambokidis et al. (2008) noted that humpbacks along the coast of Asia appear to be subject to high incidental mortality.

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

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

In the western North Pacific, most humpback whales winter and calve near Okinawa (Ryukyu Island) and Ogasawara (Bonin Islands) (Nishiwaki 1959; Rice 1989; Darling and Mori 1993). Calambokidis et al. (2008) also included the waters of Taiwan and the Mariana Islands as part of the humpback winter range. There is potential for the mixing of the western and eastern North Pacific humpback populations, as several individuals have been seen in the wintering areas of Japan and Hawaii in separate years (Darling and Cerchio 1993; Salden et al. 1999; Calambokidis et al. 2001, 2008). Whales from these wintering areas have been shown to travel to summer feeding areas in British Columbia (B.C.), Canada, and Kodiak Island, Alaska (Darling et al. 1996; Calambokidis et al. 2001), but feeding areas in Russian waters may be most important (Calambokidis et al. 2008). There appears to be a very low level of interchange between wintering and feeding areas in Asia and those in the eastern and central Pacific (Calambokidis et al. 2008).

During Japanese sighting surveys from 1994 to 2007, numerous humpback whales sightings were made off northern Japan, the Kuril Islands, and Kamchatka (Matsuoka et al. 2009). Sightings were reported for the months of April through September, with lowest densities in April and September (Matsuoka et al. 2009). In May and June, sightings were concentrated east of northern Japan; highest densities were reported for July and August off the Kuril Islands and Kamchatka (Matsuoka et al. 2009). Humpback whales were encountered directly north of the proposed Shatsky Rise study area in May; some sightings reported in June and July were also near the study area (Matsuoka et al. 2009). In August, sightings were farther to the north (Matsuoka et al. 2009). Most of the animals in this population are on their way to northern feeding grounds in June and July; thus, few individuals are expected to occur within the proposed study area at the time of the survey.

Minke Whale (*Balaenoptera acutorostrata*)

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

In the North Pacific, the summer range of the minke whale extends to the Chukchi Sea; in the winter, the whales move further south to within 2º of the equator (Perrin and Brownell 2002). Three stocks of minke whales are currently recognized 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). The current abundance estimate for the Northwest Pacific and Okhotsk Sea is 25,000 minkes (Buckland et al. 1992; IWC 2010b).

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

North Pacific minke whales are known to occur in the Yellow, East China and South China Seas (Parsons et al. 1995), as well as in the waters of the open Pacific (Hakamada et al. 2009). Minke whales have been hunted off Japan for many years (see IWC 2010b). They are seen regularly during Japanese sighting surveys south of 41°N in May–June, and migrate to north of 41°N in July–August (Hakamada et al. 2009).

Bryde's Whale (*Balaenoptera edeni/brydei*)

Bryde's whale is found in tropical and subtropical waters throughout the world between 40ºN and 40ºS, generally in waters warmer than 20ºC, but at minimum 15ºC (Reeves et al. 1999; Kato 2002; Kanda et al. 2007). Long confused with sei whales, *Balaenoptera edeni* was named in 1913 and *B. brydei* was named in 1950, although it is still uncertain whether the two are distinct species or subspecies (Kato 2002). The smaller *B. edeni* (the pygmy Bryde's or Eden's whale) may be a distinct species from the larger *B. brydei* or Bryde's whale (Wada et al. 2003; Sasaki et al. 2006). The small form is known to occur in southwestern Japan, Hong Kong/Macau, and Australia, but this form has not been distinguished from the common Bryde's whale (Jefferson et al. 2008). Populations in the western North Pacific, western South Pacific, eastern South Pacific, and eastern Indian Ocean currently show low levels of genetic interchange (Kanda et al. 2007). Here, we follow Kato (2002) in recognizing the uncertainty and using *B. edeni/brydei*.

Bryde's whales are known to occur in both shallow coastal and deeper offshore waters (Jefferson et al. 2008). Some populations show a general pattern of movement toward the equator in winter and toward higher latitudes in summer, though the locations of actual winter breeding grounds are unknown (Reeves et al. 1999; Kato 2002; Kanda et al. 2007). Bryde's whales are usually solitary or in pairs, although groups of 10–20 are known from feeding grounds (Jefferson et al. 2008). Wade and Gerrodette (1993) reported a mean group size of 1.7 for the ETP. The durations of Bryde's whale dives are 1–20 min (Cummings 1985).

In the western North Pacific, Bryde's whales occur off the Pacific coasts of Japan, Taiwan, and the Philippines (Kato 2002), in Hong Kong (Parsons et al. 1995; Jefferson and Hung 2007), as well as in the Yellow, East China, and South China Seas (Parsons et al. 1995; Chou 2004). Whales in the East China Sea and coastal waters of Kochi, Japan, differ from the whales in offshore waters of the western North Pacific, perhaps at the subspecific level (Yoshida and Kato 1999). However, the reclassification of Bryde's whales remains unresolved (Jefferson et al. 2008). Bryde's whales are hunted off the coast of Japan (see IWC 2010b). The current population estimate for the western North Pacific is 20,501 (Kitakado et al. 2008; IWC 2010a). Bryde's whales are seen regularly during Japanese summer sighting

surveys (Shimada 2004; Hakamada et al. 2009). Near the Shatsky Rise survey area, sightings are highest during July and August (Shimada 2004; Hakamada et al. 2009).

Sei Whale (*Balaenoptera borealis*)

The sei whale is listed as ***Endangered*** under the U.S. ESA and on the IUCN Red List of Threatened Species (IUCN 2011), and is listed in CITES Appendix I (UNEP-WCMC 2011) (Table 2). Sei whale populations were depleted by whaling, and their current status is generally uncertain (Horwood 1987). The global population is thought to be ~80,000 (Horwood 2002), with up to ~12,620 animals in the North Pacific (Tillman 1977). Although Hakamada et al. (2004) extrapolated an abundance estimate for the entire Northwest Pacific based on one part of that region, this estimate (68,000) has not yet been accepted (Reilly et al. 2008b). The sei whale is poorly known because of confusion with Bryde's whale and unpredictable distribution patterns, such that it may be common in an area for several years and then seemingly disappears (Schilling et al. 1992; Jefferson et al. 2008).

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). In the North Pacific, the sei whale can be found across the Bering Sea and off the coasts of Japan and Korea in the summer. Its winter distribution is concentrated at about 20°N. No breeding grounds have been identified for sei whales; however, calving is thought to occur from September to March.

The sei whale is pelagic and generally not found in coastal waters (Harwood and Wilson 2001). It is found in deeper waters characteristic of the continental shelf edge region (Hain et al. 1985) and in other regions of steep bathymetric relief such as 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, and dive durations are 15 min or longer (Gambell 1985a).

Sei whales are hunted off Japan (see IWC 2010b). They are seen regularly during Japanese sighting surveys in the summer (Hakamada et al. 2009). Sei whales have been sighted in and near the Shatsky Rise survey area in greatest numbers in May, June, and July; in August, sightings occur farther to the north (Hakamada et al. 2009). During the summer, sei whales travel northward. They are seen regularly during Japanese sighting surveys south of 41°N in May–June, and migrate to north of 41°N in July–August (Hakamada et al. 2009).

Fin Whale (*Balaenoptera physalus*)

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 IUCN Red List of Threatened Species (IUCN 2011), and is listed in CITES Appendix I (UNEP-WCMC 2011) (Table 2). Northern and southern fin whale populations are distinct and are sometimes recognized as different subspecies (Aguilar 2002). Abundance estimates for the northern populations are 13,620–18,680 for the North Pacific (Ohsumi and Wada 1974), 30,000 for the central and northeastern Atlantic (IWC 2010a), and 3200 for West Greenland (IWC 2010a). Miyashita and Kato (2005 *in* Kato et al. 2005) provided an abundance estimate of 13,000 for the Sea of Okhotsk.

Fin whales occur in coastal, shelf, and oceanic waters. Sergeant (1977) proposed that fin whales tend to follow steep slope contours, either because they detect them readily or because biological productivity is high along steep contours because of tidal mixing and perhaps current mixing. They can be found as individuals or groups of 2–7, but can form much larger feeding aggregations, sometimes with humpback and minke whales (Jefferson et al. 2008). Foraging fin whales reach mean dive depths and times of 98 m and 6.3 min, respectively, while recorded mean dive depths and times for non-foraging fin whales in the Pacific are 59 m and 4.2 min, respectively (Croll et al. 2001). Dive depths of >150 m coinciding with the diel migration of krill were reported by Panigada et al. (1999).

The current distribution of fin whales in the western North Pacific is largely unknown. Fin whales undergo seasonal migrations, and are known to winter in the Yellow, East China, and South China Seas (Parsons et al. 1995; Rudolph and Smeenk 2002). 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). In the summer, fin whales are seen off northern Japan, the Kuril Islands, and Kamchatka (Matsuoka et al. 2009). During Japanese sightings surveys in the western North Pacific from 1994 to 2007, the fin whale was sighted more frequently than the blue, humpback or right whale (Matsuoka et al. 2009). Most sightings were made in July and August; sightings in August were concentrated towards the northern parts of the area (Matsuoka et al. 2009). During these sighting surveys, fin whales were seen in and near the proposed Shatsky Rise study area during May, June, and July; in August and September, fin whale sightings were farther to the north (Matsuoka et al. 2009). Thus, fin whales could be encountered during the proposed seismic survey.

Blue Whale (*Balaenoptera musculus*)

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 IUCN Red List of Threatened Species (IUCN 2011), and is listed in CITES Appendix I (UNEP-WCMC 2011) (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 2010a), 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 two or three (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 ETP. Croll et al. (2001) reported mean dive depths and times of 140 m and 7.8 min for foraging blue whales, and 68 m and 4.9 min for non-foraging individuals. Dives of up to 300 m were recorded for tagged blue whales (Calambokidis et al. 2003).

Generally, blue whales are seasonal migrants between high latitudes in the summer, where they feed, and low latitudes in the winter, where they mate and give birth (Lockyer and Brown 1981). However, little information is available on blue whale 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). Moore et al. (2002) reported that blue whale calls are received in the North Pacific year-round. 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).

The current distribution of blue whales in the western North Pacific is largely unknown. However, numerous blue whale sightings have been made in the western North Pacific during recent Japanese sighting surveys during 1994-2007 (Matsuoka et al. 2009). The highest blue whale densities were seen southeast of Kamchatka (Matsuoka et al. 2009). Most sightings were made in July and August; sightings in August were concentrated towards the northern parts of the area (Matsuoka et al. 2009). Blue whales were seen in and near the proposed Shatsky Rise survey area during May, June, and July; sightings in August and September were farther to the north (Matsuoka et al. 2009). Thus, it is possible that blue whales could be encountered at Shatsky Rise during the proposed seismic survey.

Odontocetes

Sperm Whale (*Physeter macrocephalus*)

Sperm whales are the largest of the toothed whales, with an extensive worldwide distribution (Rice 1989). The species is listed as ***Endangered*** under the U.S. ESA, but on a worldwide basis it is abundant and not biologically endangered. It is listed as ***Vulnerable*** on the IUCN Red List of Threatened Species (IUCN 2011), and is listed in CITES Appendix I (UNEP-WCMC 2011) (Table 2). There currently is no accurate estimate for the size of any sperm whale population (Whitehead 2002a). Best estimates probably are those of Whitehead (2002b), who provided a sperm whale population size estimate of 29,674 for the western North Pacific.

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). Mature male sperm whales migrate to warmer waters to breed when they are in their late twenties (Best 1979). They spend periods of at least months on the breeding grounds, moving between mixed groups of 20–30 on average (Whitehead 1993, 2003). Mean group sizes were reported as 3.5 for the western North Pacific (Kato and Miyashita 1998) and 7.9 for the ETP (Wade and Gerrodette 1993).

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

In the western North Pacific, sperm whales are known to occur in the waters of Japan (Kato and Miyashita 1998; Hakamada et al. 2009), Hong Kong (Parsons et al. 1995; Jefferson and Hung 2007), the Philippines (Acebes et al. 2000 *in* Perrin et al. 2005; Acebes and Lesaca 2003), and Taiwan (Chou 2004). During winter, few sperm whales are sighted off the east coast of Japan (Kato and Miyashita 1998), but sperm whales are seen regularly during sighting surveys in the summer (Hakamada et al. 2009). They have been sighted in and near the Shatsky Rise survey area from May through August (Hakamada et al. 2009). Thus, sperm whales could be encountered during the proposed Shatsky Rise seismic program.

Dwarf and Pygmy Sperm Whales (*Kogia breviceps and K. sima*)

Pygmy sperm whales and dwarf sperm whales are distributed widely throughout tropical and temperate seas, but their precise distributions are unknown as most information on these species comes from strandings (McAlpine 2002). They are difficult to sight at sea, perhaps because of their avoidance

reactions to ships and behavior changes in relation to survey aircraft (Würsig et al. 1998). The two species are difficult to distinguish from one another when sighted (McAlpine 2002). During sighting surveys and, hence, in population and density estimates, the two species are most often categorized together as *Kogia* spp. (Waring et al. 2009).

Pygmy sperm whales may inhabit waters beyond the continental shelf edge, whereas dwarf sperm whales are thought to inhabit the shelf-edge and slope waters (Rice 1998). Also, the dwarf sperm whale may prefer warmer waters than the pygmy sperm whale (McAlpine 2002). Pygmy sperm whales feed mainly on various species of squid in the deep zones of the continental shelf and slope (McAlpine et al. 1997). Pygmy sperm whales occur in small groups of up to six, and dwarf sperm whales can form groups of up to 10 (Caldwell and Caldwell 1989). Wade and Gerrodette (1993) noted a mean group size of 1.7 for the dwarf sperm whale in the ETP.

Although there are few useful estimates of abundance for pygmy or dwarf sperm whales anywhere in their range, they are thought to be fairly common in some areas. In the western North Pacific, confirmed *Kogia* records exist for the East and South China seas off mainland China, Taiwan, Hong Kong, and the Philippines (Parsons et al. 1995; Zhou et al. 1995; Perrin et al. 2005; Chou 2004; Jefferson and Hung 2007). Although *Kogia* spp. have been seen during Japanese sighting surveys in the western North Pacific in August/September (Kato et al. 2005), to the best of our knowledge, there are no direct data available for the Shatsky Rise survey area with respect to *Kogia* spp. Given their habitat preferences, it is more likely that pygmy sperm whales rather than dwarf sperm whales would be encountered in the study area.

Cuvier's Beaked Whale (*Ziphius cavirostris*)

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 Gisiner 2006). Adult males of this species usually travel alone, but these whales can be seen in groups of up to 15 individuals, with a mean group size of 2.3 (MacLeod and D'Amico 2006). Cuvier's beaked whale is an offshore species that feeds on fish and squid (Heyning 2002). Its dives generally last 30–60 min, but dives of 85 min have been recorded (Tyack et al. 2006). Wade and Gerrodette (1993) reported a mean group size of 2.2 for the ETP.

In the western Pacific, Cuvier's beaked whales are known to occur in the waters of Japan (Nishiwaki and Oguro 1972 *in* Wang et al. 1995) and parts of southeast Asia (Heyning 1989). They were also seen during Japanese sighting surveys in August/September in the western North Pacific (Kato et al. 2005). There is very little information on this species for the Shatsky Rise study area, but what is known of its distribution and habitat preferences suggests that it may occur there.

Baird's Beaked Whale (*Berardius bairdii*)

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 2002a). The whales occur year-round in the Sea of Okhotsk and the Sea of Japan (Kasuya 2002a). Their abundance is estimated at 5029 for the Pacific coast of Japan, 1260 for the eastern Sea of Japan, and 660 for the southern Okhotsk Sea (Kasuya 2002a).

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 2002a). Off Japan and California, they primarily feed on benthic fishes and cephalopods, although pelagic fishes are also taken occasionally (Kasuya 2002a). 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 2002a). They travel in groups of a few to several dozen (Balcomb 1989). Off Japan, they form groups of up to 30 individuals, although groups of 2 to 9 animals are seen most often (Kasuya 2002a). Wade et al. (2003) reported a mean group size of 10.8 for the ETP. There appears to be a calving peak in March and April (Jefferson et al. 1993).

Baird's beaked whales have been hunted for centuries in the far western North Pacific. Before 1840, the annual catch in Japan was <25 animals; after World War II, the fishery expanded to the entire northern Pacific, with a reported catch of over 300, but subsequently declined (Kasuya 2002a). Currently, Baird's beaked whales are hunted off the west coast of Japan in the summer; Kasuya (2002a) reported quotas of eight Baird's beaked whales for the Sea of Japan, two for the southern Okhotsk Sea, and 52 for the Pacific coast. Off Japan's Pacific coast, Baird's beaked whales start to appear in May, numbers increase over the summer, and decrease toward October (Kasuya 2002a). During this time, they are nearly absent in offshore waters (Kasuya 2002a). Kato et al. (2005) also reported the presence of Baird's beaked whales in the western North Pacific in August/September. Thus, it is possible that this species could be encountered at Shatsky Rise during the proposed seismic survey in spring.

Longman's Beaked Whale (*Indopacetus pacificus*)

Until very recently, Longman's beaked whale was thought to be extremely rare, and it was known only from two skulls (Pitman et al. 1987). Recent morphometric and genetic analyses of those two original specimens and an additional four specimens have allowed a more detailed characterization of the species (Dalebout et al. 2003). It seems likely that it is, in fact, the cetacean that has been seen in Indo-Pacific waters and called the "tropical bottlenose whale". Some authorities place the species in the genus *Mesoplodon*, but there now seems to be sufficient information to afford it status as a separate genus (Dalebout et al. 2003). Records of this species exist within an area from 10ºS to 40ºN.

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

In eastern Asia, records for this species exist for Japan (Yamada et al. 2004), the Philippines (Acebes et al. 2005), and Taiwan (Yang et al. 2008). Kato et al. (2005) also reported on sightings of this species during Japanese surveys in the western North Pacific in August/September. Given that this species prefers tropical and sub-tropical waters, the Shatsky Rise survey area would be at the limit of its range. Thus, encounters with this species in the proposed study area are considered unlikely.

Mesoplodont Beaked Whales

Four species of mesoplodont whales may occur in deep waters of the Shatsky Rise study area: Blainville's (*Mesoplodon densirostris*), gingko-toothed (*Mesoplodon ginkgodens*), Stejneger's (*M. stejnegeri*), and Hubb's (*M. carlhubbsi*) beaked whales. No population estimates exist for any of these species for the western North Pacific.

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

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

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

In Asia, sighting records exist for Blainville's beaked whale for the East China Sea off mainland China and for the Philippines (Perrin et al. 2005). They are also known to occur off Taiwan (Zhou et al. 1995; Chou 2004; Perrin et al. 2005). To the best of our knowledge, there are no published sighting records near the Shatsky Rise, but this area is believed to be within the distribution range for this species (Jefferson et al. 2008).

Ginkgo-toothed beaked whale.—This species is only known from stranding records (Mead 1989; Jefferson et al. 2008). In the South Pacific Ocean, it has stranded in New South Wales, Australia, and the North Island and Chatham Islands, New Zealand (Mead 1989; Baker and van Helden 1999). The ginkgo-toothed whale is hypothesized to occupy tropical and warm temperate waters of the Indian and Pacific oceans (Pitman 2002). Its occurrence has been confirmed in the Yellow and East China seas off mainland China (Perrin et al. 2005), as well as off Taiwan (Yang 1976 *in* Zhou et al. 1995; Chou 2004; Wang and Yang 2006). The distributional range of this species suggests that any occurrence in the study area would be rare.

Stejneger's beaked whale.—Stejneger's beaked whale occurs in subarctic and cool temperate waters of the North Pacific (Mead 1989). Most records are from Alaskan waters, and the Aleutian Islands appear to be its center of distribution (Mead 1989). The species typically occurs in groups of 3–4, ranging to ~15 (Reeves et al. 2002). It is known to occur in the Sea of Japan and possibly the southern Okhotsk Sea (MacLeod et al. 2006). Stejneger's beaked whale was also seen during Japanese sighting surveys in the western North Pacific during August/September (Kato et al. 2005). Seasonal peaks in strandings along the western coast of Japan suggest that this species may migrate north in the summer from the Sea of Japan (Mead 1989).

Hubb's beaked whale.—This species occurs in temperate waters of the North Pacific (Mead 1989). Most of the stranding records are from California, but at least seven strandings have been recorded along the B.C. coast as far north as Prince Rupert (Houston 1990; Willis and Baird 1998). Its distribution appears to be correlated with the deep subarctic current (Mead et al. 1982). The range of this species is believed to be continuous across the North Pacific (Macleod et al. 2006), although this has yet to be substantiated because very few direct at-sea observations exist. Hubb's beaked whale was seen during Japanese sighting surveys in the western North Pacific during August/September (Kato et al. 2005). This species has been taken in Japanese hunts for small cetaceans and sold at markets (Dalebout et al. 2001).

Rough-toothed Dolphin (*Steno bredanensis*)

The rough-toothed dolphin is widely distributed around the world, but mainly occurs in tropical and warm temperate waters (Miyazaki and Perrin 1994). Rough-toothed dolphins generally occur in deep, oceanic waters, but can be found in shallower coastal waters in some regions (Jefferson et al. 2008). Rough-toothed dolphins are deep divers and can dive for up to 15 min (Jefferson et al. 2008). They usually form groups of 10–20, but aggregations of hundreds have been seen (Jefferson et al. 2008). Wade and Gerrodette (1993) reported a mean group size of 14.7 for the ETP.

In the Pacific, rough-toothed dolphins occur from central Japan and northern Australia to Baja California, Mexico, and southern Peru (Jefferson 2002). Rough-toothed dolphins are also known to occur in the Philippines (Acebes et al. 2000 *in* Perrin et al. 2005; Acebes and Lesaca 2003; Perrin et al. 2005) and in the East and South China seas (Parsons et al. 1995; Zhou et al. 1995; Chou 2004; Perrin et al. 2005; Jefferson and Hung 2007). There are no estimates of abundance for rough-toothed dolphins in the western Pacific. Rough-toothed dolphins were seen during Japanese sighting surveys in the western North Pacific during August/September (Kato et al. 2005). In Japan, rough-toothed dolphins have been taken in drive and harpoon hunts (Miyazaki and Perrin 1994). As the Shatsky Rise study area is known to be within this species' range, the rough-toothed dolphin may be encountered during the proposed survey.

Common Bottlenose Dolphin (*Tursiops truncatus*)

The bottlenose dolphin is distributed worldwide. It is found mainly where surface temperatures range from 10–32ºC (Reeves et al. 2002). Generally, there are two distinct bottlenose dolphin types: a shallow water type, mainly found in coastal waters, and a deep water type, mainly found in oceanic waters (Duffield et al. 1983; Hoelzel et al. 1998; Walker et al. 1999). As well as inhabiting different areas, these ecotypes differ in their diving abilities (Klatsky 2004) and prey types (Mead and Potter 1995). Bottlenose dolphins have been reported to regularly dive to depths >450 m for periods of >5 min (Klatsky 2004), and even down to depths of 600–700 m for up to 12 min (Klatsky et al. 2005). Mean group sizes have been reported as 66.9 for the western North Pacific (Miyashita 1993a), 22–24 for the ETP (Wade and Gerrodette 1993; Smith and Whitehead 1999).

In the western Pacific, the bottlenose dolphin is distributed from Japan to Australia and New Zealand. In Japan, bottlenose dolphins are hunted by whalers in drive and harpoon fisheries (Kasuya 2007). Bottlenose dolphins are also known to occur in the Philippines and the Yellow, East, and South China seas off China and Taiwan (Perrin et al. 2005), and Hong Kong (Parsons et al. 1995; Jefferson and Hung 2007). It has been estimated that 168,000 bottlenose dolphins inhabit the western North Pacific (Miyashita 1993a). Bottlenose dolphins were regularly seen during Japanese summer sighting surveys in the western North Pacific (Miyashita 1993a). They were seen in groups of 1 to 500 animals and were often sighted in mixed schools with other dolphin species (Miyashita 1993a). Occurrence in the western North Pacific was patchy, but high densities were generally observed in coastal waters as well as in some offshore areas (Miyashita 1993a). Bottlenose dolphins have been sighted in the proposed Shatsky Rise study area in August, and near the study area in June and July (Miyashita 1993a).

Pantropical Spotted Dolphin (*Stenella attenuata*)

The pantropical spotted dolphin can be found throughout tropical and some subtropical oceans of the world (Perrin and Hohn 1994). The southernmost limit of its range is ~40°S (Perrin 2002a). There are two forms of pantropical spotted dolphin—coastal and offshore—although the coastal form occurs mainly in the ETP from Baja California to South America (Jefferson et al. 2008). In the ETP, this dolphin is associated with warm (>25ºC) tropical surface water (Au and Perryman 1985; Reilly 1990; Reilly and Fiedler 1994; Reeves et al. 1999). The offshore form inhabits tropical, equatorial, and

southern subtropical water masses (Perrin 2002a). This species is found primarily in deeper waters, and rarely over the continental shelf or continental shelf edge (Davis et al. 1998).

Pantropical spotted dolphins are extremely gregarious, forming groups of hundreds or even thousands. In the western North Pacific, groups of 3 to 2500 striped dolphins were seen, and the mean group size was 226 (Miyashita 1993a). Wade and Gerrodette (1993) reported a mean group size of 149.4 for the western/southern stock in the ETP. Pantropical spotted and spinner dolphins are commonly seen together in mixed-species groups, e.g., in the ETP (Au and Perryman 1985), off Hawaii (Psarakos et al. 2003), and off the Marquesas Archipelago (Gannier 2002).

In the western Pacific, pantropical spotted dolphins occur from Japan south to Australia; they have been hunted in drive fisheries off Japan for decades (Kasuya 2007). Pantropical spotted dolphins are also known to occur in the Philippines and in the East and South China seas off China (Perrin et al. 2005), in Taiwan (Parsons et al. 1995; Zhou et al. 1995; Chou 2004), and off Hong Kong (Parsons et al. 1995; Jefferson and Hung 2007). Their abundance in the western North Pacific has been estimated at 438,000 (Miyashita 1993a). They were regularly seen during Japanese summer sighting surveys in the western North Pacific (Miyashita 1993a). Densities were highest in offshore waters between 30ºN and 37ºN (Miyashita 1993a). Pantropical spotted dolphins have been sighted in the proposed Shatsky Rise study area in June, August, and September; survey effort was low in July (Miyashita 1993a).

Spinner Dolphin (*Stenella longirostris*)

The spinner dolphin is distributed in oceanic and coastal tropical waters between 40ºN and 40ºS (Jefferson et al. 2008). In the Pacific, two subspecies of spinner dolphin occur in the western Pacific: the widespread, offshore spinner dolphin (*Stenella longirostris longirostris*) and the dwarf spinner dolphin (*S. l. roseiventris*). There is little or no genetic interchange between the two subspecies (Dizon et al. 1991). *S. l. longirostris* feeds on small mesopelagic fish and squid, whereas *S. l. roseiventris* preys on benthic and coral reef fishes and invertebrates (Perrin et al. 1999). *S. l. longirostris* occurs in the deep inner waters of the Philippines as well as Japan, whereas *S. l. roseiventris* inhabits the shallow waters of inner southeast Asia (Perrin et al. 1999).

Kato et al. (2005) noted that this species was seen during Japanese sighting surveys in the western North Pacific in August/September. Spinner dolphins are also known to occur in the East and South China seas off China and Taiwan (Perrin et al. 2005) and Hong Kong (Parsons et al. 1995; Jefferson and Hung 2007). To the best of our knowledge, there are no known estimates of abundance near the Shatsky Rise. However, the study area is within the known range of the offshore subspecies of spinner dolphins.

Striped Dolphin (*Stenella coeruleoalba*)

The striped dolphin has a cosmopolitan distribution in tropical to warm temperate waters (Perrin et al. 1994a) and is generally seen south of 43ºN (Archer 2002). It is typically found in waters outside the continental shelf and is often associated with convergence zones and areas of upwelling (Archer 2002). The striped dolphin is fairly gregarious (groups of 20 or more are common) and active at the surface (Whitehead et al. 1998). Mean group sizes were reported as 37 for Hawaii (Barlow 2006), 46 for the PICEAS area (Barlow et al. 2008), and 50 for the Galápagos Islands (Smith and Whitehead 1999). For the ETP, reported mean group sizes were 52–61 (Wade and Gerrodette 1993; Ferguson et al. 2006b; Jackson et al. 2008).

In Hawaii, the population size in 2002 was estimated at 13,143 (Barlow 2006), and in the ETP, the population size in 2006 was estimated at 964,362 (Gerrodette et al. 2008). The striped dolphin is expected to be one of the most abundant cetaceans in the proposed survey area; based on the SWFSC surveys and model used to calculate densities in the study area (see § VII), it is the third-ranked species

there. Striped dolphins have been seen just to the east of the proposed survey area during summer–fall surveys of the ETP in 1986–2006 (Wade and Gerrodette 1993; Ferguson and Barlow 2001; Gerrodette et al. 2008; Jackson et al. 2008). During the PICEAS survey in July–November 2005, at least 12 sightings were made near Palmyra Atoll (Barlow et al. 2008). Acoustic detections were also made in the PICEAS area and east of the proposed survey area (Barlow et al. 2008; Rankin et al. 2008).

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In the western North Pacific, striped dolphins are known to occur in the Philippines (Perrin et al. 2005), in the East and South China seas off China and Taiwan (Parsons et al. 1995; Zhou et al. 1995; Chou 2004; Perrin et al. 2005), Hong Kong (Parsons et al. 1995; Jefferson and Hung 2007), and Japan (Miyashita 1993a). In Japan, striped dolphins have been hunted in drive and harpoon fisheries for many decades (Kasuya 2007). The abundance estimate for striped dolphins in the western North Pacific is estimated at 570,000 (Miyashita 1993a). The striped dolphin was one of the most common dolphin species seen during Japanese summer sighting surveys in the western North Pacific (Miyashita 1993a). During these surveys, densities were highest in offshore areas between 35ºN and 40ºN, and in coastal waters of southeastern Japan (Miyashita 1993a). Striped dolphins were seen in the proposed Shatsky Rise study area in July, August, and September; survey effort in June was limited (Miyashita 1993a).

Fraser's Dolphin (*Lagenodelphis hosei*)

Fraser's dolphin is a tropical species found between 30°N and 30°S (Dolar 2009). It only occurs rarely in temperate regions, and then only in relation to temporary oceanographic anomalies such as El Niño events (Perrin et al. 1994b). The species typically occurs in deep, oceanic waters. In the ETP, most sightings were 45–100 km from shore in waters 1500–2500 m deep (Dolar 2009). Off Huahine and Tahiti (Society Islands), it was observed in waters 500–1500 m deep (Gannier 2000).

Fraser's dolphins travel in groups ranging from just a few animals to 100 or even 1000 (Perrin et al. 1994b). Wade and Gerrodette (1993) reported a mean group size of 395 for the ETP. Fraser's dolphins were seen during Japanese sighting surveys in the western North Pacific during August/September (Kato et al. 2005). Fraser's dolphins are also known to occur in the Philippines and in the East and South China seas off China and Taiwan (Perrin et al. 2005), as well as Hong Kong (Parsons et al. 1995; Jefferson and Hung 2007). In the eastern Sulu Sea adjacent to the Philippines, abundance is estimated at 8700 (Dolar 1999 *in* Perrin et al. 2003). Given its habitat preferences, the Shatsky Rise area is probably at the northern limit of the Fraser's dolphin's range. Therefore, it seems likely that any occurrence in the study area would be rare.

Short-beaked Common Dolphin (*Delphinus delphis*)

The common dolphin is found in tropical and warm temperate oceans around the world (Perrin 2002b). It ranges as far south as 40°S in the Pacific Ocean, is common in coastal waters 200–300 m deep, and is also associated with prominent underwater topography, such as seamounts (Evans 1994). There are two species of common dolphins: the short-beaked common dolphin (*Delphinus delphis*) and the long-beaked common dolphin (*D. capensis*). The short-beaked common dolphin is found in offshore

waters, and the long-beaked common dolphin is more prominent in coastal areas. Off northern New Zealand, the short-beaked common dolphin is generally seen at a mean distance <10 km from shore in the summer, but animals move further offshore in winter (Neumann 2001).

Common dolphins often travel in fairly large groups; schools of hundreds or even thousands are common. Smith and Whitehead (1999) noted that common dolphins were frequently seen in waters near the Galápagos Islands, with a mean group size of 125. Wade and Gerrodette reported a mean group size of 472.8 in the southern portion of the ETP.

There are no abundance estimates for *Delphinus* for the western Pacific. During Japanese sighting surveys in the western North Pacific in August/September, both long- and short-beaked common dolphins have been seen (Kato et al. 2005). As the short-beaked common dolphin is found in offshore waters, it is the most likely species of *Delphinus* to occur at the Shatsky Rise study area. Besides Japan, short-beaked common dolphins have also been reported to occur off Taiwan (Rudolph and Smeenk 2002).

Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*)

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). From surveys conducted in the North Pacific, Buckland et al. (1993) estimated that there were a total of 931,000 Pacific white-sided dolphins, and Miyashita (1993b) estimated an abundance of 988,000.

The species is common both on the high seas and along the continental margins (see Leatherwood et al. 1984; Dahlheim and Towell 1994; Ferrero and Walker 1996). Pacific white-sided dolphins often associate with other species, including cetaceans (especially Risso's and northern right whale dolphins; Green et al. 1993), pinnipeds, and seabirds. Pacific white-sided dolphins are very inquisitive and may approach stationary boats (Carwardine 1995).

Pacific-white sided dolphins have been seen during Japanese sighting surveys in the western North Pacific in August/September (Kato et al. 2005). During the 1970s and 1980s, Pacific white-sided dolphins were often killed as bycatch in the high-seas drift gillnet fisheries of the western North Pacific. Those fisheries ceased to operate following the United Nations moratorium in 1993. Although the estimates of abundance and levels of removal are not very precise, the number of Pacific white-sided dolphins in the western North Pacific was probably not highly depleted as a result of that bycatch (Hobbs and Jones 1993). Pacific white-sided dolphins are known to occur in the Shatsky Rise study area (Buckland et al 1993).

Northern Right Whale Dolphin (*Lissodelphis borealis*)

The northern right whale dolphin is found in cool temperate and sub-arctic waters of the North Pacific, ranging from 30°N to 50°N (Reeves et al. 2002). Their abundance has been estimated at 307,000 (Miyashita 1993b). In the North Pacific Ocean, the northern right whale dolphin is one of the most common marine mammal species, occurring primarily in shelf and slope waters ~100 m to >2000 m deep (see Green et al. 1993; Barlow 2003; Carretta et al. 2007). The northern right whale dolphin does, however, come closer to shore where there is deep water, such as over submarine canyons (Carwardine 1995; Reeves et al. 2002). Northern right whale dolphins are gregarious, and groups of several hundred to over a thousand dolphins are not uncommon (Reeves et al. 2002). They are often seen in mixed-species schools with Pacific white-sided dolphins.

Northern right whale dolphins were seen during Japanese sighting surveys in the western North Pacific in August/September (Kato et al. 2005). Like Pacific white-sided dolphins, northern right whale dolphins were killed in large numbers as bycatch in the high-seas drift gillnet fisheries of the western North Pacific. It seems likely that the number of northern right whale dolphins was noticeably reduced in

this region as a result. Although the magnitude of this reduction is uncertain, Mangel (1993) estimates that it is likely to have been 30% or less of the pre-exploitation numbers. Northern right whale dolphins are known to occur near the Shatsky Rise and are most likely to be encountered in the northern half of the study area (Buckland et al. 1993).

Risso's Dolphin (*Grampus griseus*)

Risso's dolphin is primarily a tropical and mid-temperate species distributed worldwide. It occurs between 60ºN and 60ºS, where surface water temperatures are at least 10ºC (Kruse et al. 1999). In the northern Gulf of Mexico, Risso's dolphin usually occurs over steeper sections of the upper continental slope (Baumgartner 1997) in waters 150–2000 m deep (Davis et al. 1998). In Monterey Bay, California, it is most numerous where there is steep bottom topography (Kruse et al. 1999). Risso's dolphins occur individually or in small to moderate-sized groups, normally ranging from 2 to <250. The majority of groups consist of <50 (Kruse et al. 1999; Miyashita 1993a). In the western North Pacific, Miyashita (1993a) reported groups of 1 to 200 individuals and a mean group size of 32.6. Wade and Gerrodette (1993) reported a mean group size of 12 in the ETP.

In the western Pacific, Risso's dolphins range from the Kuril Islands to New Zealand and Australia. In Japan, Risso's dolphins are hunted in small cetacean drive and hand harpoon fisheries, as well as small-type whaling operations (Kasuya 2007). Risso's dolphins are also known to occur in the Philippines, off mainland China in the Yellow, East, and South China seas (Perrin et al. 2005), and around Taiwan and Hong Kong (Parsons et al. 1995). The abundance in the western North Pacific has been estimated at 838,000 (Miyashita 1993a). Risso's dolphins were regularly seen during Japanese summer sighting surveys in the western North Pacific (Miyashita 1993a). Occurrence was patchy, but high densities were observed in coastal waters, between 148ºE–157ºE, and east of 162ºE (Miyashita 1993a). Risso's dolphins have been sighted in the proposed Shatsky Rise study area in August and September; effort in June and July was low, but they were also sighted near the study area during those months (Miyashita 1993a).

Melon-headed Whale (*Peponocephala electra*)

The melon-headed whale is a pantropical and pelagic species that occurs mainly between 20ºN and 20ºS in offshore waters (Perryman et al. 1994). Melon-headed whales tend to occur in groups of 100–500, but have also been seen in groups of up to 2000 (Jefferson et al. 2008). Wade and Gerrodette (1993) reported a mean group size of 199 for the ETP. Melon-headed whales are commonly seen in mixed groups with other cetaceans (Jefferson and Barros 1997).

Melon-headed whales have been seen during Japanese sighting surveys in the western North Pacific in August/September (Kato et al. 2005). In the western North Pacific, melon-headed whales are known to occur off mainland China in the East and South China seas, off Taiwan, and in the Philippines (Perrin et al. 2005). There is little information on abundance for this species near the Shatsky Rise. The study area is near the northern limit of its range; therefore, any occurrence would likely be rare.

Pygmy Killer Whale (*Feresa attenuata*)

The pygmy killer whale is distributed throughout tropical and subtropical oceans worldwide (Ross and Leatherwood 1994; Donahue and Perryman 2002). In warmer water, it is usually seen close to the coast (Wade and Gerrodette 1993), but it is also found in deep waters. In Hawaiian waters, the pygmy killer whale is found in nearshore waters, but not in the offshore waters (Barlow 2006). In the Marquesas, it was sighted in water 100 m deep (Gannier 2002). Pygmy killer whales tend to travel in groups of 15–50, although herds of a few hundred have been sighted (Ross and Leatherwood 1994). Wade and Gerrodette (1993) reported a mean group size of 27.9 in the ETP.

In the Northwest Pacific, the pygmy killer whale is frequently sighted off Hawaii and Japan (Donahue and Perryman 2002). Kato et al. (2005) reported the occurrence of this species during Japanese sighting surveys in the western North Pacific in August/September. The pygmy killer whale is also known to occur off mainland China in the East China Sea (Perrin et al. 2005), in Taiwan (Zhou et al. 1995; Chou 2004; Wang and Yang 2006), and in the Philippines (Perrin et al. 2005). There is little information on abundance for this species near the Shatsky Rise area. In general, pygmy killer whales are uncommon and are unlikely to be encountered during the proposed seismic survey.

False Killer Whale (*Pseudorca crassidens*)

The false killer whale is found in all tropical and warmer temperate oceans, especially in deep, off-shore waters (Odell and McClune 1999). However, it is also known to occur in nearshore areas (e.g., Stacey and Baird 1991). False killer whales travel in pods of 20–100 (Baird 2002), although groups of several hundred are sometimes observed. Groups of 1–40 animals were mostly seen during sighting surveys in the western North Pacific, although one group of ~500 animals was also sighted (Miyashita 1993a). Mean group sizes have been reported as 32.2 for the western North Pacific (Miyashita 1993a) and 11.4 for the ETP (Wade and Gerrodette 1993).

Nothing is known of the stock structure of false killer whales in the North Pacific Ocean (Miyashita 1993a). In the western Pacific, the false killer whale is distributed from Japan to Australia. The false killer whale is hunted in Japan (Kasuya 2007). It is also known to occur in the Philippines and in the Yellow, East, and South China seas off China and Taiwan (Perrin et al. 2005), and Hong Kong (Parsons et al. 1995; Jefferson and Hung 2007). The abundance estimate for the western North Pacific is 16,000 (Miyashita 1993a). False killer whales have been seen during Japanese summer sighting surveys (Miyashita 1993a). Distribution was patchy, with several high-density areas in offshore waters (Miyashita 1993a). False killer whales have been sighted in the proposed Shatsky Rise study area in August and September; survey effort was low in June and July, but animals were also seen near the study area during those months (Miyashita 1993a).

Killer Whale (*Orcinus orca*)

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

Very little is known about killer whale abundance and distribution in the western Pacific Ocean. Miyashita and Kato (2005 *in* Kato et al. 2005) provided an abundance estimate of 720 for the Sea of Okhotsk. Kato et al. (2005) reported sightings of this species during Japanese sighting surveys in the western North Pacific in August/September. Killer whales are also known to occur off China in the Yellow and East China seas (Zhou et al. 1995; Perrin et al. 2005), off Taiwan (Zhou et al. 1995; Chou 2004; Chou et al. 2007), and in the Philippines (Perrin et al. 2005). It is possible that killer whales could be encountered during the Shatsky Rise survey.

Short-finned Pilot Whale (*Globicephala macrorhynchus*)

The short-finned pilot whale is found in tropical and warm temperate waters (Olson and Reilly 2002); it is seen as far south as ~40ºS, but is more common north of ~35ºS (Olson and Reilly 2002). Pilot

whales occur on the shelf break, over the slope, and in areas with prominent topographic features; they are usually seen in groups of 20–90 (Olson and Reilly 2002). In the western North Pacific, Miyashita (1993a) reported sightings of 10–300 animals, although most sightings were of groups with <100 animals. 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). 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).

In the western North Pacific, short-finned pilot whales are known to occur off mainland China in the South China Sea (Perrin et al. 2005), Taiwan (Miyashita et al. 1995 *in* Zhou et al. 1995; Chou 2004), the Philippines (Acebes et al. 2000 *in* Perrin et al. 2005; Acebes and Lesaca 2003; Perrin et al. 2005), and Japan (Miyashita 1993a). In Japan, they are taken by whalers in the drive fishery (Kasuya 2007). The abundance of short-finned pilot whales has been estimated at 53,000 for the western North Pacific (Miyashita 1993a). Stock structure of short-finned pilot whales has not been adequately studied in the North Pacific, except in Japanese waters, where two stocks have been identified based on pigmentation patterns and head shape differences of adult males (Kasuya et al. 1988). The southern stock of short-finned pilot whales has been observed during Japanese summer sightings surveys (Miyashita 1993a). Distribution of short-finned pilot whales in the western North Pacific was patchy, but high densities were observed in coastal waters of central and southern Japan and in some areas offshore (Miyashita 1993a). Short-finned pilot whales have also been seen in the proposed Shatsky Rise survey area in August and September; survey effort in June and July was low, but animals were also seen near the study area during those months (Miyashita 1993a).

Dall's Porpoise (*Phocoenoides dalli*)

Dall's porpoise is only found in the North Pacific and adjacent seas. It is widely distributed across the North Pacific 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. 1993). Dall's porpoises usually occur in small groups of 2 to 12 individuals, characterized by fluid associations (Reeves et al. 2002). Dall's porpoises are fast-swimming and active porpoises, and readily approach vessels to ride the bow wave.

Buckland et al. (1993) provided an abundance estimate of 1.3 million Dall's porpoises for the North Pacific, and Miyashita (1991) estimated the abundance in the Sea of Okhotsk at 443,000. In the western North Pacific, there are two different color morphs that are also considered sub-species: the *truei*-type and the *dalli*-type. They can be distinguished from each other by the extent of their white thoracic patches—the *truei*-type has a much broader patch, which extends nearly the length of the body. They were one of the most common cetaceans in the bycatch of the central and western North Pacific high-seas driftnet fisheries, but that source of mortality is not thought to have substantially depleted their abundance in the region (Hobbs and Jones 1993). Currently, Dall's porpoises are hunted using hand harpoons by Japanese whalers, with annual catch quotas of 17,300 animals from stocks that summer in the Okhotsk Sea (Kasuya 2007). Dall's porpoise (of the *dalli*-type) that are known to occur at Shatsky Rise during summer are from a different stock than those that summer in the Okhotsk Sea.

Pinniped

Northern Fur Seal (*Callorhinus ursinus*)

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. Two stocks are recognized, 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. The population of northern fur seals has declined from a peak of ~2.1 million in the 1950s to ~1.1 million in 2004-2005 (Gelatt and Lowry 2008). The population estimate for the eastern Pacific stock in 2008 was ~665,550 (Allen and Angliss 2010).

During the breeding season, 74% of the worldwide population of northern fur seals inhabits the Pribilof Islands in the southern Bering Sea (Lander and Kajimura 1982). A small percentage of seals breed at San Miguel Island off southern California. When not on rookery islands, northern fur seals are primarily pelagic but occasionally haul out on rocky shorelines. During the breeding season, adult males usually come ashore in May–August and may sometimes be present until November, and adult females are found ashore from June to November (Carretta et al. 2007). After reproduction, northern fur seals spend the next 7–8 months feeding at sea (Roppel 1984). Once weaned, juveniles spend 2–3 years at sea before returning to the rookeries. During that time, animals may migrate off Japan and California. The southern extent of the migration is about 35ºN. Northern fur seals have been sighted in the Shatsky Rise area (Buckland et al. 1993). However, it is likely that any occurrence at Shatsky Rise would be rare.

V. TYPE OF INCIDENTAL TAKE AUTHORIZATION REQUESTED

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

L-DEO requests an IHA pursuant to Section 101 (a)(5)(D) of the Marine Mammal Protection Act (MMPA) for incidental take by harassment during its planned seismic survey in the northwestern Pacific Ocean during March–April 2012.

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 northwestern Pacific Ocean during March–April 2012. 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 and toothed whales have been shown to react behaviorally to airgun pulses under some conditions, at other times mammals of both types have shown no overt reactions. The relative responsiveness of baleen and toothed whales are quite 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 μPa·m_{p-p}. McCauley et al. (1998) documented that avoidance reactions began at 5–8 km from the array, and that those reactions kept most pods ~3–4 km from the operating seismic boat. McCauley et al. (2000a) noted localized displacement during migration of 4–5 km by traveling pods and 7–12 km by more sensitive resting pods of cow-calf pairs. Avoidance distances with respect to the single airgun were smaller but consistent with the results from the full array in terms of the received sound levels. The mean received level for initial avoidance of an approaching airgun was 140 dB re 1 μPa_{rms} for humpback pods containing females, and at the mean closest point of approach (CPA) distance the received level was 143 dB re 1 μPa_{rms}. The initial avoidance response generally occurred at distances of 5–8 km from the airgun array and 2 km from the single airgun. However, some individual humpback whales, especially males, approached within distances of 100–400 m, where the maximum received level was 179 dB re 1 μPa_{rms}.

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

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

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

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

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

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

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

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

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

Smultea et al. 2004; Moulton and Miller 2005; Bain and Williams 2006; Holst et al. 2006; Stone and Tasker 2006; Potter et al. 2007; Hauser et al. 2008; Holst and Smultea 2008; Weir 2008; Barkaszi et al. 2009; Richardson et al. 2009; Moulton and Holst 2010).

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

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

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

Most studies of sperm whales exposed to airgun sounds indicate that the sperm whale shows considerable tolerance of airgun pulses (e.g., Stone 2003; Stone and Tasker 2006; Weir 2008; Moulton and Holst 2010). In most cases the whales do not show strong avoidance, and they continue to call (see Appendix B of the EA for review). However, controlled exposure experiments in the Gulf of Mexico indicate that foraging behavior was altered upon exposure to airgun sound (Jochens et al. 2008; Miller et al. 2009; Tyack 2009).

There are almost no specific data on the behavioral reactions of beaked whales to seismic surveys. However, some northern bottlenose whales remained in the general area and continued to produce high-frequency clicks when exposed to sound pulses from distant seismic surveys (Gosselin and Lawson 2004; Laurinolli and Cochrane 2005; Simard et al. 2005). Most beaked whales tend to avoid approaching vessels of other types (e.g., Würsig et al. 1998). They may also dive for an extended period when approached by a vessel (e.g., Kasuya 1986), although it is uncertain how much longer such dives may be as compared to dives by undisturbed beaked whales, which also are often quite long (Baird et al. 2006; Tyack et al. 2006). Based on a single observation, Aguilar-Soto et al. (2006) suggested that foraging efficiency of Cuvier's beaked whales may be reduced by close approach of vessels. In any event, it is likely that most beaked whales would also show strong avoidance of an approaching seismic vessel,

although this has not been documented explicitly. In fact, Moulton and Holst (2010) reported 15 sightings of beaked whales during seismic studies in the Northwest Atlantic; seven of those sightings were made at times when at least one airgun was operating. There was little evidence to indicate that beaked whale behavior was affected by airgun operations; sighting rates and distances were similar during seismic and non-seismic periods (Moulton and Holst 2010).

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

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

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

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 should not be exposed to impulsive sounds with received levels ≥180 dB re 1 μPa_{rms} (NMFS 2000). This criterion has been used in establishing the exclusion (=shut-down) zones planned for the proposed seismic survey. However, this criterion was 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 have been published (Southall et al. 2007). Those recommendations have not, as of mid 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 cetaceans and (to a limited degree) sea turtles show some avoidance of the area where received levels of airgun sound are high enough such that hearing impairment could potentially occur. In those cases, the avoidance responses of the animals themselves will reduce or (most likely) avoid any possibility of hearing impairment.

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might (in theory) occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, and other types of organ or tissue damage. It is possible that some marine mammal species (i.e., beaked whales) may be especially susceptible to injury and/or stranding when exposed to strong transient sounds. However, as discussed below, there is no definitive evidence that any of these effects occur even for marine mammals in close proximity to large arrays of airguns. It is unlikely that any effects of these types would occur during the present project given the brief duration of exposure of any given mammal, 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). Based on these data, the received energy level of a single seismic pulse (with no frequency weighting) might need to be ~186 dB re 1 $\mu Pa^2 \cdot s$ (i.e., 186 dB SEL or ~196–201 dB re 1 μPa_{rms}) in order to produce brief, mild TTS[1]. Exposure to several strong seismic pulses that each have received levels near 190 dB re 1 μPa_{rms} might result in cumulative exposure of ~186 dB SEL and thus slight TTS in a small odontocete assuming the TTS threshold is (to a first approximation) a function of the total received pulse energy; however, this 'equal-energy' concept is an oversimplification. The distances from the *Langseth*'s airguns at which the received energy level (per pulse, flat-weighted) would be expected to be ≥190 dB re 1 μPa_{rms} are estimated in Table 1. Levels ≥190 dB re 1 μPa_{rms} are expected to be restricted to radii no more than 235 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 $\mu Pa^2 \cdot s$ (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

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

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 note 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 and sea turtles. The planned monitoring and mitigation measures, including visual monitoring, passive acoustic monitoring (PAM) to complement visual observations (if practicable), power downs, and shut downs of the airguns when mammals are seen within or approaching the "exclusion zones", will further reduce the probability of exposure of marine mammals to sounds strong enough to induce PTS.

Stranding and Mortality.—Marine mammals close to underwater detonations of high explosives can be killed or severely injured, and the auditory organs are especially susceptible to injury (Ketten et al. 1993; Ketten 1995). However, explosives are no longer used for marine 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 pulses, occurring for 2–15 ms once every 5–20 s, depending on water depth. Most of the energy in the sound emitted by this MBES is at frequencies near 12 kHz, and the maximum source level is 242 dB re 1 $\mu Pa_{rms} \cdot m$. The beam is narrow (1–2º) in fore-aft extent and wide (150º) in the cross-track extent. Each ping consists of eight (in water >1000 m deep) or four (<1000 m deep) successive fan-shaped transmissions (segments) at different cross-track angles. Any given mammal at depth near the trackline would be in the main beam for only one or two of the segments. Also, marine mammals that encounter the Kongsberg EM 122 are unlikely to be subjected to repeated pulses because of the narrow fore–aft width of the beam and will receive only limited amounts of pulse energy because of the short pulses. Animals close to the ship (where the beam is narrowest) are especially unlikely to be ensonified for more than one 2–15 ms pulse (or two pulses if in the overlap area). Similarly, Kremser et al. (2005) noted that the probability of a cetacean swimming through the area of exposure when an MBES emits a pulse is

small. The animal would have to pass the transducer at close range and be swimming at speeds similar to the vessel in order to receive the multiple pulses that might result in sufficient exposure to cause TTS.

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

Masking

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

Behavioral Responses

Behavioral reactions of free-ranging marine mammals to sonars, echosounders, and other sound sources appear to vary by species and circumstance. Observed reactions have included silencing and dispersal by sperm whales (Watkins et al. 1985), increased vocalizations and no dispersal by pilot whales (Rendell and Gordon 1999), and the previously-mentioned beachings by beaked whales. During exposure to a 21–25 kHz "whale-finding" sonar with a source level of 215 dB re 1 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 L-DEO, and to shorter broadband pulsed signals. Behavioral changes typically involved what appeared to be deliberate attempts to avoid the sound exposure (Schlundt et al. 2000; Finneran et al. 2002; Finneran and Schlundt 2004). The relevance of those data to free-ranging odontocetes is uncertain, and in any case, the test sounds were quite different in duration as compared with those from an MBES.

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

Hearing Impairment and Other Physical Effects

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

horizontally-directed sound. Those factors would all reduce the sound energy received from the MBES rather drastically relative to that from the sonars used by the navy.

Given the maximum source level of 242 dB re 1 $\mu Pa \cdot m_{rms}$ (see § I), the received level for an animal within the MBES beam 100 m below the ship would be ~202 dB re 1 μPa_{rms}, assuming 40 dB of spreading loss over 100 m (circular spreading). Given the narrow beam, only one pulse is likely to be received by a given animal as the ship passes overhead. The received energy level from a single pulse of duration 15 ms would be about 184 dB re 1 $\mu Pa^2 \cdot s$, i.e., 202 dB + 10 log (0.015 s). That is below the TTS threshold for a cetacean receiving a single non-impulse sound (195 dB re 1 $\mu Pa^2 \cdot s$) and even further below the anticipated PTS threshold (215 dB re 1 $\mu Pa^2 \cdot s$) (Southall et al. 2007). In contrast, an animal that was only 10 m below the MBES when a ping is emitted would be expected to receive a level ~20 dB higher, i.e., 204 dB re 1 $\mu Pa^2 \cdot s$ in the case of the 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 pulses, occurring for up to 64 ms once every second. Most of the energy in the sound pulses emitted by the SBP is at 3.5 kHz, and the beam is directed downward. The sub-bottom profiler on the *Langseth* has a maximum source level of 222 dB re 1 $\mu Pa \cdot m$ (see § I). Kremser et al. (2005) noted that the probability of a cetacean swimming through the area of exposure when a bottom profiler emits a pulse is small—even for an SBP more powerful than that on the *Langseth*—if the animal was in the area, it would have to pass the transducer at close range and in order to be subjected to sound levels that could cause TTS.

Masking

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

Behavioral Responses

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

Hearing Impairment and Other Physical Effects

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

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 36-airgun array to be used during ~1216 km of seismic surveys in the northwestern Pacific Ocean. 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"

Density data on 18 marine mammal species in the Shatsky Rise area are available from two sources using conventional line transect methods: Japanese sighting surveys conducted since the early 1980s, and fisheries observers in the high-seas driftnet fisheries during 1987–1990 (Table 3). For the 16 other marine mammal species that could be encountered in the proposed survey area, data from the western North Pacific are not available (Table 3). We are not aware of any density estimates for three of those species—Hubb's, Stejneger's, and gingko-toothed beaked whales. For the remaining 13 species (Table 3), density estimates are available from other areas of the Pacific: 11 species from the offshore stratum of the 2002 Hawaiian Islands survey (Barlow 2006) and two species from surveys of the California Current ecosystem off the U.S. west coast between 1991 and 2005 (Barlow and Forney 2007). Those estimates are based on standard line-transect protocols developed by NMFS Southwest Fisheries Science Center (SWFSC).

Densities for 14 species are available from Japanese sighting surveys in the Shatsky Rise survey area. Miyashita (1993a) provided estimates for six dolphin species in this area that have been taken in the Japanese drive fisheries. The densities used here are Miyashita's (1993a) estimates for the 'Eastern offshore' survey area (30–42°N, 145°E–180°). Kato and Miyashita (1998) provided estimates for sperm whale densities from Japanese sightings data during 1982–1996 in the western North Pacific (0–50°N, 130°E–180°), and Hakamada et al. (2004) provided density estimates for sei whales during August–September in the JARPN II sub-areas 8

TABLE 3. Densities of marine mammals from various sources (see text for rationale and details): Japanese sighting surveys in the western North Pacific, North Pacific driftnet fisheries observer coverage, and NMFS surveys offshore from Hawaii or the U.S. west coast. Species listed as endangered under the ESA are in italics. N.A. means not available.

	Density (#/1000 km^2)		
Species	**Density**	**CV[1]**	**Source**
Mysticetes			
North Pacific right whale	*0.04*	*N.A.*	*Western North Pacific*[2]
Humpback whale	*0.47*	*N.A.*	*Western North Pacific*[2]
Minke whale	2.51	0.58	Western North Pacific[3]
Bryde's whale	0.52	0.64	Western North Pacific[4]
Sei whale	*1.78*	*0.28*	*Western North Pacific*[5]
Fin whale	*0.74*	*N.A.*	*Western North Pacific*[2]
Blue whale	*0.39*	*N.A.*	*Western North Pacific*[2]
Odontocetes			
Sperm whale	*1.04*	*0.11*	*Western North Pacific*[6]
Pygmy sperm whale	3.19	1.12	Offshore Hawaii[7]
Dwarf sperm whale	7.82	0.74	Offshore Hawaii[7]
Cuvier's beaked whale	6.80	1.43	Offshore Hawaii[7]
Baird's beaked whale	0.88	0.37	CA/OR/WA[8]
Longman's beaked whale	0.45	1.26	Offshore Hawaii[7]
Blainville's beaked whale	1.28	1.25	Offshore Hawaii[7]
Mesoplodon spp.[9]	0.01	N.A.	N.A.
Rough-toothed dolphin	3.12	0.45	Offshore Hawaii[7]
Bottlenose dolphin	23.99	0.34	Western North Pacific[10]
Pantropical spotted dolphin	70.41	0.19	Western North Pacific[10]
Spinner dolphin	0.83	0.74	Offshore Hawaii[7]
Striped dolphin	119.07	0.18	Western North Pacific[10]
Fraser's dolphin	4.57	1.16	Offshore Hawaii[7]
Short-beaked common dolphin	309.35	0.18	CA/OR/WA[8]
Pacific white-sided dolphin	36.40	N.A.	North Pacific[11]
Northern right whale dolphin	0.41	N.A.	North Pacific[11]
Risso's dolphin	10.8	0.27	Western North Pacific[10]
Melon-headed whale	1.32	1.17	Offshore Hawaii[7]
Pygmy killer whale	0	-	Offshore Hawaii[7]
False killer whale	2.05	0.34	Western North Pacific[10]
Killer whale	0.16	0.98	Offshore Hawaii[7]
Short-finned pilot whale	5.00	0.38	Western North Pacific[10]
Dall's porpoise	21.94	N.A.	North Pacific[11]
Pinnipeds			
Northern fur seal	1.79	N.A.	North Pacific[11]

[1]CV (Coefficient of Variation) is a measure of a number's variability, as given by the authors of the density documents. The larger the CV, the higher the variability.
[2] Matsuoka et al. (2009).
[3] Hakamada et al. (2009).
[4] Kitakado et al. (2008).
[5] Hakamada et al. (2004).
[6] Kato and Miyashita (1998).
[7] Barlow (2006).
[8] California/Oregon/Washington (Barlow and Forney 2007).
[9] Could include ginkgo-toothed, Stejneger's, or Hubb's beaked whales; density (N.A.) is an arbitrary low value.
[10] Miyashita (1993a).
[11] Buckland et al. (1993).

and 9 (35–50ºN, 150–170ºE excluding waters in the EEZ of Russia) during 2002–2003. We used density estimates during May–June 2006 and 2007 for minke whales at 35–40ºN, 157–170ºE from Hakamada et al. (2009), density estimates during 1998–2002 for Bryde's whales at 31–43ºN, 145–165ºE from Kitakado et al. (2008), and density estimates during 1994–2007 for blue, fin, humpback, and North Pacific right whales at 31–51ºN, 140–170ºE calculated from data in Matsuoka et al. (2009).

For four species (northern fur seal, Dall's porpoise, Pacific white-sided dolphin, northern right-whale dolphin), estimates of densities in the Shatsky Rise area are available from sightings data collected by observers in the high-seas driftnet fisheries during 1987–1990 (Buckland et al. 1993). Those data were analysed for 5° x 5° blocks, and the densities used here are from blocks for which available data overlap the proposed survey area. In general, those data represent the average annual density in the northern half of the Shatsky Rise survey area (35–40°N).

The densities mentioned above had been corrected by the original authors for detectability bias and, with the exception of Kitakado et al. 2008 and Hakamada et al. 2009, for availability bias. Detectability bias is associated with diminishing sightability with increasing lateral distance from the track line [$f(0)$]. Availability bias refers to the fact that there is <100% probability of sighting an animal that is present along the survey track line, and it is measured by $g(0)$. Densities calculated from effort, sightings, and mean group sizes in Matsuoka et al. (2009) used a value for $f(0)$ of 0.682 from Hakamada et al. (2009) for the same surveys, and a value for $g(0)$ of 0.921 from Barlow and Forney (2007).

There is some uncertainty about the representativeness of the density data and the assumptions used in the calculations. The available densities in Miyashita (1993a) and Buckland et al. (1993) are from the 1980s; although these densities represent the best available information for the Shatsky Rise area at present, they will be biased if abundance or distributions of those species have changed since the data were collected. Therefore, there is uncertainty with respect to the expected marine mammal densities during this time. However, the approach used here is based on the best available data.

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

It should be noted that the following estimates of exposures to various sound levels assume that the surveys will be fully completed; in fact, the ensonified areas calculated using the planned number of line-kilometers ***have been increased by 25%*** to accommodate turns, lines that may need to be repeated equipment testing, etc. As is typical during 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-dB re 1 μPa_{rms} sounds are precautionary, and probably overestimate the actual numbers of marine mammals that might be involved. These estimates assume that there will be no weather, equipment, or mitigation delays, which is highly unlikely.

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

Potential Number of Marine Mammals Exposed to ≥160 dB

The number of different individual cetaceans 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 majority of seismic lines are widely spaced in the survey area, so few individual mammals would be exposed numerous times during the survey; the area including overlap is only 1.01 x the area excluding overlap. Thus, an average individual marine mammal would be exposed only once during the survey. Moreover, it is unlikely that a particular animal would stay in the area during the entire survey.

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

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

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

Applying the approach described above, ~9229 km^2 would be within the 160-dB isopleth on one or more occasions during the survey (11,536 km^2 including the 25% contingency). 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 § IV a).

Table 4 shows the estimates of the number of different individual cetaceans 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*** is given in the far right column of Table 4. For ***endangered*** species, the ***Requested Take Authorization*** has been increased to the mean group size for the particular species in cases where the calculated number of individuals exposed was between 0.05 and the mean group size (i.e., for the North Pacific right whale). For non-listed species, the ***Requested Take Authorization*** has been increased to the mean group size for the particular species in cases where the calculated number of individuals exposed was between 1 and the mean group size. Group sizes are from the sources listed in Table 3.

Number of Cetaceans that could be Exposed to ≥160 dB.— The estimate of the number of individual cetaceans that could be exposed to seismic sounds with received levels ≥160 dB re 1 μPa_{rms} during the proposed survey is 7354 (Table 4). That total includes 74 baleen whales, 39 of which are ***endangered***: 5 humpback whales or 0.53% of the regional population, 21 sei whales (0.21%), 9 fin whales (0.05%), and 4 blue whales (0.13%) (Table 4).

In addition, 12 sperm whales (also listed as ***endangered under*** the ESA) or 0.04% of the regional population could be exposed during the survey, and 108 beaked whales including Cuvier's, Longman's, Baird's, and Blainville's beaked whales (Table 4). Most (96%) of the cetaceans potentially exposed are delphinids; short-beaked common, striped, pantropical spotted, and Pacific white-sided dolphins are

TABLE 4. Estimates of the possible numbers of marine mammals exposed to different sound levels during L-DEO's proposed seismic survey at the Shatsky Rise during March–April 2012. The proposed sound source is a 36-airgun array with a discharge volume of ~6600 in³. Received levels of airgun sounds are expressed in dB re 1 µPa (rms, averaged over pulse duration), consistent with NMFS' practice. Not all marine mammals will change their behavior when exposed to these sound levels, but some may alter their behavior when levels are lower (see text). Species in italics are listed under the ESA as *endangered*.

Species	Number of Individuals Exposed to Sound Levels >160 dB		Requested Take Authorization
	Number[1]	% Regional Pop'n[2]	
North Pacific right whale	*0*	*0.23*	*2*[3]
Humpback whale	*5*	*0.53*	*5*
Minke whale	29	0.12	29
Bryde's whale	6	0.03	6
Sei whale	*21*	*0.21*	*21*
Fin whale	*9*	*0.05*	*9*
Blue whale	*4*	*0.13*	*4*
Sperm whale	*12*	*0.04*	*12*
Pygmy sperm whale	37	N.A.	37
Dwarf sperm whale	90	<0.01	90
Cuvier's beaked whale	78	0.39	78
Baird's beaked whale	10	N.A.	10
Longman's beaked whale	5	N.A.	18[3]
Blainville's beaked whale	15	0.06	15
Mesoplodon spp.[4]	0	<0.01	0
Rough-toothed dolphin	36	0.02	36
Bottlenose dolphin	277	0.16	277
Pantropical spotted dolphin	812	0.19	812
Spinner dolphin	10	<0.01	32[3]
Striped dolphin	1374	0.24	1374
Fraser's dolphin	53	0.02	286[3]
Short-beaked common dolphin	3569	0.12	3569
Pacific white-sided dolphin	420	0.04	420
Northern right whale dolphin	5	<0.01	5
Risso's dolphin	125	0.01	125
Melon-headed whale	15	0.03	89[3]
Pygmy killer whale	0	<0.01	0
False killer whale	24	0.15	24
Killer whale	2	0.02	7[3]
Short-finned pilot whale	58	0.11	65[3]
Dall's porpoise	253	0.02	253
Northern fur seal	21	<0.01	21

[1] Estimates are based on densities in Table 3 and an ensonified area (including 25% contingency 11,536 km²).
[2] Regional population size estimates are from Table 3; NA means not available.
[3] Requested Take Authorization increased to mean group size from density sources in Table 4.
[4] Could include ginkgo-toothed, Stejneger's, or Hubb's beaked whales; density (not available) is an arbitrary low value

estimated to be the most common species in the area, with estimates of 3569 (0.12% of the regional population), 1374 (0.24%), 812 (0.19%), and 420 (0.04%) exposed to ≥160 dB re 1 μPa_{rms}, respectively.

Number of Pinnipeds that could be Exposed to ≥160 dB.— The only pinniped species that could occur in the offshore waters of the survey area is the northern fur seal. As summarized in § IV(1)(a) and Appendix B, some studies suggest that most pinnipeds, like delphinids, may be less sensitive to airgun sounds than mysticetes.

The methods described previously for cetaceans were also used to calculate the numbers of individual northern fur seals that may be exposed during the survey. Based on the estimated density, ~21 northern fur seals could be exposed to airgun sounds ≥160 dB re 1 μPa_{rms}.

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. If mysticetes are encountered, the numbers estimated to occur within the 160-dB isopleth in the survey area are expected to be relatively low.

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".

Estimates of the numbers of marine mammals that might be exposed to airgun sounds ≥160 dB re 1 μPa_{rms} during the proposed program have been presented with a corresponding requested "take authorization" for each species. Those figures likely overestimate the actual number of animals that will be exposed to and will react to the seismic sounds. The reasons for that conclusion are outlined above. The relatively short-term exposures are unlikely to result in any long-term negative consequences for the individuals or their populations.

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

Pinnipeds.— Only one pinniped species—the northern fur seal—is likely to occur in the offshore waters of the survey area. An estimate of 21 northern fur seals could be exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms}. As for cetaceans, the estimated numbers of pinnipeds that may be exposed to received levels ≥160 dB are probably overestimates of the actual numbers that will be affected significantly. Any effects are expected to be short-term, with no lasting biological consequence.

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 subsistence hunting for eastern North Pacific gray whales by natives of Chukotka, Russia. However, the study area is located far from Chukotka in offshore waters, 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 giant squid strandings were caused by exposure to commercial seismic survey activities (Guerra et al. 2004), but there was little evidence to support the claim. André et al. (2011) exposed cephalopods, primarily cuttlefish, to continuous 50–400 Hz sinusoidal wave sweeps for two hours while captive in relatively small tanks, and reported morphological and ultrastructural evidence of massive acoustic trauma (i.e., permanent and substantial alterations of statocyst sensory hair cells). The received SPL was reported as 157±5 dB re 1µPa, with peak levels at 175 dB re 1µPa. As in the McCauley et al. (2003) paper on sensory hair cell damage in pink snapper as a result of exposure to seismic sound, the cephalopods were subjected to higher sound levels than they would be under natural conditions, and they were unable to swim away from the sound source.

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

Planning Phase

This survey was originally proposed and initiated in 2010. NEPA documentation pursuant to EO 12114 was prepared for the proposed survey, an ESA Section 7 consultation was completed, and an

Incidental Harassment Authorization was obtained. During the survey, the scientific work was disrupted twice by medical diversions to Japan, each of which took about a week because of the remoteness of the study area, and as a result, the study remained unfinished.

Subsequently, the PIs worked with L-DEO and NSF to identify potential time periods to complete the survey, taking into consideration key factors such as environmental conditions (i.e., the seasonal presence of marine mammals, sea turtles, and seabirds), weather conditions, equipment, and optimal timing for other proposed seismic surveys using the R/V *Langseth*. As was determined necessary for the 2010 survey, the PIs confirmed that use of the 36-airgun array with a total volume of ~6600 in^3 would still be required to achieve the project research goals; given the research goals, location of the survey and associated deep water, this energy source level was still viewed appropriate.

Most marine mammal species are expected to occur in the area year-round, therefore altering the timing of the proposed project from the original survey timeframe likely would result in no changes in the potential impacts to marine species noted in the original 2010 survey environmental analysis. The environmental analysis prepared for the 2010 survey formed the basis for this assessment, but has been updated to reflect current scientific information and the revisions to the proposed survey and timing. The environmental analysis prepared for this proposed 2012 survey will also be open for a public comment period, an IHA application will be submitted to NMFS, and ESA Section 7 consultation will be requested.

Proposed Exclusion Zones

Received sound levels have been predicted by L-DEO's model, 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 have been 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). Results of the propagation measurements showed that radii around the airguns for various received levels varied with water depth (Tolstoy et al. 2009). In addition, propagation varies with array tow depth. The empirical values that resulted from Tolstoy et al. (2009) are used here to determine exclusion zones for the 36-airgun array. However, 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-, 180-, and 190-dB distances from the modeled results for the 6600-in^3 airgun array towed at 6 m vs. 9 m, from LGL (2008): 1.285; 1.338; and 1.364, respectively.

Using the corrected measurements (array) or model (single airgun), Table 1 shows the distances at which three 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; Holst 2009; Antochiw et al. n.d.). If marine mammals or sea turtles are detected within or about to enter the appropriate exclusion zone, the airguns will be powered down (or shut down if necessary) immediately (see below).

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

Mitigation During Operations

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

Power-down Procedures

A power down involves decreasing the number of airguns in use such that the radius of the 180-dB (or 190-dB) zone is decreased to the extent that marine mammals or turtles are no longer in or about to enter the EZ. A power down of the airgun array 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 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. During past R/V *Langseth* marine geophysical surveys, following an extended power-down period, the seismic source followed ramp-up procedures to return to the full seismic source level. Under a power-down scenario, however, a single mitigation airgun still would be operating to alert and warn animals of the on-going activity. Furthermore, under these circumstances, ramp-up procedures may unnecessarily extend the length of the survey time needed to collect seismic data. LDEO, NSF, and NMFS have discussed this mitigation practice and have concluded that a ramp-up procedure following an extended power down is not necessary. This assessment therefore does not include this practice as part of the monitoring and mitigation plan.

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 survey, 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 average planned speed of the *Langseth* while shooting (7.4 km/h). Similar periods (~8–10 min) were used during previous L-DEO surveys. Ramp up will not occur if a marine mammal or sea turtle has not cleared the safety zone as described earlier.

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 EZ, 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 night.

As noted above under "Power-down Procedures", during past R/V *Langseth* marine geophysical surveys, following an extended power-down period, the seismic source followed ramp-up procedures to return to the full seismic source level. Under a power-down scenario, however, a single mitigation airgun still would be operating to alert and warn animals of the on-going activity. Furthermore, under these circumstances, ramp-up procedures may unnecessarily extend the length of the survey time needed to collect seismic data. LDEO, NSF, and NMFS have discussed this mitigation practice and have concluded that a ramp-up procedure following an extended power down is not necessary. This assessment therefore does not include this practice as part of the monitoring and mitigation plan.

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 northwestern Pacific Ocean, and no activities will take place in or near a traditional Arctic subsistence hunting area.

XIII. MONITORING AND REPORTING PLAN

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

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

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

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

Vessel-based Visual Monitoring

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

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

The *Langseth* is a suitable platform for marine mammal and turtle observations. When stationed on the observation platform, the eye level will be ~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.

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

One acoustic PSO or PSAO (in addition to the 4 visual PSOs) will be on board. The towed hydrophones will ideally be monitored 24 h per day while at the seismic survey area during airgun operations, and during most periods when the *Langseth* is underway while the airguns are not operating. However, PAM may not be possible if damage occurs to the array or back-up systems during operations. One PSO will monitor the acoustic detection system at any one time, by listening to the signals from two channels via headphones and/or speakers and watching the real-time spectrographic display for frequency ranges produced by cetaceans. The PSAO monitoring the acoustical data will be on shift for 1–6 h at a time. All observers 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 PSAO 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.

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.

L-DEO and NSF will coordinate the planned marine mammal monitoring program associated with the seismic survey with other parties that may have interest in this area. L-DEO and NSF will coordinate with applicable U.S. agencies (e.g., NMFS), and will comply with their requirements.

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