Request by Scripps Institution of Oceanography for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during a Low-Energy Marine Seismic Survey in the Western Tropical Pacific Ocean, November–December 2011

submitted by

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to

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SUMMARY

The oceanographic research vessel R/V *Thomas G. Thompson* is operated by the University of Washington (UW) under a charter agreement with the U.S. Office of Naval Research (ONR). The title of the vessel is held by the U.S. Navy. Scripps Institution of Oceanography (SIO), a part of the University of California, in collaboration with UW, Woods Hole Oceanographic Institution (WHOI), Texas A&M University (TAMU), and Kutztown University, plans to conduct a magnetic and seismic study of the Hawaiian Jurassic crust_onboard the R/V *Thompson* in the western tropical Pacific Ocean north of the Marshall Islands for ~32 days in November–December 2011. The survey will use a pair of GI airguns, each with a discharge volume of 105 in^3. SIO 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). The seismic survey will be conducted in partly in International Waters and partly in the Exclusive Economic Zone (EEZ) of Wake Island (U.S.), and possibly partly in the EEZ of the Republic of the Marshall Islands.

Numerous species of cetaceans and pinnipeds occur in the western tropical Pacific Ocean. Several of these species are listed as ***endangered*** under the U.S. Endangered Species Act (ESA), including the humpback, fin, blue, and sperm whales, and the Hawaiian monk seal. SIO is proposing a marine mammal monitoring and mitigation program to minimize the potential impacts of the proposed activity on marine mammals present during conduct of the proposed research, and to document the nature and extent of any effects.

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

The Principal Investigators (PIs) plan to conduct a seismic survey in the western tropical Pacific as part of an integrated magnetic and seismic study of the Hawaiian Jurassic crust (Fig. 1). The survey is scheduled to take place for ~32 days in November–December 2011.

The goal of the proposed research is to define the global nature and significance of variations in intensity and direction of the Earth's magnetic field during the Jurassic time period (~145–180 million years ago), which appears to have been a period of sustained low intensity and rapid directional changes or polarity reversals compared to other periods in Earth's magnetic field history. Access to Jurassic-aged crust with good magnetic signals is very limited, with the best continuous records in ocean crust, but only one area of the ocean floor has been measured to date: the western Pacific Japanese magnetic lineations. To properly assess the global significance of the variations and to eliminate local crustal and tectonic complications, it is necessary to measure Jurassic magnetic signals in a different area of the world. The proposed study will attempt to verify the unusual behavior of the Jurassic geomagnetic field and test whether it was behaving in a globally coherent way by conducting a near-bottom marine magnetic field survey of Pacific Hawaiian Jurassic crust located between Hawaii and Guam.

Widespread, younger, Cretaceous-aged (65–140 million years ago) volcanism overprinted much of the western Pacific, so it is important to know the extent of Cretaceous-aged volcanic crust. This will be assessed by carrying out a seismic reflection and refraction survey of the Hawaiian Jurassic crust. First, the autonomous underwater vehicle (AUV) SENTRY and a simultaneously deployed deep-towed magnetometer system will acquire two parallel profiles of the near-bottom crustal magnetic field 10 km apart and ~800 km long. Second, the seismic survey will be conducted using airguns, a hydrophone streamer, and sonobuoys directly over the same profile as the AUV magnetic survey.

The program will consist of ~1600 km of surveys (Fig. 1). Water depths within the seismic survey area are ~2000–6000 m. The GI airguns will be operated along two parallel lines 10 km apart and 800 km long (Fig. 1) that are also the lines along which magnetic profiles will be acquired using the autonomous underwater vehicle (AUV) *Sentry*. As the airguns are towed along the survey lines, an 800-m, 48-channel hydrophone streamer and directional, passive sonobuoys will receive the returning acoustic signals and transfer the data to the on-board processing system

In addition to the GI airguns, a multibeam echosounder (MBES) and a sub-bottom profiler (SBP) will be used throughout the cruise. A surface towed magnetometer will also be operated during transit near the proposed survey area to determine the exact locations of the survey lines.

All planned geophysical data acquisition activities will be conducted by technicians provided by SIO with on-board assistance by the scientists who have proposed the study. The Principal Investigators are Drs. Masako Tominaga, Maurice A. Tivey, and Daniel Lizarralde of WHOI, William W. Sager of TAMU, and Adrienne Oakley of Kutztown University. The vessel will be self-contained, and the crew will live aboard the vessel for the entire cruise.

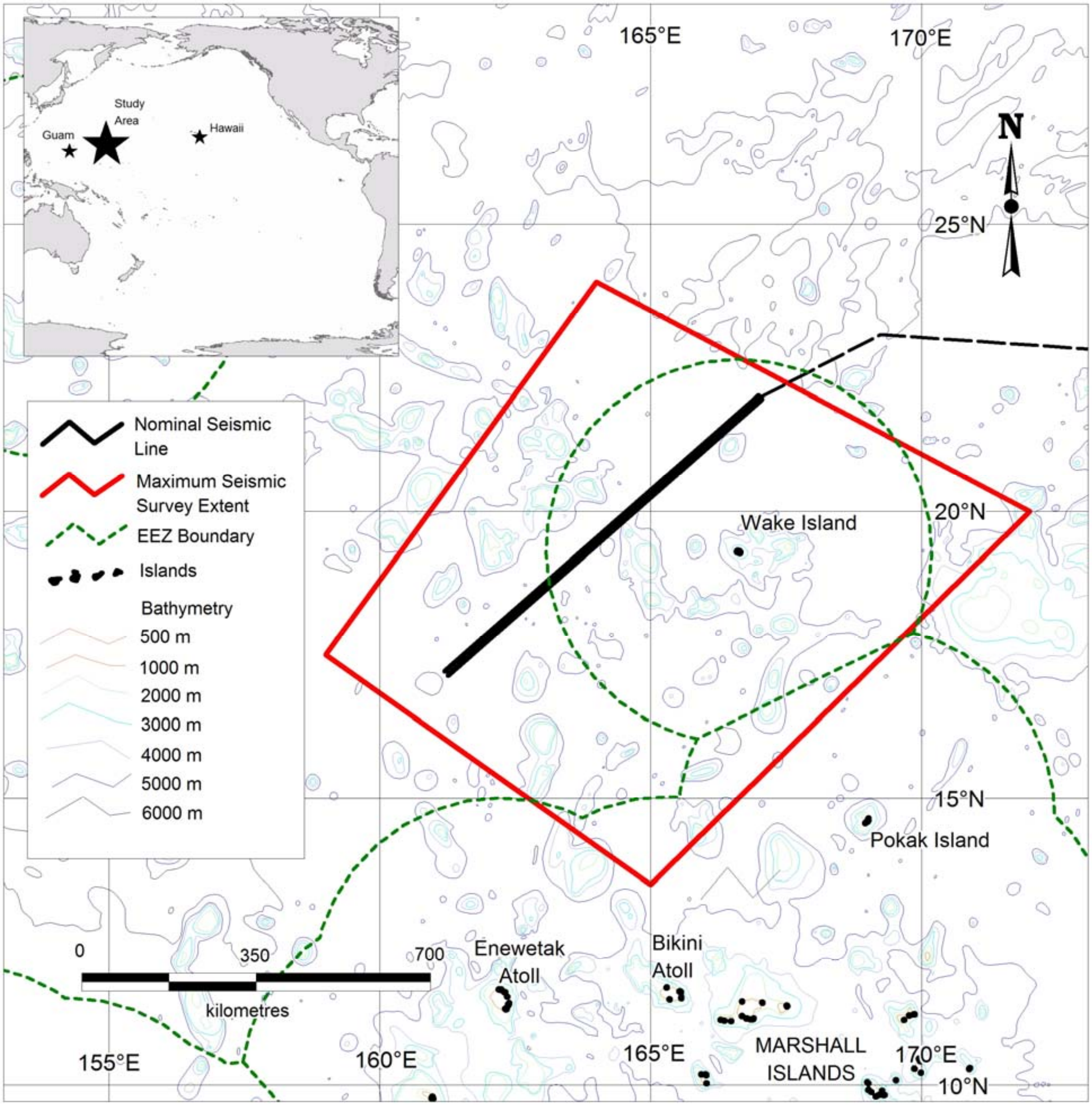

FIGURE 1. Proposed survey area for the proposed survey in the western tropical Pacific Ocean, November–December 2011.

Vessel Specifications

The R/V *Thompson* has a length of 83.5 m, a beam of 16 m, and a full load draft of 5.8 m. It is equipped with twin 360°-azimuth stern thrusters each powered by a 3000-hp DC motor and a water-jet bow thruster powered by a 1600-hp DC motor. The motors are driven by up to three 1500-kW and three 715-kW generators; normal operations use two 1500-kW and one 750-kW generator, but this changes with ship speed, sea state, and other variables. An operation speed of 7.4 km/h (4 kt) will be used during seismic acquisition. When not towing seismic survey gear, the R/V *Thompson* cruises at 22 km/h (12 kt) and has a maximum speed of 26.9 km/h (14.5 kt). It has a normal operating range of ~24,400 km.

The R/V *Thompson* 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. The characteristics of the vessel that make it suitable for visual monitoring are described in § XI.

Other details of the R/V *Thompson* include the following:

Owner:	U.S. Navy
Operator:	University of Washington
Flag:	United States of America
Launch Date:	8 July 1991
Gross Tonnage:	3250 LT
Compressors for Airguns:	2 x LMF DC, capable of 175 scfm at 2000 psi
Accommodation Capacity:	60 including 36 scientists

Airgun Description

The R/V *Thompson* will tow a pair of 45–105-in^3 Sercel GI airguns and a streamer containing hydrophones along predetermined lines. Seismic pulses will be emitted at intervals of 5 or 10 seconds. At speeds of ~7.4 km/h, the 5–10-s spacing corresponds to shot intervals of ~10–20 m.

The generator chamber of each GI airgun, the one responsible for introducing the sound pulse into the ocean, is either 45 in^3 or 105-in^3, depending on how it is configured. The injector chamber injects air into the previously-generated bubble to maintain its shape, and does not introduce more sound into the water. The two GI airguns will be towed 8 m apart side by side, 21 m behind the R/V *Thompson*, at a depth of 3 m. Depending on configuration, the total effective volume will be 90 in^3 or 210 in^3. As a precautionary measure, we assume that the larger volume will be used.

As the GI airgun is towed along the survey line, the towed hydrophone array in the streamer and the sonobuoys receive the reflected signals and transfer the data to the on-board processing system. Given the relatively short streamer length behind the vessel, the turning rate of the vessel while the gear is deployed is much higher than the limit of five degrees per minute for a seismic vessel towing a streamer of more typical length (>>l km). Thus, the maneuverability of the vessel is not limited much during operations.

GI Airgun Specifications

Energy Source	Two GI airguns of 105 in^3
Source output (downward)	0-pk is 5.5 bar-m (234.4 dB re 1 μPa · m); pk-pk is 9.8 bar-m (239.8 dB re 1 μPa · m)
Towing depth of energy source	3 m
Air discharge volume	~210 in^3
Dominant frequency components	0–188 Hz
Gun positions used	Two side by side airguns 8 m apart
Gun volumes at each position (in^3)	105, 105

The nominal downward-directed source levels indicated above do not represent actual sound levels that can be measured at any location in the water. Rather, they represent the level that would be found 1 m from a hypothetical point source emitting the same total amount of sound as is emitted by the combined GI airguns. The actual received level at any location in the water near the GI airguns will not exceed the source level of the strongest individual source. In this case, that will be about 234.4 dB re 1 µPa ·m peak, or 239.8 dB re 1µPa ·m peak-to-peak. Actual levels experienced by any organism more than 1 m from either GI airgun will be significantly lower.

A further consideration is that the rms[1] (root mean square) received levels that are used as impact criteria for marine mammals are not directly comparable to the peak (p or 0–p) or peak to peak (p–p) values normally used to characterize source levels of airgun arrays. The measurement units used to describe airgun sources, peak or peak-to-peak decibels, are always higher than the rms decibels referred to in biological literature. A measured received level of 160 dB re 1 μPa_{rms} in the far field would typically correspond to ~170 dB re 1 μPa_{p}, and to ~176–178 dB re 1 $\mu Pa_{p\text{-}p}$, as measured for the same pulse received at the same location (Greene 1997; McCauley et al. 1998, 2000a). The precise difference between rms and peak or peak-to-peak values depends on the frequency content and duration of the pulse, among other factors. However, the rms level is always lower than the peak or peak-to-peak level for an airgun-type source.

Received sound levels have been modeled by Lamont-Doherty Earth Observatory of Columbia University (L-DEO) for a number of airgun configurations, including two 105-in^3 GI Guns, in relation to distance and direction from the airguns (Fig. 2). The model does not allow for bottom interactions, and is most directly applicable to deep water. Based on the modeling, estimates of the maximum distances from the GI airguns where sound levels of 190, 180, and 160 dB re 1 μPa_{rms} are predicted to be received in deep (>1000-m) water are shown in Table 1.

Empirical data concerning the 190-, 180-, 170- and 160-dB distances were acquired for various airgun arrays based on measurements during the acoustic verification studies conducted by L DEO in the northern Gulf of Mexico in 2003 (6-, 10-, 12-, and 20-airgun arrays, and 2 GI airguns; Tolstoy et al. 2004) and 2007–2008 (36-airgun array; Tolstoy et al. 2009). Results for the 36-airgun array are not relevant for the 2 GI airguns to be used in the proposed survey. The empirical data for the 6-, 10-, 12-, and 20-airgun arrays indicate that, for deep water (>1000 m), the L-DEO model tends to overestimate the received sound levels at a given distance (Tolstoy et al. 2004). Measurements were not made for the 2 GI airgun array in deep water, however, we propose to use the safety radii predicted by L-DEO's model for the proposed GI airgun operations in deep water, although they are likely conservative given the empirical results for the other arrays. Table 1 shows the distances at which three rms sound levels are expected to be received from the GI airguns. 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; Holst and Beland 2008; Holst and Smultea 2008; Hauser et al. 2008). If marine mammals or sea turtles are detected within or about to enter the appropriate exclusion zone, the airguns will be shut down immediately.

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

[1] The rms (root mean square) pressure is an average over the pulse duration.

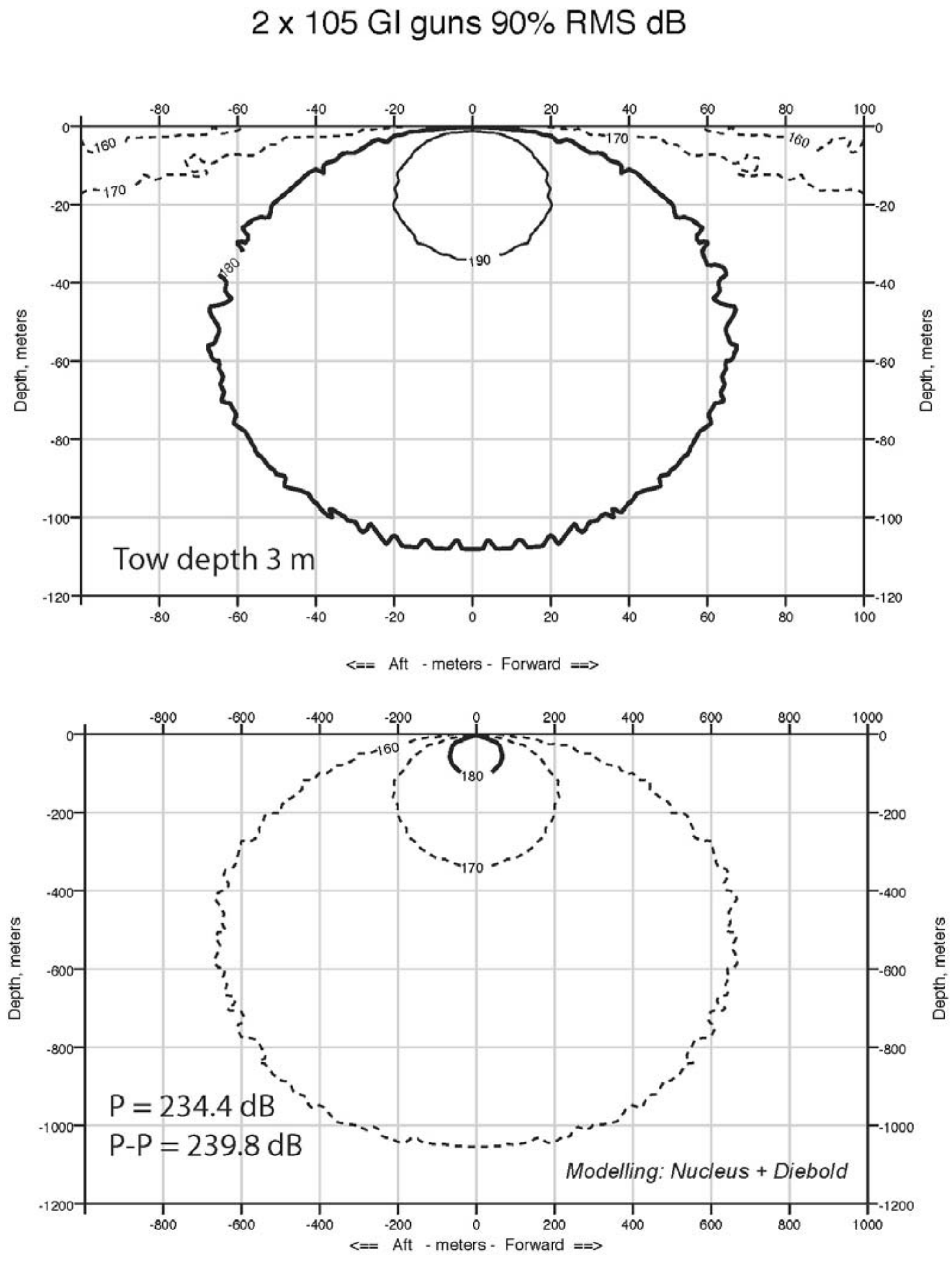

FIGURE 2. Modeled received sound levels from two 105-in^3 GI airguns that will be used during the SIO survey in the western tropical Pacific Ocean during November–December 2011. Model results provided by the Lamont-Doherty Earth Observatory of Columbia University (L-DEO).

TABLE 1. Distances to which sound levels ≥190, 180, and 160 dB re 1 μPa_{rms} could be received from two 105-in^3 GI airguns that will be used during the proposed seismic survey in the western tropical Pacific Ocean during November–December 2011. Distances are based on model results provided by L-DEO.

	Estimated Distances at Received Levels (m)		
Water depth	190 dB	180 dB	160 dB
>1000 m	20	70	670

Echosounder Descriptions

Kongsberg EM300 Multibeam Echosounder.—The Kongsberg EM300 MBES has a hull-mounted transducer within a transducer pod that is located amidships. The system's normal operating frequency is ~30 kHz. The transmit fan-beam is split into either three or nine narrower beam sectors with independent active steering to correct for vessel yaw. Angular coverage is 36° (in Extra Deep Mode, for use in water depths 3000 to 6000 m) or 150° (in shallower water). The total angular coverage of 36° or 150° consists of the 3 or 9 beams transmitted at slightly different frequencies. The sectors are frequency coded between 30 and 34 kHz and they are transmitted sequentially at each ping. Except in very deep water where the total beam is 36° × 1°, the composite fan beam is 150° × 1°, 150° × 2° or 150° × 4° depending on water depth. The 9 beams making up the composite fan beam will overlap slightly if the vessel yaw is less than the fore-aft width of the beam (1, 2, or 4°, respectively). Achievable swath width on a flat bottom will normally be ~5× the water depth. The maximum source level is 237 dB re 1 $\mu Pa \cdot m_{rms}$ (Hammerstad 2005). In deep water (500–3000 m), a pulse length of 5 ms is normally used, and the ping rate is mainly limited by the round trip travel time in the water.

ODEC Bathy-2000 Sub-bottom Profiler.—The Ocean Data Equipment Corporation (ODEC) Bathy-2000 has a maximum 7-kW transmit capacity into the underhull array. The energy from the sub-bottom profiler is directed downward from a 3-kHz transducer in the transducer array mounted in the hull of the vessel. Pulse duration ranges from 1.5 to 24 ms and the interval between pulses is controlled automatically by the system or manually by an operator depending on water depth and reflectivity of the bottom sediments. The system produces one sound pulse and then waits for its return before transmitting again. The swept (chirp) frequency ranges from 35 kHz to 6 kHz. The maximum source output (downward) is 221 dB re 1uPa, but in practice, the system is rarely operated above 80% power level.

Description of Operations

The survey will involve one source vessel, the R/V *Thompson*. For the seismic component of the research program, the source vessel will deploy a pair of low-energy Sercel Generator-Injector (GI) airguns as an energy source (each with a discharge volume of 105 in^3), an 800-m, 48-channel hydrophone streamer, and sonobuoys. The energy to the airguns is compressed air supplied by compressors on board the source vessel. As the airguns are towed along the survey lines, the hydrophone streamer and sonobuoys will receive the returning acoustic signals and transfer the data to the on-board processing system. Over the course of the seismic operations, 50 Ultra Electronics AN/SSQ-53D(3) directional, passive sonobuoys will be deployed from the vessel. The sonobuoys consist of a hydrophone, electronics, and a radio transmitter. The seismic signal is measured by the hydrophone and transmitted by radio back to the source vessel. The sonobuoys are expendable, and after a pre-determined time (usually 8 h), they self-scuttle and sink to the ocean bottom.

The program will consist of ~1600 km of surveys (Fig. 1). Water depths within the seismic survey area are ~2000–6000 m. The GI airguns will be operated along two parallel lines 10 km apart and 800 km long that are also the lines along which magnetic profiles will be acquired using the autonomous underwater vehicle (AUV) *Sentry*. More information about the AUV *Sentry* is available at http://www.whoi.edu/page.do?pid=38098. The survey lines will be within the area enclosed by red lines in Figure 1, but the exact locations of the survey lines will be determined during transit after observing the location of the appropriate magnetic lineation by surface-towed magnetometer. Magnetic and seismic data acquisition will alternate on a daily basis; seismic surveys will take place while the AUV used to collect magnetic data is on deck to recharge its batteries. There will be additional seismic operations associated with equipment testing, startup, and possible line changes or repeat coverage of any areas where initial data quality is sub-standard. In our calculations [see § VII(c)], 25% has been added for these contingency operations.

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 R/V *Thompson* is expected to depart Honolulu, HI, on 5 November 2011 and spend ~7 days in transit to the proposed survey area, 32 days alternating between acquiring magnetic and seismic data, and ~3 days in transit, arriving at Apra Harbor, Guam, on 17 December 2011. Seismic operations will be conducted for a total of ~16 days. Some minor deviation from these dates is possible, depending on logistics and weather. The survey will encompass the area ~13ºN–23°N, ~158–172°E, just north of the Marshall Islands (Fig. 1). Water depths in the survey area generally range from ~2000 m to ~6000 m; Wake Island is included in the survey area. The seismic survey will be conducted partly in International Waters and partly in the EEZ of Wake Island (U.S.), and possibly partly in the EEZ of the Republic of the Marshall Islands

III. Species and Numbers of Marine Mammals in Area

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

Twenty-six marine mammal species are known to occur in the Marshall Island Marine Ecoregion (MIME), including 19 odontocetes (dolphins and toothed whales), 6 mysticetes (baleen whales), and one pinniped (seals and sea lions).

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

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

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

Sections III and IV are integrated here to minimize repetition.

Twenty-six marine mammal species are known to occur in the MIME, including 19 odontocetes (dolphins and toothed whales), 6 mysticetes (baleen whales), and one pinniped (seals and sea lions). Information on the occurrence, distribution, population size, and conservation status for each of the 26 marine mammal species that could occur in the proposed survey area is given in Table 2. The status of these species is based on the ESA, the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species, and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Six species are listed under the ESA as ***Endangered***: sperm, humpback, fin, sei, and blue whales, and the Hawaiian monk seal. The North Pacific right whale, listed as ***Endangered***, was historically distributed throughout the North Pacific Ocean north of 35ºN and occasionally occurred as far south as 20ºN. Whaling records indicate that the MIME was not part of its range (Townsend 1935).

The dugong (*Dugong dugon*), also listed under the ESA as ***Endangered***, is distributed in shallow coastal waters throughout most of the Indo-Pacific region between ~27º north and south of the Equator (Marsh 2008). It's historical range extended to the Marshall Islands (Nair et al. 1975). However, the dugong is declining or extinct in at least $^{1}/_{3}$ of its range and no longer occurs in the MIME (Marsh 2008) and is therefore not discussed further in this analysis.

Mysticetes

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, ***Least Concern*** on the 2010 IUCN Red List of Threatened Species (IUCN 2010), and is listed in CITES Appendix I (UNEP-WCMC 2010) (Table 2). The world-wide 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). The North Pacific stock has been recently estimated at 18,302 whales, excluding calves (Calambokidis et al. 2008; IUCN 2010). Barlow et al. (2009) provided a bias-corrected abundance estimate of 20,800.

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 can occur in groups of up to 15 (Leatherwood and Reeves 1983; Donoghue 1996).

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

Species	Habitat	Regional pop'n size[1]	U.S. ESA[2]	IUCN[3]	CITES[4]
Mysticetes					
Humpback whale	Mainly nearshore waters and banks	20,800 [5]	EN	LC	I
Minke whale	Pelagic and coastal	25,000 [6]	NL	LC	I
Bryde's whale	Pelagic and coastal	20,000–30,000[7]	NL	DD	I
Sei whale	Primarily offshore, pelagic	7260–12,620 [9]	EN	EN	I
Fin whale	Continental slope, mostly pelagic	13,620–18,680 [9]	EN	EN	I
Blue whale	Pelagic and coastal	N.A.	EN	EN	I
Odontocetes					
Sperm whale	Usually pelagic and deep seas	29,674 [10]	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	NL	DD	II
Cuvier's beaked whale	Pelagic	20,000	NL	LC	II
Longman's beaked whale	Deep water	N.A.	NL	DD	II
Blainville's beaked whale	Pelagic	25,300 [11]	NL	DD	II
Ginkgo-toothed beaked whale	Pelagic	N.A.	NL	DD	II
Rough-toothed dolphin	Deep water	146,000	NL	LC	II
Common bottlenose dolphin	Coastal and oceanic, shelf break	243,500	NL	LC	II
Pantropical spotted dolphin	Coastal and pelagic	800,000[12]	NL	LC	II
Spinner dolphin	Coastal and pelagic	800,000[13]	NL	DD	II
Striped dolphin	Off continental shelf	1 million[14]	NL	LC	II
Fraser's dolphin	Waters >1000 m	289,000	NL	LC	II
Risso's dolphin	Waters >1000 m, seamounts	176,000	NL	LC	II
Melon-headed whale	Oceanic	45,000	NL	LC	II
Pygmy killer whale	Deep, pantropical waters	39,000	NL	DD	II
False killer whale	Pelagic	40,000	NL	DD	II
Killer whale	Widely distributed	8500	NL	DD	II
Short-finned pilot whale	Mostly pelagic, high-relief topography	500,000[14]	NL	DD	II
Pinniped					
Hawaiian monk seal	Coastal and pelagic	1129 [15]	EN	CR	I

N.A. - Data not available or species status not assessed. ? indicates uncertainty.

[1] Eastern Tropical Pacific or ETP in 1986–1990 (Wade and Gerrodette 1993) unless otherwise indicated

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

[3] Codes for IUCN classifications (IUCN 2010): CR = Critically Endangered; EN = Endangered; VU = Vulnerable; LC = Least Concern; DD = Data Deficient.

[4] CITES (UNEP-WCMC 2010): Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled.

[5] North Pacific (Barlow et al. 2009)

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

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

[8] North Pacific (Tillman 1977)

[9] North Pacific (Ohsumi and Wada 1974)

[10] Western North Pacific (Whitehead 2002a)

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

[12] Western/Southern Offshore Stock in ETP in 2000 (Jefferson et al. (2008)

[13] ETP in 2000 (Jefferson et al. (2008)

[14] ETP (Jefferson et al. (2008)

[15] Entire species (Carretta et al. 2010)

North Pacific humpback whales migrate between summer feeding grounds along the Pacific Rim and the Bering and Okhotsk Seas, and winter calving and breeding areas in subtropical and tropical waters (Pike and MacAskie 1969; Rice 1978). North Pacific humpback whales are known to assemble in three different winter breeding areas: (1) the eastern North Pacific along the coast of Mexico and central

America, and near the Revillagigedo Islands; (2) around the main Hawaiian Islands; and (3) in the west Pacific, particularly around Ogasawara and Ryukyu Islands in southern Japan and the northern Philippines (Perry et al. 1999a; Calambokidis et al. 2008). In other breeding areas during the winter, humpback whales are most often found in insular shelf waters, but are also detected in deeper waters. For example, calls of humpback whales have been detected in an area northeast and east of the Puerto Rican Trench, >6000 m deep and far from banks or islands (Swartz et al. 2002).

There is potential for the mixing of the western and eastern North Pacific humpback populations, as several individuals have been seen in the wintering areas of Japan and Hawaii in separate years (Darling and Cerchio 1993; Salden et al. 1999; Calambokidis et al. 2001). Whales from these wintering areas have been shown to travel to summer feeding areas in British Columbia, Canada, and Kodiak Island, Alaska (Darling et al. 1996; Calambokidis et al. 2001), but feeding areas in Russian waters may be most important (Calambokidis et al. 2008). There appears to be a very low level of interchange between Asian wintering or feeding areas and those in the eastern and central Pacific (Calambokidis et al. 2008).

Whaling charts indicate a historical concentration of humpbacks in the Commonwealth of the Northern Mariana Islands (CNMI) and the occurrence of humpback whales in the region of the Marshall Islands (Townsend 1935; Kellogg 1928 *in* Miller 2009). At least five sightings of humpback whales from 1978 to 1996 near Guam, Saipan, or Rota were described in Eldredge (2003). Calambokidis et al. (2008) included the waters of the Mariana Islands as part of the humpback winter range. One humpback whale was sighted (off-effort) near Saipan during the January–April 2007 survey in the waters of Guam and the CNMI and 11 humpbacks were detected acoustically, in both deep and shallow water around and north of Tinian and Saipan (~15–16°N; 146–147°E), most (10) during 6–25 February (SRS-Parsons et al. 2007). Acoustic detections of singing humpback whales suggest a small wintering population in the region. There were no humpback sightings during the January–February 2010 survey from Oahu to Guam via Wake Island (PIFSC 2010a) or during the return April–May 2010 survey from Guam to Oahu (PIFSC 2010b). Given their low abundance regionally, humpback whales sightings likely would be rare during the proposed seismic 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 migration in spring and summer, and southward migration in autumn (Stewart and Leatherwood 1985).

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).

In the North Pacific, three stocks of minke whales are currently recognized: the Sea of Japan/East China Sea, the rest of the western Pacific west of 180ºN, and the remainder of the Pacific (Donovan 1991). During the January–April 2007 survey in the waters of Guam and the CNMI, the minke whale was not sighted (Fulling et al. in press), but was the baleen whale species most frequently detected acoustically; there were 29 acoustic detection ranging from ~12–18°N; 143–148°E; SRS-Parsons 2007). Minke whales sightings have been reported for the Marshall Islands (Miller 2009). One minke whale sighting was recorded during the January–February 2010 survey from Oahu to Guam via Wake Island (specific location unreported; PIFSC 2010a). Despite a lack of visual detections, minke whales were the baleen whale species most frequently detected acoustically during the April–May 2010 survey from Guam to Oahu; there were 23 acoustic detections on the towed array and 31 acoustic detections on sonobuoys. Eight of the acoustic sightings occurred between 160ºE and 170ºE (PIFSC 2010b).

Bryde's Whale (*Balaenoptera edeni*)

Bryde's whale is found in tropical and subtropical waters throughout the world between 40ºN and 40ºS, generally in waters warmer than 16.3ºC (Reeves et al. 1999; Kanda et al. 2007; Kato and Perrin 2009). 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. 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 and Perrin (2009) in recognizing the uncertainty and using *Balaenoptera 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; Kanda et al. 2007; Kato and Perrin 2009). Bryde's whales are usually solitary or in pairs, although groups of 10–20 are known from feeding grounds (Jefferson et al. 2008). Fulling et al. (in press) reported a mean group size of 1.4 for Guam and the CNMI. The durations of Bryde's whale dives are 1–20 min (Cummings 1985).

During summer, Bryde's whale are considered the most common baleen whale in the Marianas region, typically occurring from May to July and possibly August (Eldredge 2003; Miyashita et al. 1996). During winter, Bryde's whales occur throughout the western North Pacific, including the Mariana Islands (Ohizumi et al. 2002). Records of Bryde's-like whales have been reported in the Marshall Islands (Patterson and Alverson 1986 *in* Miller 2009). Three *Balaenoptera edeni/brydei* sightings were reported during the January–February 2010 survey from Oahu to Guam via Wake Island (specific location unreported; PIFSC 2010a). During April–May visual surveys in 2010, one *Balaenoptera edeni/brydei* was sighted within Wake Island EEZ waters (PIFSC 2010b). There were no acoustic detections of Bryde's whales during the survey. During the January–April 2007 survey in the waters of Guam and the CNMI, there were 18 sightings of Bryde's whales (Fulling et al. in press).

Sei Whale (*Balaenoptera borealis*)

The distribution of the sei whale is not well known, but it is found in all oceans and appears to prefer mid-latitude, temperate waters (Jefferson et al. 2008). The species 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 disappear (Schilling et al. 1992; Jefferson et al. 2008). It is listed as ***Endangered*** under the U.S. ESA and on the 2010 IUCN Red List of Threatened Species (IUCN 2010), and is listed in CITES Appendix I (UNEP-WCMC 2010) (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 in the North Pacific (Tillman 1977).

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, they 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). Fulling et al. (in press) reported a mean group size of 1.3 for Guam and the CNMI. Sei whales generally do not dive deeply, and dive durations are 15 min or longer (Gambell 1985a). Sei whales migrate from temperate zones occupied in winter to higher latitudes in the summer, where most feeding takes place (Gambell 1985a).

Sei whale migrations are less extensive than those of other baleen whales. 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. Sei whales are generally considered uncommon in the Marianas region, although during the January–April 2007 survey in the waters of Guam and the southern CNMI (Fulling at al. in press), Bryde's and sei whales were the most frequently encountered baleen whales (18 and 16 sighted, respectively), and another 3 undifferentiated Bryde's or sei whales were also sighted. All sightings were south of Saipan in water >1000 m deep, with a number of sightings directly over the Mariana Trench. There were four acoustic detections of sei whales during the survey, two occurring at ~147.5°E (SRS-Parsons et al. 2007). Reese (1984 *in* Miller 2009) reported a group of sei whales in the waters of the Marshall Islands. However, they were later believed to likely be Bryde's whales (Miller 2009). Three sei whale sightings were reported during the January–February 2010 survey from Oahu to Guam via Wake Island (specific location unreported, PIFSC 2010a). An additional three undifferentiated Bryde's or sei whales were also reported during the survey (PIFSC 2010a). During April–May surveys in 2010, one undifferentiated Bryde's or sei whale sighting was reported in the Wake Island EEZ (PIFSC 2010b). There were seven acoustic detections of probable sei whales on the towed array during the survey, and two acoustic detections on sonobuoys occurred ~ 400 km east of the proposed survey area (PIFSC 2010b).

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 2010 IUCN Red List of Threatened Species (IUCN 2010), and is listed in CITES Appendix I (UNEP-WCMC 2010) (Table 2). Northern and southern fin whale populations are distinct, and are sometimes recognized as different subspecies (Aguilar 2002). The current distribution of fin whales in the western North Pacific is largely unknown.

Fin whales occur in coastal, shelf, and oceanic waters. Sergeant (1977) suggested that fin whales tend to follow steep slope contours, either because they detect them readily or because biological productivity is high along steep contours because of tidal mixing and perhaps current mixing. 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 have mean dive depths and times of 98 m and 6.3 min, and non-foraging fin whales have mean dive depths and times of 59 m and 4.2 min (Croll et al. 2001). Dive depths of >150 m coinciding with the diel migration of krill were reported by Panigada et al. (1999).

Fin whales migrate in the open oceans and their winter breeding areas are uncertain. However, they are known to winter in the Yellow, East China, and South China seas (Parsons et al. 1995; 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). Records of fin whales exist for the Marshall Islands (Miller 2009), but no fin whales were sighted or detected acoustically during the January–April 2007 survey in the waters of Guam and the CNMI (Fulling et al. in press) or in the January–February and April–May 2010 surveys in the waters between Guam and

Oahu (PIFSC 2010a,b). However, the survey area is within the known distribution range for this species (Reilly et al. 2008).

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 2010 IUCN Red List of Threatened Species (IUCN 2010), and is listed in CITES Appendix I (UNEP-WCMC 2010) (Table 2). All blue whale populations have been exploited commercially, and many have been severely depleted as a result. The worldwide population has been estimated at 15,000, with 10,000 in the Southern Hemisphere (Gambell 1976), 3500 in the eastern North Pacific, and up to 1400 in the North Atlantic (NMFS 1998). Blue whale calls monitored from the U.S. Navy Sound Surveillance System (SOSUS) and other offshore hydrophones suggest that separate populations occur in the eastern and western North Pacific (Stafford et al. 1999, 2001, 2007; Watkins et al. 2000a; Stafford 2003).

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

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

The current distribution of blue whales in the western North Pacific is largely unknown. The North Pacific stock of blue whales is reported to winter off Taiwan, Japan, and Korea. There is almost no information on the occurrence of blue whales in Micronesia, other than near the Solomon Islands (Reeves et al. 1999). There have been blue whale calls recorded at Wake Island during January 1997 suggesting that blue whales occur within several hundred kilometers of the island during winter (NMFS 1998; Stafford et al. 1999, 2001).

No blue whales were sighted or detected acoustically during the January–April 2007 survey in the waters of Guam and the CNMI (Fulling et al. in press) or in the January–February and April–May 2010 surveys in the waters between Guam and Oahu (PIFSC 2010a,b). Given their overall low abundance, blue whales sightings likely would be rare during the proposed seismic surveys.

Odontocetes

Sperm Whale (*Physeter macrocephalus*)

The sperm whale is the largest of the toothed whales, with an extensive worldwide distribution (Rice 1989). The species is listed as ***Endangered*** under the U.S. ESA, but on a worldwide basis it is abundant and not biologically endangered. It is listed as ***Vulnerable*** on the 2010 IUCN Red List of Threatened Species (IUCN 2010), and is listed in CITES Appendix I (UNEP-WCMC 2010) (Table 2).

Sperm whale distribution is linked to social structure: mixed groups of adult females and juveniles 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). There currently is no accurate estimate for the size of any sperm whale population (Whitehead 2002b). Best estimates probably are those of Whitehead (2002a), who provided a sperm whale population size estimate of 29,674 for the western North Pacific.

Mature male sperm whales migrate to warmer waters to breed when they are in their late twenties (Best 1979). They spend periods of at least months on the breeding grounds, moving between mixed groups of 20–30 on average (Whitehead 1993, 2003). Fulling et al. (in press) reported a mean group size of 5.1 for Guam and the CNMI. In the Southern Hemisphere, mating occurs from July to March, with a peak from September to December, and most calves are born between November and March (Rice 1989).

Sperm whales generally are distributed over large areas that have high secondary productivity and steep underwater topography, in waters at least 1000 m deep (Jaquet and Whitehead 1996; Whitehead 2002b). They are often found far from shore, but can be found closer to oceanic islands that rise steeply from deep ocean waters (Whitehead 2002b). 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).

The sperm whale was the most frequently sighted cetacean (23 sightings) during the January–April 2007 survey in the waters of Guam and the southern CNMI (Fulling et al. in press), and acoustic detections were three times higher than visual detections (SRS-Parsons et al. 2007). Sperm whales were observed in waters ~800 to 10,000 m deep throughout most of the survey area. During the survey, there were multiple sightings of groups that included calves (SRS-Parsons et al. 2007), and Eldredge (2003) reported a sighting of a group of sperm whales including a newborn calf off the west coast of Guam. Observations were made during the January–April 2007 survey of several large bulls with fresh tooth marks (one male rammed the survey ship), which suggests that these males were engaged in competition for mates (Fulling and Salinas Vega 2009). Hence, there is evidence that this area is used for breeding and calving by sperm whales.

Whaling records confirm sperm whales occurrence in the Marshall Islands and near Wake Island (Townsend 1935). Three sperm whale sightings were reported during the January–February 2010 survey from Oahu to Guam via Wake Island (specific location unreported, PIFSC 2010a). During April–May surveys from Guam to Oahu in 2010, four sperm whales were reported > 850 km east of the proposed survey area (PIFSC 2010b). During the survey, sperm whales were the most common odontocete species detected acoustically. There were 37 and 8 acoustic detections of sperm whales on the towed array and sonobuoys, respectively. One acoustic detection occurred near the proposed survey area at 19.0°N, 166.7°E on 26 April (PIFSC 2010b). Female and immature sperm whales could occur in the survey area at any time of the year, and large male sperm whales could be found in the area during the winter breeding season.

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

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, thus in population and density estimates, the two species are most often categorized together as *Kogia* spp.

Pygmy sperm whales may inhabit waters beyond the continental shelf edge, whereas dwarf sperm whales are thought to inhabit the shelf edge and slope waters (Rice 1998). Also, the dwarf sperm whale could prefer warmer waters than the pygmy sperm whale (McAlpine 2002). Pygmy sperm whales feed mainly on various species of squid in the deep zones of the continental shelf and slope (McAlpine et al. 1997). Pygmy sperm whales occur in small groups of up to six, and dwarf sperm whales can form groups of up to 10 (Caldwell and Caldwell 1989). Wade and Gerrodette (1993) reported 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. There are no sightings records of either *Kogia* species in the Marshall Islands (Miller 2009) and the southern CNMI (Fulling et al. in press), but there are strandings records for Guam, including five strandings of dwarf sperm whales and one stranding of a pygmy sperm whale (Kami and Lujan 1976; Reeves et al. 1999; Eldredge 1991, 2003). There were no sightings of either species during the January–February and April–May 2010 surveys in the waters between Guam and Oahu via Wake Island (PIFSC 2010a,b). However, the MIME is considered to be within the known range for both species (Taylor et al. 2008a,b).

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 Cuvier's whale can be seen in groups of up to 15, with a mean group size of 2.3 (MacLeod and D'Amico 2006). Wade and Gerrodette (1993) reported a mean group size of 2.2 for the ETP. Cuvier's beaked whale is an offshore, deep-diving species that feeds on fish and squid (Heyning 2002). Its dives generally last 30–60 min, but dives of 85 min have been recorded (Tyack et al. 2006). The maximum dive depth recorded by Baird et al. (2006) was 1450 m.

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 SE Asia (Heyning 1989). Cuvier's beaked whales occur in bycatch in the Philippines (Perrin et al. 2005). Cuvier's beaked whale has been reported in the Mariana and Bonin islands area (Masaki 1972 *in* Eldredge 2003), and there was a live stranding at Piti, Guam, in August 2007 (NMFS 2007a). One ziphiid whale not identified to species level was observed in deep water (~145.5°E) during the January–April 2007 survey in the waters of Guam and the southern CNMI (Fulling et al. in press). There are no sightings or stranding records for the Marshall Islands (Miller 2009) but the species is thought to occur at Wake Island (WPRFMC 2005). There were no sightings of Cuvier's beaked whale during the January–February and April–May 2010 surveys in the waters between Guam and Oahu via Wake Island (PIFSC 2010a,b). However, the survey area is considered to be within the known range for this species (Taylor et al. 2008c).

Longman's Beaked Whale (*Indopacetus pacificus*)

Initially, Longman's beaked whale was thought to be extremely rare, and was known only from two skulls (Pitman et al. 1987). Subsequent 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 whale has been seen alone, but more commonly in groups of at least 10 and up to 100, with an average group size of 15–20 (Jefferson et al. 2008). Pitman et al. (1999) reported a mean group size of 18.5 in the tropics. Dives are thought to last 18–33 min (Jefferson et al. 2008).

Sightings of Longman's beaked whale have occurred at many locations in tropical waters of the Indo-Pacific region (Rudolph and Smeenk 2002; Jefferson et al. 2008). In SE Asia and the surrounding area, records for this species exist for Japan (Yamada et al. 2004), the Philippines (Acebes et al. 2005), and Taiwan (Yang et al. 2008). There are no records of Longman's beaked whale for the Marshall Islands (Miller 2009) or in the Marianas, and there were no sightings during the January–April 2007 survey in the waters of Guam and the southern CNMI (Fulling et al. in press) or during the January–February and April–May 2010 surveys in the waters between Guam and Oahu via Wake Island (PIFSC 2010a,b). However, the MIME is considered to be within the known range for this species (Taylor et al. 2008d).

Mesoplodont Beaked Whales (*Mesoplodon* spp.)

Two species of mesoplodont whales likely occur in the deep waters of the MIME: Blainville's beaked whale (*Mesoplodon densirostris*) and the gingko-toothed beaked whale (*Mesoplodon ginkgodens*). No population estimates exist for either of these species in the western Central 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 during sighting surveys, thus in density and population estimates, as *Mesoplodon* spp. They are all thought to be deep-water animals, only rarely seen over the continental shelf. Typical group sizes range from one to six (Pitman 2002). Because of the scarcity of sightings, most are thought to be rare.

One *Mesoplodon* not identified to the species level was sighted during the January–April 2007 survey in the waters of Guam and the CNMI (Fulling et al. in press) and in the January–February 2010 survey in the waters from Oahu to Guam via Wake Island (PIFSC 2010a).

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 water 200–1400 m deep (Gannier 2000; Jefferson et al. 2008). Maximum dive depths have been reported as 1251 m (Tyack et al. 2006) and 1408 m (Baird et al. 2006), and dives have lasted as long as 54 min (Baird et al. 2006) to

57 min (Tyack et al. 2006). However, they also can occur in coastal areas and have been known to spend long periods of time at depths <50 m (Jefferson et al. 2008).

Sighting records exist for Blainville's beaked whale for the East China Sea off mainland China and for the Philippines (Perrin et al. 2005). They are also known to occur off Taiwan (Zhou et al. 1995; Chou 2004; Perrin et al. 2005). There are no occurrence records for this species in the MIME (Miller 2009), but the MIME is within its known distribution range (Taylor et al. 2008e).

Ginkgo-toothed beaked whale.—This species is only known from a few stranding records and captures and is hypothesized to occupy tropical and warm temperate waters of the Indian and Pacific oceans (Mead 1989; Pitman 2002; Taylor et al. 2008f). In the eastern Pacific Ocean, it has stranded in the Galápagos Islands and California (Taylor et al. 2008f). In the South Pacific, strandings have been reported in New South Wales, Australia, and the North Island and Chatham Islands, New Zealand (Mead 1989; Baker and van Helden 1999).

There are no occurrence records for this species in the MIME (Miller 2009), but the MIME is within its known distribution range (Taylor et al. 2008f). The occurrence of the species in the proposed survey area would be rare.

Rough-toothed Dolphin *(Steno bredanensis)*

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

Rough-toothed dolphins are known to occur in the CNMI. Two rough-toothed dolphin sightings were reported during the January–April 2007 survey in the waters of Guam and the CNMI. The sightings were in deep (1000–4500 m) water, one at ~17ºN and the other at ~10ºN (Fulling et al. in press).

There is a single record of a rough-toothed dolphin skull collected from a northern atoll in the Marshall Islands (Rongerik Atoll) in 1946 (Reeves et al. 1999 *in* Miller 2009). There were no sightings rough-toothed dolphins during the January–February and April–May 2010 surveys in the waters between Guam and Oahu via Wake Island (PIFSC 2010a,b). The MIME is considered to be within the known range for this species (Hammond et al. 2008a).

Bottlenose Dolphin (*Tursiops truncatus*)

The bottlenose dolphin is distributed worldwide. It is found mainly where surface temperatures are 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 size in the ETP has been estimated at 24 (Smith and Whitehead 1999) and 22.7 (Wade and Gerrodette 1993). The average group size off the Marquesas Islands was 8.2 (Gannier 2002).

Bottlenose dolphins are known to occur in Guam and the CNMI (Fulling et al. in press). Two bottlenose dolphin sightings during the January–April 2007 survey were in the vicinity of Challenger Deep (~10–12°N; 143°E), and the other was east of Saipan near the Mariana Trench in water depths 4200–5000 m (~15°N; 147°E). One of the sightings near the Challenger Deep was a mixed-species aggregation that included sperm whales (with calves) logging at the surface. Another mixed-species aggregation involved bottlenose dolphins with short-finned pilot whales and rough-toothed dolphins. Bottlenose dolphin group sizes were 3–10, and calves were seen.

Sightings of bottlenose dolphins have been reported for the Marshall Islands (Miller 2009) and bottlenose dolphins are thought to occur at Wake Island (WPRFMC 2005). There were no sightings of bottlenose dolphins during the January–February and April–May 2010 surveys in the waters between Guam and Oahu via Wake Island (PIFSC 2010a,b). The MIME is considered to be within the known range for this species (Hammond et al. 2008b).

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 2002). In the ETP, this dolphin is associated with warm (>25ºC), tropical surface water (Au and Perryman 1985; Reilly 1990; Reilly and Fiedler 1994; Reeves et al. 1999). There are two forms of pantropical spotted dolphin, coastal and offshore forms, although the coastal form occurs mainly in the ETP from Baha California to South America (Jefferson et al. 2008). The offshore form inhabits tropical, equatorial, and southern subtropical water masses (Perrin 2002). This species is found primarily in deeper waters, and rarely over the continental shelf or continental shelf edge (Davis et al. 1998).

Pantropical spotted dolphins are extremely gregarious, forming groups of hundreds or even thousands. Wade and Gerrodette (1993) reported a mean group size of 149 for the western/southern stock in the ETP, and Fulling et al. (in press) reported a mean group size of 64 for Guam and the CNMI. Pantropical spotted and spinner dolphins are commonly seen together in mixed-species groups, e.g., in the ETP (Au and Perryman 1985), off Hawaii (Psarakos et al. 2003), and off the Marquesas Archipelago (Gannier 2002).

In the western Pacific, pantropical spotted dolphins occur from Japan south to Australia. They are known to occur in the Marshall Islands (Miller 2009) and in the southern CNMI (Fulling et al. in press). During the January–April 2007 survey in Guam and the CNMI, pantropical spotted dolphins were sighted throughout the survey area and in waters with a variable bottom depth, ranging from ~100 to 5600 m. Most (11 of 17) sightings were in deep (>3000 m) water (Fulling et al. in press). Group size was 1–115, and there were multiple sightings that included calves, one mixed-species aggregation with melon-headed whales, and another with an unidentified rorqual. The pantropical spotted dolphins encountered during that survey were identified as the offshore morphotype (Fulling et al. in press).

Pantropical spotted dolphins were not sighted during the January–February 2010 survey from Oahu to Guam (PIFSC 2010a). Five pantropical spotted dolphin sightings were reported during the return April–May 2010 survey, four near Oahu and one near the Marianas Islands (PIFSC 2010b).

Spinner Dolphin (*Stenella longirostris*)

The spinner dolphin is distributed in oceanic and coastal tropical waters between 40ºN and 40ºS (Jefferson et al. 2008). In Southeast Asian, spinner dolphins are known to occur in the Philippines and in the East and South China seas off China and Taiwan (Perrin et al. 2005), and in Hong Kong (Parsons et al. 1995; Jefferson and Hung 2007). Two subspecies of spinner dolphin occur in the western Pacific: the widespread, offshore spinner dolphin (*Stenella longirostris longirostris*) and the dwarf spinner dolphin (*S. l. roseiventris*). There is little or no genetic interchange between the two subspecies (Dizon et al. 1991). *S. l. longirostris* feeds on small mesopelagic fish and squid, whereas *S. l. roseiventris* preys on benthic and coral reef fishes and invertebrates (Perrin et al. 1999). *S. l. longirostris* occurs in the deep inner waters of the Philippines as well as Japan, whereas *S. l. roseiventris* inhabits the shallow waters of inner SE Asia (Perrin et al. 1999).

Spinner dolphins travel among the Mariana island chain (Trianni and Kessler 2002) and have been seen at Farallon de Medinilla (Trianni and Kessler 2002), Guam (Trianni and Kessler 2002), and Rota (Jefferson et al. 2006). Spinner dolphins have been reported in the Marshall Islands (Miller 2009) and at Wake Island (WPRFMC 2005). There was one sighting of spinner dolphins during the January–April 2007 survey in the waters of Guam and the southern CNMI (Fulling et al. in press). The school was encountered northeast of Saipan in 425 m of water, and was estimated to contain 98 individuals. Spinner dolphins were not sighted during the January–February 2010 survey from Oahu to Guam (PIFSC 2010a). One spinner dolphin sighting was reported near Oahu during the return survey in April–May 2010 (PIFSC 2010b).

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 below 43ºN (Archer 2002). It is typically found in waters outside the continental shelf and is often associated with convergence zones and areas of upwelling (Archer 2002). Striped dolphins are fairly gregarious (groups of 20 or more are common) and active at the surface (Whitehead et al. 1998). Wade and Gerrodette (1993) reported a mean group size of 61 in the ETP, and Fulling et al. (in press) reported a mean group size of 27 for Guam and the CNMI.

In the western Pacific, two areas of concentration of striped dolphins have been identified: one located between 30°N and 40°N and another between 20°N and 30°N (Hammond et al. 2008c). The putative population south of 30°N has been estimated to number about 52,600 (Miyashita 1993), and any animals in the MIME are probably part of that population.

Striped dolphins were sighted 10 times during the January–April 2007 survey in the waters of Guam and the southern CNMI (Fulling et al. in press), in water depths ~2350–7600 m. Group sizes were 7–44, and several groups contained calves. Sightings were throughout the northern (>13ºN) part of the survey area. Striped dolphins sightings are reported for the Marshall Islands (Miller 2009). One striped dolphin was sighted during the January–February 2010 survey from Oahu to Guam via Wake Island (specific location unreported; PIFSC 2010a).

Fraser's Dolphin (*Lagenodelphis hosei*)

Fraser's dolphin is a tropical species found between 30°N and 30°S (Dolar 2002). It only occurs rarely in temperate regions, and then only in relation to temporary oceanographic anomalies such as El Niño events (Perrin et al. 1994b). The species typically occurs in deep, oceanic waters. In the ETP, most sightings were 45–100 km from shore in waters 1500–2500 m deep (Dolar 2002). Off Huahine and Tahiti (Society Islands), it was observed in waters 500–1500 m deep (Gannier 2000).

Fraser's dolphins travel in groups ranging from just a few animals to 100 or even 1000 (Perrin et al. 1994b). Wade and Gerrodette (1993) reported a mean group size of 395 for the ETP.

There are no records for Fraser's dolphin in the CNMI (Fulling et al. in press) or the Marshall Islands (Miller 2009), and there were no sightings during the January–February or April–May 2010 surveys in the waters between Guam and Oahu (PIFSC 2010a,b). However, the MIME is within the distributional range of this species (Hammond et al. 2008d).

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). Water temperature appears to be an important factor affecting its distribution (Kruse et al. 1999; see also Becker 2007). Off the U.S. west coast, Risso's dolphin is believed to make seasonal north-south movements related to water temperature, spending colder winter months off California and moving north to waters off Oregon–Washington during the spring and summer as northern waters begin to warm (Green et al. 1992, 1993; Buchanan et al. 2001; Barlow 2003; Becker 2007).

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 individuals (Kruse et al. 1999). Mean group sizes were reported as 15 for Hawaii (Barlow 2006) and 9–19 for the ETP (Wade and Gerrodette 1993; Ferguson et al. 2006; Jackson et al. 2008).

In the western Pacific, Risso's dolphins range from the Kuril Islands to New Zealand and Australia. No Risso's dolphins were sighted during the January–April 2007 survey in the waters of Guam and the southern CNMI (Fulling et al. in press) or during the January–February 2010 or April–May surveys between Guam and Oahu (PIFSC 2010a,b), but the MIME is within the distributional range of this species (Taylor et al. 2008g).

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). For the ETP, Wade and Gerrodette (1993) and Ferguson et al. (2006) reported mean group sizes of 199 and 258, respectively. Melon-head whales are commonly seen in mixed groups with other cetaceans (Jefferson and Barros 1997). Most sightings are from the continental shelf seaward, and around oceanic islands (Taylor et al. 2008h). In the ETP, the species is primarily found in the upwelling-modified and equatorial waters (Perryman et al. 1994).

Melon-headed whales are known to occur off mainland China in the East and South China seas, off Taiwan, and in the Philippines and the CNMI (Perrin et al. 2005; Fulling et al. in press). There was a live stranding on the beach at Inarajan Bay, Guam, in April 1980 (Kami and Hosmer 1982; Donaldson 1983). There have been sightings at Rota and Guam (DoN 2005), including a sighting at Rota of an estimated 500–700 melon-headed whales and an undetermined smaller number of rough-toothed dolphins in water ~75 m deep at Sasanhayan Bay (Jefferson et al. 2006). During the January–April 2007 survey in the waters of Guam and the southern CNMI, two groups of melon-headed whales were sighted in water depths ~3200–3900 m, both southwest of Guam (Fulling et al. in press). One melon-headed whale was detected acoustically in the same area.

There have been sighting reports of melon-headed whales at the Marshall Islands (Miller 2009). There was one sighting of melon-headed whales during the January–February 2010 survey from Oahu to Guam (specific location unreported; PIFSC 2010a) and three sightings on the return trip from Guam to Oahu April–May, two at ~170.5°W and one at ~180°W (PIFSC 2010b). One melon-headed whale was also acoustically detected on the towed array during the survey.

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). Little is known about the species in most of its range, but it is sighted frequently in the ETP, off Hawaii, and off Japan (Donahue and Perryman 2002). In warmer water, it is usually seen close to the coast (Wade and Gerrodette 1993), but it is also found in deep oceanic waters. In the Marquesas, it was sighted in water 100 m deep (Gannier 2002). Pygmy killer whales tend to travel in groups of 15–50, although herds of a few hundred have been sighted (Ross and Leatherwood 1994). Mean group sizes have been reported as 14 for Hawaii (Barlow 2006) and 25–30 for the ETP (Wade and Gerrodette 1993; Ferguson et al. 2006; Jackson et al. 2008).

There was one sighting of a group of six pygmy killer whales during the January–April 2007 survey in the waters of Guam and the southern CNMI (Fulling et al. in press), south of Guam (~12°N) where the bottom depth was ~4400 m. This is consistent with the known habitat preferences of the species for deep, oceanic waters. No pygmy killer whales were sighted or detected acoustically during the January–February or April–May 2010 surveys in the waters between Guam and Oahu (PIFSC 2010a,b). However, the MIME is considered to be within the known range for this species (Taylor et al. 2008i).

False Killer Whale (*Pseudorca crassidens*)

The false killer whale is found in all tropical and warmer temperate oceans, especially in deep, offshore waters (Odell and McClune 1999). It is also known to occur in nearshore areas (e.g., Stacey and Baird 1991). In the ETP, it is usually seen far offshore (Wade and Gerrodette 1993). False killer whales travel in pods of 20–100 (Baird 2002), although groups of several hundred are sometimes observed. Mean group sizes have been reported as 10 for Hawaii (Barlow 2006) and 11–12 for the ETP (Wade and Gerrodette 1993; Ferguson et al. 2006; Jackson et al. 2008).

In the west Pacific, the false killer whale is distributed from Japan to Australia. Nothing is known of the stock structure of false killer whales in the North Pacific Ocean. However, there are estimated to be about 6000 false killer whales in the area surrounding the Mariana Islands (Miyashita 1993). Ten sightings of false killer whales were made during the January–April 2007 survey in the waters of Guam and the southern CNMI (Fulling et al. in press). Group sizes were 2–26, including some groups that contained calves. False killer whales were sighted in water depths of ~3000–8000 m, and several sightings were made southeast of the Mariana Islands at ~148°E in water depths >5000 m (Fulling et al. in press).

The distribution range of the false killer whale includes the Marshall Islands (Taylor et al. 2008j). One sighting of false killer whales was reported during the January–February 2010 survey from Oahu to Guam (PIFSC 2010a). One sighting was reported during the April–May 2010 survey from Guam to Oahu near Wake Island EEZ waters (~175°W), and one false killer whale was detected acoustically during the survey (PIFSC 2010b).

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). Mean group sizes have been reported as 6.5 for Hawaii (Barlow 2006) and 5.4–8.1 for the ETP (Wade and Gerrodette 1993; Ferguson et al. 2006; Jackson et al. 2008). The maximum depth to which seven tagged free-ranging killer whales dove off B.C. was 228 m, but only an average of 2.4% of their time was spent below 30-m depth (Baird et al. 2003).

There are a few sightings (most unconfirmed) of killer whales off Guam (Eldredge 1991), including a sighting ~25 km west of Tinian during January 1997 reported to the NMFS Platforms of Opportunity Program. There was also a badly decomposed killer whale found stranded on Guam in August 1981 (Kami and Hosmer 1982). No killer whales were sighted during the January–April 2007 survey in the waters of Guam and the southern CNMI (Fulling et al. in press). Killer whales are known to occur in the Marshall Islands (Miller 2009). No killer whales were sighted or detected acoustically during the January–February or April–May 2010 surveys in the waters between Guam and Oahu (PIFSC 2010a,b). However, the MIME is within the known distribution range for this species (Taylor et al. 2008k).

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, and are usually seen in groups of 20–90 (Olson and Reilly 2002). Mean group sizes have been reported as 22.5 for Hawaii (Barlow 2006) and 18.0–18.3 for the ETP (Wade and Gerrodette 1993; Ferguson et al. 2006; Jackson et al. 2008). Long-finned pilot whales outfitted with time-depth recorders dove to depths up to 828 m, although most of their time was spent above depths of 7 m (Heide-Jørgensen et al. 2002). The species' maximum recorded dive depth is 971 m (Baird pers. comm. *in* DoN 2005).

Short-finned pilot whales are known to occur in the Philippines and off mainland China in the South China Sea (Perrin et al. 2005) and off Taiwan (e.g., Chou 2004). Prior to 2007, there were a small number of occurrence records for the short-finned pilot whale around the Mariana Islands. Miyashita et al. (1996) reported sightings in the vicinity of the CNMI during February–March 1994, but did not provide the sighting coordinates. A group of more than 30 was sighted in late April 1977 off the northwest coast of Guam (Birkeland 1977), and a stranding occurred on Guam in July 1980 (Schulz 1980; Kami and Hosmer 1982; Donaldson 1983).

There were five sightings of short-finned pilot whales during the January–April 2007 survey in the waters of Guam and the southern CNMI (Fulling et al. in press), three of which were at ~147.5°E, over the West Mariana Ridge (an area of seamounts). Short-finned pilot whales were sighted in water depths of ~900–4500 m. Group sizes were 5–43, and no calves were observed. One of the groups was in a mixed-species aggregation of bottlenose dolphins, short-finned pilot whales, and rough-toothed dolphins

(SRS-Parsons et al. 2007). Short-finned pilot whales are known to occur in the Marshall Islands (Miller 2009). One short-finned pilot whale sighting was reported at ~ 170°W during the April–May 2010 survey from Guam to Oahu, and there was one acoustic detection of short-finned pilot whale on the towed array during the survey (PIFSC 2010b).

Pinniped

Only one species of pinniped has the potential to occur within the MIME: the Hawaiian monk seal. The Hawaiian monk seal is listed as ***Endangered*** under the ESA and ***Critically Endangered*** on the 2010 IUCN Red List of Threatened Species (IUCN 2010), and is listed in CITES Appendix I (UNEP-WCMC 2010). The Hawaiian monk seal occurs throughout the Hawaiian Island chain, mostly in six main breeding locations in the northwestern Hawaiian Islands, with a small but increasing number of births documented in the main Hawaiian Islands (Lowry and Aguilar 2008). It is estimated that the population has declined by 68% in 49 years. Since 1999 the population has declined at a rate of ~4% per year (Lowry and Aguilar 2008). The best estimate for the population is 1129 (Carretta et al. 2010).

Monk seals are benthic foragers that feed on marine terraces of atolls and banks, generally to depths <40 m but occasionally to depths >500m (Parrish et al. 2000; Stewart et al. 2006). Stewart et al. (2006) used satellite tracking to examine the foraging behavior of monk seals at the six main breeding colonies in the northwestern Hawaiian Islands. Foraging trips varied by sex and by age and ranged from <1 km up to 217 km from haul-out sites. Satellite tracking of Hawaiian monk seals in the main Hawaiian Islands revealed home ranges of 34 to 800 km^2. The home ranges for monk seals in the northwestern Hawaiian Islands were much greater (163–7400 km^2; NMFS 2007b).

Hawaiian monk seals are seen occasionally at Johnston Atoll (~16.8°N; 169.5°W), 1390 km west of Hawaii, and at least one birth has occurred at the atoll (NMFS 2007b). In addition, twelve males were translocated to Johnston Atoll over the past 20 years. In the late 1980s two Hawaiian monk seal sightings were reported at Palmyra Atoll (~6°N; 162.5W°), and one tagged seal was observed near Wake Island (Westlake and Gilmartin 1990).

Given the very low population abundance and that the proposed survey area is >3500 km from their most common coastal habitat, sightings in the proposed survey area are not expected.

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.

SIO requests an IHA pursuant to Section 101(a)(5)(D) of the MMPA for incidental take by harassment during its planned seismic survey in the western tropical Pacific during November–December 2011.

The operations outlined in § I have the potential to take marine mammals by harassment. Sounds will be generated by the GI airguns used during the surveys, two echosounders, and general vessel operations. “Takes” by harassment potentially will result when marine mammals near the activities are exposed to the pulsed sounds generated by the seismic sources or echosounders. The effects will depend on the species of cetacean or pinniped, the behavior of the animal at the time of reception of the stimulus, and received level of the sound (see § VI/VII). Disturbance reactions are likely by some of the marine mammals in the general vicinity of the tracklines of the source vessel. No take by serious injury is anticipated, given the nature of the planned operations and the mitigation measures that are planned (see § XI, Mitigation Measures). No lethal takes are expected.

VI. NUMBERS OF MARINE MAMMALS THAT MAY BE TAKEN

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

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

- First we summarize the potential impacts on marine mammals of airgun operations, as called for in Section VII. A more comprehensive review of the relevant background information appears in Appendix A of the Environmental Assessment (EA) that supports this IHA application. That Appendix is similar to corresponding parts of previous EAs and associated IHA applications concerning other SIO and L-DEO seismic surveys since 2003, updated in 2009.
- Then we discuss the potential impacts of operations by SIO's multibeam echosounder and sub-bottom profilers.
- Finally, we estimate the numbers of marine mammals that could be affected by the proposed activity in the western tropical Pacific Ocean during November–December 2011. This section includes a description of the rationale for SIO's estimates of the potential numbers of harassment "takes" during the planned survey, as called for in Section 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). With the possible exception of some cases of temporary threshold shift in harbor seals and perhaps some other seals, 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 A (3) of the supporting 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 A (5) of the EA. That is often true even in cases when the pulsed sounds must be readily audible to the animals based on measured received levels and the hearing sensitivity of that mammal group. Although various baleen whales, toothed whales, and (less frequently) pinnipeds have been shown to react behaviorally to airgun pulses under some conditions, at other times mammals of all three types have shown no overt reactions. In general, pinnipeds usually seem to be more tolerant of exposure to airgun pulses than are cetaceans, with the relative responsiveness of baleen and toothed whales being variable.

Masking

Masking effects of pulsed sounds (even from large arrays of airguns) on marine mammal calls and other natural sounds are expected to be limited, although there are very few specific data on this. Because of the intermittent nature and low duty cycle of seismic pulses, animals can emit and receive sounds in the relatively quiet intervals between pulses. However, in exceptional situations, reverberation occurs for much or all of the interval between pulses (e.g., Simard et al. 2005; Clark and Gagnon 2006), which could mask calls. Some baleen and toothed whales are known to continue calling in the presence of seismic pulses, and their calls usually can be heard between the seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999a,b; Nieukirk et al. 2004; Smultea et al. 2004; Holst et al. 2005a,b, 2006; Dunn and Hernandez 2009). However, Clark and Gagnon (2006) reported that fin whales in the northeast Pacific Ocean went silent for an extended period starting soon after the onset of a seismic survey in the area. Similarly, there has been one report that sperm whales ceased calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994). However, more recent studies found that sperm whales 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 A (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, and on ringed seals. Less detailed data are available for some other species of baleen whales, small toothed whales, and sea otters, but for many species there are no data on responses to marine seismic surveys.

Baleen Whales.—Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to pulses from large arrays of airguns at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, as reviewed in Appendix A (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 pulses in the 160–170 dB re 1 μPa_{rms} range seem to cause obvious avoidance behavior in a substantial fraction of the animals exposed (Richardson et al. 1995). In many areas, seismic pulses from large arrays of airguns diminish to those levels at distances ranging from 4.5 to 14.5 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 A (5) of the EA have shown that some species of baleen whales, notably bowhead and humpback whales, at times show strong avoidance at received levels lower than 160–170 dB re 1 μPa_{rms}.

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

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

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

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

There are no data on reactions of *right whales* to seismic surveys, but results from the closely-related *bowhead whale* show that their responsiveness can be quite variable depending on their activity (migrating vs. feeding). Bowhead whales migrating west across the Alaskan Beaufort Sea in autumn, in particular, are unusually responsive, with substantial avoidance occurring out to distances of 20–30 km from a medium-sized airgun source at received sound levels of around 120–130 dB re 1 μPa_{rms} [Miller et al. 1999; Richardson et al. 1999; see Appendix A (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 A 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; Moulton et al. 2005, 2006a; 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 A of the EA for review). However, controlled exposure experiments in the Gulf of Mexico indicate that foraging behavior was altered upon exposure to airgun sound (Jochens et al. 2008; Miller et al. 2009; Tyack 2009).

There are almost no specific data on the behavioral reactions of beaked whales to seismic surveys. However, some northern bottlenose whales remained in the general area and continued to produce high-frequency clicks when exposed to sound pulses from distant seismic surveys (Gosselin and Lawson 2004; Laurinolli and Cochrane 2005; Simard et al. 2005). Most beaked whales tend to avoid approaching vessels of other types (e.g., Würsig et al. 1998). They may also dive for an extended period when approached by a vessel (e.g., Kasuya 1986), although it is uncertain how much longer such dives may be as compared to dives by undisturbed beaked whales, which also are often quite long (Baird et al. 2006; Tyack et al. 2006). In any event, it is likely that most beaked whales would also show strong avoidance of an approaching seismic vessel, although this has not been documented explicitly. 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 A of the EA). A ≥170 dB re 1 μPa_{rms} disturbance criterion (rather than ≥160 dB) is considered appropriate for delphinids (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 A (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). Even if reactions of any pinnipeds that might be encountered in the present study area are as strong as those evident in the telemetry study, reactions are expected to be confined to relatively small distances and durations, with no long-term effects on pinniped individuals or populations. As for delphinids, a ≥170 dB disturbance criterion is considered appropriate for pinnipeds, which tend to be less responsive than many cetaceans.

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

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

Recommendations for new science-based noise exposure criteria for marine mammals, frequency-weighting procedures, and related matters were published recently (Southall et al. 2007). Those recommendations have not, 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 airguns, and to avoid exposing them to sound pulses that might, at least in theory, cause hearing impairment (see § XI, "MITIGATION MEASURES"). In addition, many cetaceans and (to a limited degree) pinnipeds 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 could (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, permanent threshold shift (PTS), and non-auditory physical effects.

Temporary Threshold Shift (TTS).—TTS is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter 1985). While experiencing TTS, the hearing threshold rises and a sound must be stronger in order to be heard. 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). Given the available data, the received energy level of a single seismic pulse (with no frequency weighting) might need to be ~186 dB re 1 $\mu Pa^2 \cdot s$ (i.e., 186 dB SEL or ~196–201 dB re 1 μPa_{rms}) in order to produce brief, mild TTS[2]. Exposure to several strong seismic pulses that each have received levels near 190 dB re 1 μPa_{rms}

[2] If the low frequency components of the watergun sound used in the experiments of Finneran et al. (2002) are downweighted as recommended by J. 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).

might result in cumulative exposure of ~186 dB SEL and thus slight TTS in a small odontocete, assuming the TTS threshold is (to a first approximation) a function of the total received pulse energy. The distances from the *Thompson*'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 20 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 proposed survey area at the time of the proposed 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 180 and 190 dB re 1 μPa_{rms}, respectively. Those sound levels are ***not*** considered to be the levels above which TTS might occur. Rather, they were the received levels above which, in the view of a panel of bioacoustics specialists convened by NMFS before TTS measurements for marine mammals started to become available, one could not be certain that there would be no injurious effects, auditory or otherwise, to marine mammals. As summarized above and in Southall et al. (2007), data that are now available imply that TTS is unlikely to occur in most odontocetes (and probably mysticetes as well) unless they are exposed to a sequence of several airgun pulses stronger than 190 dB re 1 μPa_{rms}. On the other hand, for the harbor seal and any species with similarly low TTS thresholds (possibly including the harbor porpoise), TTS may occur upon exposure to one or more airgun pulses whose received level equals the NMFS "do not exceed" value of 190 dB re 1 μPa_{rms}. That criterion corresponds to a single-pulse SEL of 175–180 dB re 1 $\mu Pa^2 \cdot s$ in typical conditions, whereas TTS is suspected to be possible (in harbor seals) with a cumulative SEL of ~171 dB re 1 $\mu Pa^2 \cdot s$.

Permanent Threshold Shift (PTS).—When PTS occurs, there is physical damage to the sound receptors in the ear. In severe cases, there can be total or partial deafness, while in other cases, the animal or human 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 A (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, p. 441-4) estimated that received levels would need to exceed the TTS threshold by at least 15 dB for there to be risk of PTS. Thus, for cetaceans they estimate that the PTS threshold might be an M-weighted SEL (for the sequence of received pulses) of ~198 dB re 1 $\mu Pa^2 \cdot s$ (15 dB higher than the TTS threshold for an impulse), where the SEL value is cumulated over the sequence of pulses. Additional assumptions had to be made to derive a corresponding estimate for pinnipeds, as the only available data on TTS-thresholds in pinnipeds pertain to non-impulse sound. Southall et al. (2007) estimated 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 the PTS threshold would probably be higher, given the higher TTS thresholds in those species.

Southall et al. (2007) also note that, regardless of the SEL, there is concern about the possibility of PTS if a cetacean or pinniped received one or more pulses with peak pressure exceeding 230 or 218 dB re 1 µPa (peak), respectively. 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 is not be entirely correct. A peak pressure of 230 dB re 1 µPa (3.2 bar·m, 0-pk) would only be found within less than a meter from a GI gun, which has a peak pressure of 224.6 dB re 1µPa·m. 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, ramp ups, 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.

Strandings and Mortality.—Marine mammals close to underwater detonations of high explosives can be killed or severely injured, and the auditory organs are especially susceptible to injury (Ketten et al. 1993; Ketten 1995). However, explosives are no longer used for marine seismic research or commercial seismic surveys, and have been replaced entirely by airguns or related non-explosive pulse generators. Airgun pulses are less energetic and have slower rise times, and there is no specific evidence that they can cause serious injury, death, or stranding even in the case of large airgun arrays. However, the association of mass strandings of beaked whales with naval exercises and, in one case, an L-DEO seismic survey (Malakoff 2002; Cox et al. 2006), has raised the possibility that beaked whales exposed to strong "pulsed" sounds may be especially susceptible to injury and/or behavioral reactions that can lead to stranding (e.g., Hildebrand 2005; Southall et al. 2007). Appendix A (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. However, there are increasing indications that gas-bubble disease (analogous to "the bends"), induced in supersaturated tissue by a behavioral response to acoustic exposure, could be a pathologic mechanism for the strandings and mortality of some deep-diving cetaceans exposed to sonar. The evidence for this remains circumstantial and associated with exposure to naval mid-frequency sonar, not seismic surveys (Cox et al. 2006; Southall et al. 2007).

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

There is no conclusive evidence of cetacean strandings or deaths at sea as a result of exposure to seismic surveys, but a few cases of strandings in the general area where a seismic survey was ongoing have led to speculation concerning a possible link between seismic surveys and strandings. Suggestions that there was a link between seismic surveys and strandings of humpback whales in Brazil (Engel et al. 2004) were not well founded (IAGC 2004; IWC 2007). In 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 SIO and those involved in the naval exercises associated with strandings.

Non-auditory Physiological Effects.—Non-auditory physiological effects or injuries that theoretically might occur in marine mammals exposed to strong underwater sound include stress, neurological effects, bubble formation, resonance, and other types of organ or tissue damage (Cox et al. 2006; Southall et al. 2007). Studies examining such effects are limited. However, resonance (Gentry 2002) and direct noise-induced bubble formation (Crum et al. 2005) are not expected in the case of an impulsive source like an airgun array. If seismic surveys disrupt diving patterns of deep-diving species, this might perhaps result in bubble formation and a form of "the bends", as speculated to occur in beaked whales exposed to sonar. However, there is no specific evidence of this upon exposure to airgun pulses.

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

Possible Effects of Multi-beam Echosounder Signals

The Kongsberg EM 300 MBES will be operated from the source vessel during the proposed survey. Information about this equipment was provided in § II. Sounds from the MBES are very short pings, occurring for 5 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 30 kHz, and the maximum source level is 237 dB re 1 $\mu Pa \cdot m_{rms}$. The beam is narrow (1º) in the fore-aft extent and wide (36º) in the cross-track extent. Each ping consists of nine (in water >1000 m deep) or three (<1000 m deep) successive fan-shaped transmissions (segments) at different cross-track angles. Any given mammal at depth near the trackline would be in the main beam for only one or two of the nine segments. Also, marine mammals that encounter the Kongsberg EM 300 are unlikely to be subjected to repeated pings because of the narrow fore–aft width of the beam and will receive only limited amounts of energy because of the short pings. Animals close to the ship (where the beam is narrowest) are especially unlikely to be ensonified for more than one 5-ms ping (or two pings if in the overlap area). Similarly, Kremser et al. (2005) noted that the probability of a cetacean swimming through the area of exposure when an MBES emits a ping is small. The animal would have to pass the transducer at close range and be swimming at speeds similar to the vessel in order to receive the multiple pings that might result in sufficient exposure to cause TTS.

Navy sonars that have been linked to avoidance reactions and stranding of cetaceans (1) generally have a longer signal duration than the Kongsberg EM 300, 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 SIO's operations, the individual pings will be very short, and a given mammal would not receive many of the downward-directed pings as the vessel passes by. Possible effects of an MBES on marine mammals are outlined below.

Masking

Marine mammal communications will not be masked appreciably by the MBES signals given the low duty cycle of the echosounder and the brief period when an individual mammal is likely to be within its beam. Furthermore, in the case of baleen whales, the echosounder signals (30 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 eastern tropical Pacific, 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 SIO, and to shorter broadband pulsed signals. Behavioral changes typically involved what appeared to be deliberate attempts to avoid the sound exposure (Schlundt et al. 2000; Finneran et al. 2002; Finneran and Schlundt 2004). The relevance of those data to free-ranging odontocetes is uncertain, and in any case, the test sounds were quite different in duration as compared with those from an MBES.

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

Hearing Impairment and Other Physical Effects

Given recent stranding events that have been associated with the operation of naval sonar, there is concern that mid-frequency sonar sounds can cause serious impacts to marine mammals (see above). However, the MBES proposed for use by SIO 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 237 dB re 1 µPa·m_{rms} (see § II), the received level for an animal within the MBES beam 100 m below the ship would be ~197 dB re 1 $µPa_{rms}$, assuming 40 dB of spreading loss over 100 m (circular spreading). Given the narrow beam, only one ping is likely to be received by a given animal as the ship passes overhead. The received energy level from a single ping of duration 5 ms would be about 174 dB re 1 $\mu Pa^2 \cdot s$, i.e., 197 dB + 10 log (0.005 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., 194 dB re 1 $\mu Pa^2 \cdot s$ in the case of the EM 300. That animal might incur some TTS (which would be fully recoverable), but the exposure would still be below the anticipated PTS threshold for cetaceans. As noted by Burkhardt et al. (2008), cetaceans are very unlikely to incur PTS from operation of scientific sonars on a ship that is underway.

Possible Effects of Sub-bottom Profiler Signals

An ODEC Bathy-2000 sub-bottom profiler will be operated from the source vessel during the planned study. Details about this equipment were provided in § I. Sounds from the sub-bottom profiler are very short pulses, occurring for up to 25 ms once every 3–8 sec. Most of the energy in the sound pulses emitted by the sub-bottom profiler is at 3–6 kHz, and the beam is directed downward. The sub-bottom profiler on the R/V *Thompson* has a maximum source level of 211 dB re 1 μPa · m (see § II). 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, and—even for an SBP more powerful than that on the R/V *Thompson*—if the animal was in the area, it would have to pass the transducer at close range and in order to be subjected to sound levels that could cause TTS.

Masking

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

Behavioral Responses

Marine mammal behavioral reactions to other pulsed sound sources are discussed above, and responses to the sub-bottom profilers likely would be similar to those for other pulsed sources if received at the same levels. However, the pulsed signals from the sub-bottom profilers 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 sub-bottom profilers produce pulse levels strong enough to cause hearing impairment or other physical injuries even in an animal that is (briefly) in a position near the source. The sub-bottom profilers are 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 sub-bottom profilers. 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 sub-bottom profiler.

Numbers of Marine Mammals that could be Exposed to Various Received Sound Levels

All anticipated takes would be "takes by harassment" as described in § I, involving temporary changes in behavior. The mitigation measures to be applied will minimize the possibility of injurious takes. (However, as noted earlier and in Appendix A of the EA, 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 consideration of the number of marine mammals that could be disturbed appreciably by ~1600 km of seismic surveys in the western tropical Pacific Ocean. The main 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 seismic sources and the other sources, any marine mammals close enough to be affected by the MBES or SBPs would already be affected by the seismic sources. However, whether or not the seismic sources 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 SBPs given their characteristics (e.g., narrow downward-directed beam) and other considerations described in § I and VII(b and c), above. Such reactions are not considered to constitute "taking" (NMFS 2001). Therefore, no additional allowance is included for animals that might be affected by sound sources other than the seismic sources.

Basis for Estimating Exposure to Various Received Sound Levels

Extensive systematic ship-based surveys have been conducted by NMFS Southwest Fisheries Science Center (SWFSC) for marine mammals in the eastern but not the western tropical Pacific Ocean. A systematic vessel-based marine mammal survey was conducted ~2500 km west of the proposed survey area in the CNMI for the U.S. Navy during January–April 2007 (SRS-Parsons et al. 2007; Fulling et al. in press). The cruise area was defined by the boundaries 10–18°N 142–148°E, encompassing an area ~585,000 km^2 including the islands of Guam and the southern CNMI. The survey was conducted using standard line-transect protocols developed by NMFS SWFSC. Observers visually surveyed 11,033 km of trackline, mostly in high sea states (88% of the time in Beaufort Sea states 4–6). Another survey was conducted by SWFSC ~3500 km east of the proposed survey area in the EEZ around Hawaii during August–November 2002; survey effort was 3550 km in the "Main Island stratum", which had a surface area of 212,892 km^2, and 13,500 km in the "Outer EEZ stratum", which had a surface area of 2,240,024 km^2 (Barlow 2006).

We used densities that were the effort-weighted means for the CNMI (Fulling et al. in press) and the outer EEZ stratum of Hawaii (Barlow 2006). The densities had been corrected, by the original authors, for trackline detection probability bias, and for data from Hawaii, for availability bias. Trackline detection probability bias is associated with diminishing sightability with increasing lateral distance from the track line, and is measured by $f(0)$. Availability bias refers to the fact that there is less-than 100% probability of sighting an animal that is present along the survey track line, and it is measured by $g(0)$. Fulling et al. (in press) did not correct the Marianas densities for availability bias (i.e., it was assumed that $g(0) = 1$), which resulted in underestimates of density. Densities are given in Table 3.

There is some uncertainty about the representativeness of the density data and the assumptions used in the calculations. For example, the timing of the surveys was different; the CNMI survey was in January–April, the Hawaii survey was in August–November, and the proposed survey is in November–

TABLE 3. Densities of marine mammals sighted during surveys in the CNMI (Fulling et al. in press) and the Outer EEZ Stratum of Hawaii (Barlow 2006). See text for rationale and details. All densities are corrected for *f*(0) and some for *g*(0); see text for details. Species listed as "Endangered" under the ESA are in italics.

	Density (#/1000 km^2)		
Species	**CNMI[1]**	**Hawaii[2]**	**Mean[3]**
Mysticetes			
Humpback whale	*0*	*0*	*0*
Minke whale	0	0	0
Bryde's whale	0.41	0.21	0.30
Sei whale	*0.29*	*0*	*0.13*
Fin whale	*0*	*0*	*0*
Blue whale	*0*	*0*	*0*
Odontocetes			
Sperm whale	*1.23*	*3.03*	*2.22*
Pygmy sperm whale	0	3.19	1.76
Dwarf sperm whale	0	7.82	4.30
Cuvier’s beaked whale	0	6.80	3.74
Longman's beaked whale	0	0.45	0.25
Blainville’s beaked whale	0	1.28	0.70
Ginkgo-toothed beaked whale	0	0	0
Rough-toothed dolphin	0.29	3.12	1.85
Bottlenose dolphin	0.21	1.23	0.77
Pantropical spotted dolphin	22.6	2.10	11.32
Spinner dolphin	3.14	0.83	1.87
Striped dolphin	6.16	5.57	5.84
Fraser's dolphin	0	4.57	2.51
Risso’s dolphin	0	0.83	0.46
Melon-headed whale	4.28	1.32	2.67
Pygmy killer whale	0.14	0	0.06
False killer whale	1.11	0.11	0.57
Killer whale	0	0.16	0.09
Short-finned pilot whale	1.59	2.54	2.11

[1] Fulling et al. (in press)
[2] Outer EEZ stratum of Barlow (2006)
[3] Weighted by survey effort

December. Locations were also different, with the proposed survey area ~2500 km east of the CNMI and ~3500 km west of Hawaii. Also, most of the Marianas survey was in high sea states that would have prevented detection of many marine mammals, especially cryptic species such as beaked whales and *Kogia* spp. However, the approach used here is believed to be the best available approach.

The estimated numbers of individuals potentially exposed presented below 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 could 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 proposed survey will be completed; in fact, the ensonified areas calculated using the planned number of line-kilometers ***have been increased by 25%*** to accommodate turns, lines that may need to be repeated, equipment testing, etc. As is typical during offshore ship surveys, inclement weather and equipment malfunctions are likely to cause delays and may limit the number of useful line-kilometers of seismic operations that can be undertaken. Also, any marine mammal sightings within or near the designated exclusion zones 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 could be involved. These estimates assume that there will be no weather, equipment, or mitigation delays, which is highly unlikely.

Furthermore, as summarized in "Summary of Potential Airgun Effects", above, and Appendix A (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 individuals that could be exposed to GI-airgun sounds with received levels ≥160 dB re 1 μPa_{rms} on one or more occasions can be estimated by considering the total marine area that would be within the 160-dB radius around the operating seismic source on at least one occasion, along with the expected density of animals in the area. The proposed seismic lines do not run parallel to each other in close proximity and the ensonified areas do not overlap, thus an individual mammal that was stationary would be exposed once during the proposed 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 GI-airgun operations. The area expected to be ensonified was determined by entering the planned survey lines into a MapInfo GIS, using the GIS to identify the relevant areas by "drawing" the applicable 160-dB buffer (see Table 1) around each seismic line, and then calculating the total area within the buffers. For this survey, there were no areas of overlap because of crossing lines.

Applying the approach described above, ~2144 km^2 (~2680 km^2 including the 25% contingency) would be within the 160-dB isopleth on one or more occasions during the proposed survey. Because this approach does not allow for turnover in the mammal populations in the area during the course of the survey, the actual number of individuals exposed may be underestimated, although the conservative (i.e., probably overestimated) line-kilometer distances used to calculate the area may offset this. Also, the approach assumes that no cetaceans will move away or toward the trackline as the R/V *Thompson* approaches in response to increasing sound levels prior to the time the levels reach 160 dB. Another way of interpreting the estimates that follow is that they represent the number of individuals that are expected (in the absence of a seismic program) to occur in the waters that will be exposed to ≥160 dB re 1 μPa_{rms}.

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

TABLE 4. Estimates of the possible numbers of individuals that might be exposed to ≥160 dB during SIO's proposed seismic survey in western tropical Pacific in November–December 2011. The proposed sound source consists of a pair of 105-in³ GI airguns. Received levels of seismic 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. The column of numbers in boldface shows the numbers of "takes" for which authorization is requested.

Species	Number[1]	% Regional Pop'n²	Requested Take Authorization
Mysticetes			
Humpback whale	*0*	*0*	***0***
Minke whale	0	0	**0**
Bryde's whale	1	<0.01	**1**[3]
Sei whale	*0*	*<0.01*	***1***[3]
Fin whale	*0*	*0*	***0***
Blue whale	*0*	*0*	***0***
Odontocetes			
Sperm whale	*6*	*0.02*	***6***
Pygmy sperm whale	5	NA	**5**
Dwarf sperm whale	12	<0.01	**12**
Cuvier's beaked whale	10	0.05	**10**
Longman's beaked whale	1	NA	**18**[4]
Blainville's beaked whale	2	<0.01	**2**
Ginkgo-toothed beaked whale	0	NA	**0**
Rough-toothed dolphin	5	<0.01	**9**[3]
Bottlenose dolphin	2	<0.01	**2**[3]
Pantropical spotted dolphin	30	<0.01	**64**[3]
Spinner dolphin	5	<0.01	**98**[3]
Striped dolphin	16	<0.01	**27**[3]
Fraser's dolphin	7	<0.01	**182**[4]
Risso's dolphin	1	<0.01	**15**[4]
Melon-headed whale	7	0.02	**95**[3]
Pygmy killer whale	0	<0.01	**0**
False killer whale	2	<0.01	**10**[3]
Killer whale	0	<0.01	**7**[4]
Short-finned pilot whale	6	<0.01	**18**[3]

[1] Estimates are based on densities from Table 3 and an ensonified area (including 25% contingency) of 2680 km².
² Regional population size estimates are from Table 2.
[3] Increased to mean group size in the CNMI (Fulling et al. in press).
[4] Increased to mean group size in Hawaii (Barlow 2006).

the CNMI (Fulling et al. in press) 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 sei whale). For non-listed species, the ***Requested Take Authorization*** has been increased to the mean group size in the CNMI (Fulling et al. in press) or, for species not sighted in the CNMI survey, Hawaii (Barlow 2006) for the particular species in cases where the calculated number of individuals exposed was between 1 and the mean group size.

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 118 (Table 4). That total includes 6 ***Endangered*** sperm whales, representing 0.02% of the regional population. Most (68.6%) of the cetaceans potentially exposed are delphinids; pantropical spotted, striped, and Fraser's dolphins are estimated to be the most common species in the area, with estimates of 30, 16, and 7 (in each case <0.01% of the regional population) exposed to ≥160 dB re 1 μPa_{rms}, respectively.

Conclusions

The proposed seismic project will involve towing a pair of GI airguns that introduce pulsed sounds into the ocean, along with, at times, simultaneous operation of an MBES and an SBP. Routine vessel operations, other than the proposed seismic 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 § IV(1)(b and c), i.e., sounds are beamed downward, the beam is narrow, and the pulses are extremely short.

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 proposed survey area are expected to be low.

Odontocete reactions to seismic pulses, or at least the reactions of delphinids, are expected to extend to lesser distances than are those of mysticetes. Odontocete low-frequency hearing is less sensitive than that of mysticetes, and delphinids are often seen from seismic vessels. In fact, there are documented instances of dolphins approaching active seismic vessels. However, delphinids as well as some other types of odontocetes sometimes show avoidance responses and/or other changes in behavior near operating seismic vessels.

Taking into account the mitigation measures that are planned (see § II), 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". Furthermore, the estimated numbers of animals potentially exposed to sound levels sufficient to cause appreciable disturbance are very low percentages of the regional population sizes (Table 4).

Estimates of the numbers of marine mammals that could be exposed to strong airgun sounds during the proposed program have been presented, together with the requested "take authorization". That figure likely overestimates the actual number of animals that will be exposed to and will react to the seismic sounds. The reasons for that conclusion are outlined above. The relatively short-term exposures are unlikely to result in any long-term negative consequences for the individuals or their populations.

The many cases of apparent tolerance by cetaceans of seismic exploration, vessel traffic, and some other human activities show that co-existence is possible. Mitigation measures such as controlled speed, course alternation, look outs, non-pursuit, and shut downs when marine mammals are seen within defined ranges should further reduce short-term reactions, and avoid or minimize any auditory effects. In all cases, the 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 no subsistence hunting near the proposed survey area, 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 surveys 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 § VI/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 very limited (see Appendix C of the EA). There are three types of potential effects of exposure to seismic surveys: (1) pathological, (2) physiological, and (3) behavioral. Pathological effects involve lethal and temporary or permanent sub-lethal injury. Physiological effects involve temporary and permanent primary and secondary stress responses, such as changes in levels of enzymes and proteins. Behavioral effects refer to temporary and (if they occur) permanent changes in exhibited behavior (e.g., startle and avoidance behavior). The three categories are interrelated in complex ways. For example, it is possible that certain physiological and behavioral changes potentially could 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. 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 aspect of potential impacts relates to how exposure to seismic survey sound affects marine fish populations and their viability, including 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 available information on the effects of exposure to seismic and other anthropogenic sound as relevant to fish. The information comprises results from scientific studies of varying degrees of rigor plus some anecdotal information. Some of the data sources may have serious shortcomings in methods, analysis, interpretation, and reproducibility that must be considered when interpreting their results (see Hastings and Popper 2005). Potential adverse effects of the program's sound sources on marine fish are then noted.

Pathological Effects

The potential for pathological damage to hearing structures in fish depends on the energy level of the received sound and the physiology and hearing capability of the species in question (see Appendix C of the EA). For a given sound to result in hearing loss, the sound must exceed, by some specific 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 is unknown; however, it likely depends 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 valid papers with proper experimental methods, controls, and careful pathological investigation implicating sounds produced by actual seismic survey airguns with 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 fishes 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 airgun arrays [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; McCauley et al. 2000a,b). The periods necessary for the biochemical changes to return to normal are variable, and depend on numerous aspects of the biology of the species and of the sound stimulus (see Appendix C of the EA).

Behavioral Effects

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

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

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

Pathological Effects

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

Some studies have suggested that seismic survey sound has a limited pathological impact on early developmental stages of crustaceans (Pearson et al. 1994; Christian et al. 2003; DFO 2004). However, the impacts appear to be either temporary or insignificant compared to what occurs under natural conditions. Controlled field experiments on adult crustaceans (Christian et al. 2003, 2004; DFO 2004) and adult cephalopods (McCauley et al. 2000a,b) exposed to seismic survey sound have not resulted in any significant pathological impacts on the animals. It has been suggested that 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). 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).

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

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

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

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

During the proposed survey, marine mammals will be distributed according to their habitat preferences, in pelagic waters with depths >1000 m and/or in the vicinity of offshore islands. Concentrations of marine mammals and/or marine mammal prey species are not expected in or near the proposed survey area, and there are no critical feeding, breeding, or migrating areas for any of the species that are found there at the time of the proposed survey.

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, seismic operations will be conducted in accordance with regulations by the National Marine Fisheries Service (NMFS) under the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA), including obtaining permission for incidental harassment or incidental 'take' of marine mammals and other endangered species. The proposed seismic activities will take place in International Waters and the EEZ of Wake Island (U.S.), and possibly in the EEZ of the Republic of the Marshall Islands.

The following subsections provide more detailed information about the monitoring and mitigation measures that are an integral part of the planned activities. The procedures described here are based on protocols used during previous SIO 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).

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

The number of individual animals expected to be approached closely during the proposed activity will be small in relation to regional population sizes. With the proposed monitoring and shut-down provisions (see below), any effects on individuals are expected to be limited to behavioral disturbance. That is expected to have negligible impacts on the species and stocks.

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

Proposed Exclusion Zones

Received sound levels have been modeled by Lamont-Doherty Earth Observatory of Columbia University (L-DEO) for a number of airgun configurations, including two 105-in^3 GI airguns, in relation to distance and direction from the airguns (Fig. 2). The model does not allow for bottom interactions, and is most directly applicable to deep water. Based on the modeling, estimates of the maximum distances from the GI airguns where sound levels of 190, 180, and 160 dB re 1 μPa_{rms} are predicted to be received in deep (>1000-m) water are shown in Table 1.

Empirical data concerning the 190-, 180-, 170- and 160-dB distances were acquired for various airgun arrays based on measurements during the acoustic verification studies conducted by L DEO in the northern Gulf of Mexico in 2003 (6-, 10-, 12-, and 20-airgun arrays, and 2 GI airguns; Tolstoy et al. 2004) and 2007–2008 (36-airgun array; Tolstoy et al. 2009). Results for the 36-airgun array are not relevant for the 2 GI airguns to be used in the proposed survey. The empirical data for the 6-, 10-, 12-, and 20-airgun arrays indicate that, for deep water (>1000 m), the L-DEO model tends to overestimate the received sound levels at a given distance (Tolstoy et al. 2004). Measurements were not made for the 2 GI airgun array in deep water, however, we propose to use the safety radii predicted by L-DEO's model for the proposed GI airgun operations in deep water, although they are likely conservative given the empirical results for the other arrays. Therefore, the assumed 180- and 190-dB radii are 70 m and 20 m, respectively.

The seismic source will be shut down immediately when cetaceans or sea turtles are detected within or about to enter the 180-dB re 1 μPa_{rms} radius, or when pinnipeds are detected within or about to enter the 190-dB re 1 μPa_{rms} radius. The 180- and 190-dB shut-down criteria are consistent with guidelines listed for cetaceans and pinnipeds, respectively, by NMFS (2000) and other guidance by NMFS.

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

Mitigation During Operations

Mitigation measures that will be adopted will include (1) vessel speed or course alteration, provided that doing so will not compromise operational safety requirements, (2) GI-gun shut down within calculated exclusion zones, (3) ramp-up procedures. Although power-down procedures are often standard operating practice for seismic surveys, they will not be used here because powering down from two airguns to one airgun would make only a small difference in the 180- or 190-dB radius—probably not enough to allow continued one-airgun operations if a mammal or turtle came within the safety radius for two airguns.

Speed or Course Alteration

If a marine mammal or sea turtle is detected outside the exclusion zone and, based on its position and the relative motion, is likely to enter the exclusion zone, the vessel's speed and/or direct course could be changed. This would be done if operationally practicable while minimizing the effect on the planned science objectives. The activities and movements of the marine mammal or sea turtle (relative to the seismic vessel) will then be closely monitored to determine whether the animal is approaching the applicable exclusion zone. If the animal appears likely to enter the exclusion zone, further mitigative actions will be taken, i.e., either further course alterations or a shut down of the seismic source. Typically, during seismic operations, the source vessel is unable to change speed or course and one or more alternative mitigation measures (see below) will need to be implemented.

Shut-down Procedures

If a marine mammal or turtle is detected outside the exclusion zone but is likely to enter the exclusion zone, and if the vessel's speed and/or course cannot be changed to avoid having the animal enter the exclusion zone, the seismic source will be shut down before the animal is within the exclusion zone. Likewise, if a mammal or turtle is already within the safety zone when first detected, the seismic source will be shut down immediately.

Following a shut down, seismic activity will not resume until the marine mammal or turtle has cleared the exclusion zone. The animal will be considered to have cleared the exclusion zone if it

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

Ramp-up Procedures

A ramp-up procedure will be followed when the GI airguns begin operating after a specified period without GI airgun operations. It is proposed that, for the present cruise, this period would be 15 min. Ramp up will begin with a single GI airgun (105 in^3). The second GI airgun (105 in^3) will be added after 5 min. During ramp up, the PSOs will monitor the exclusion zone, and if marine mammals or turtles are sighted, a shut down will be implemented as though both GI airguns were operational.

If the complete exclusion zone 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. If one GI airgun has operated, 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 GI airgun and could move away if they choose. A ramp up from a shut down may occur at night, but only where the safety radius is small enough to be visible. Ramp up of the GI airguns will not be initiated if a sea turtle or marine mammal is sighted within or near the applicable exclusion zones during day or night.

XII. PLAN OF COOPERATION

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

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

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

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

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

Not applicable. The proposed activity will take place in International Waters and the EEZs of Wake Island (U.S.) and possibly the Republic of the Marshall Islands, 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...

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

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

Vessel-based 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 subsection (e) below] where there is concern about potential effects on hearing or other physical effects. PSOs will also watch for marine mammals and turtles around the seismic vessel for at least 30 minutes prior to the start of seismic operations after an extended shutdown. When feasible, PSOs will also make observations during daytime periods when the seismic system is not operating for comparison of animal abundance and behavior.

Three PSOs will be appointed by SIO, with NMFS Office of Protected Resources concurrence. At least one PSO will monitor the EZ during seismic operations. PSOs will normally work in shifts of 4-hour duration or less. The vessel crew will also be instructed to assist in detecting marine mammals and turtles.

The *Thompson* will serve as the platform from which PSOs will watch for mammals and sea turtles before and during GI airgun operations. Two locations are likely as observation stations onboard the *Thompson*. At one station on the bridge, the eye level will be ~13.8 m above sea level and the location will offer a good view around the vessel (~310° for one observer and a full 360° when two observers are stationed at different vantage points). A second observation site is the 03 deck where the observer's eye level will be ~10.8 m above sea level. The 03 deck offers a view of 330° for two observers.

Standard equipment for marine mammal observers will be 7 x 50 reticule binoculars and optical range finders. At night, night-vision equipment will be available. The observers will be in wireless communication with ship’s officers on the bridge and scientists in the vessel’s operations laboratory, so they can advise promptly of the need for avoidance maneuvers or seismic source shut down.

MMVO 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 shutdown of the seismic source when a marine mammal or sea turtles 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 seismic source 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, as well as information regarding seismic source shutdown, will be recorded in a standardized format. Data accuracy will be verified by the PSOs at sea, and preliminary reports will be prepared during the field program and summaries forwarded to the operating institution’s shore facility and to NSF weekly or more frequently. PSO observations will provide the following information:

1. The basis for decisions about shutting down the seismic source.
2. Information needed to estimate the number of marine mammals potentially 'taken by harassment'. These data will be reported to NMFS and/or USFWS per terms of MMPA authorizations or regulations.
3. Data on the occurrence, distribution, and activities of marine mammals and turtles in the area where the seismic study is conducted.
4. Data on the behavior and movement patterns of marine mammals and turtles seen at times with and without seismic activity.

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

XIV. Coordinating Research to Reduce and Evaluate Incidental Take

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

SIO and NSF will coordinate the planned marine mammal monitoring program associated with the seismic survey (as summarized in § XI and XIII) with any parties that express interest in this survey activity. UW will work with the US Department of State to obtain the necessary approvals for operating in the foreign EEZ of the Republic of the Marshall Islands.

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