Request by Scripps Institution of Oceanography for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during a Low-Energy Marine Geophysical Survey by the R/V *Melville* in the South-Eastern Pacific Ocean, May 2012

submitted by

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Request by Scripps Institution of Oceanography for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during a Low-Energy Marine Geophysical Survey by the R/V *Melville* in the South-Eastern Pacific Ocean, May 2012

SUMMARY

Scripps Institution of Oceanography (SIO), with research funding from the National Science Foundation (NSF), plans to conduct a low-energy seismic survey in the South-east Pacific ~50 km off the coast of Chile during May 2012. The survey will take place in the Exclusive Economic Zone (EEZ) of Chile, in water depths of ~1000 –5300 m. The seismic survey will use a towed pair of 45-105 in^3 GI airguns. On behalf of SIO, the U.S. State Department will seek authorization from Chile for clearance to work in its EEZ. 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).

Numerous species of cetaceans and pinnipeds inhabit the proposed survey area in the south-eastern Pacific. Several of these species are listed as ***endangered*** under the ESA, including the humpback, sei, fin, blue, and sperm whales. Other species of special concern that could occur in the study area are the ***endangered*** leatherback, and South Pacific DPS of loggerhead turtles and ***threatened*** green, and olive ridley turtles.

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

I. OPERATIONS TO BE CONDUCTED

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

Overview of the Activity

SIO plans to conduct a low-energy seismic survey ~34º–36°S, ~72–74°W, off the coast of Chile (Fig. 1). Water depths in the survey area range from 1000 m to ~5300 m. The ~5-11 days seismic survey will be conducted in the EEZ of Chile, and is scheduled to occur 4 – 18 May 2012. Some minor deviation from these dates is possible, depending on logistics and weather.

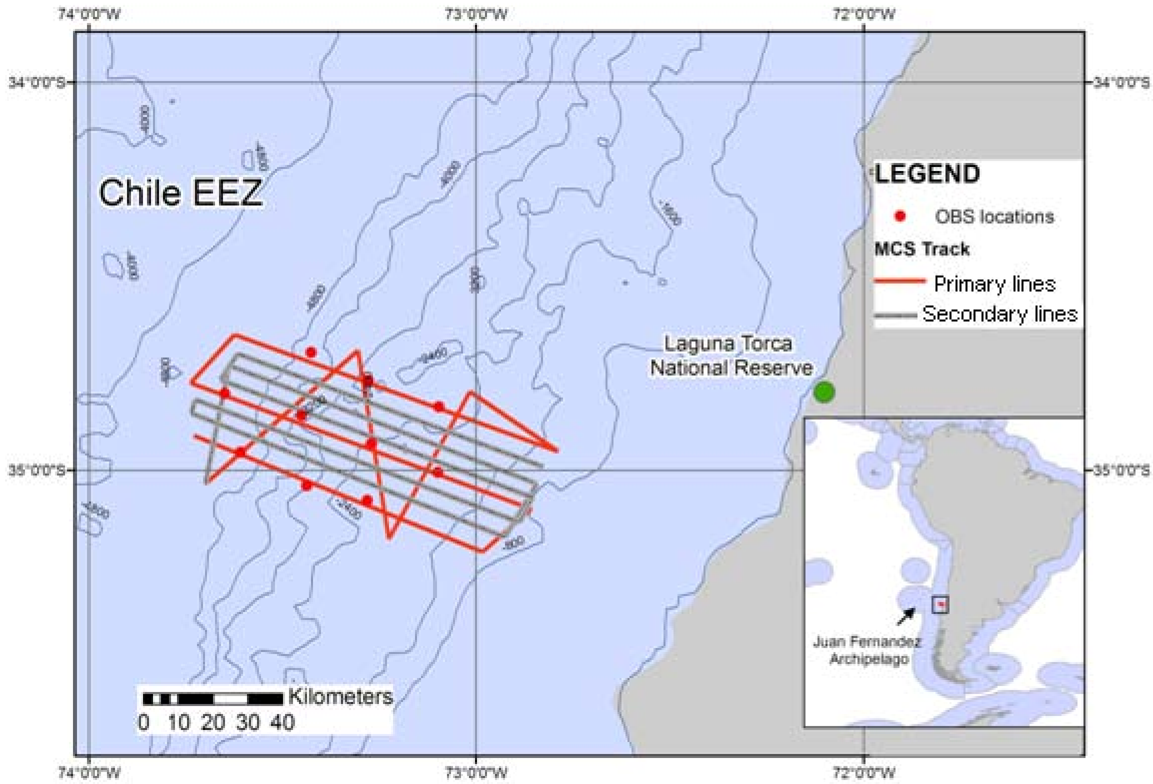

FIGURE 1. Proposed study areas for the survey in the SEP, May 2012. The Primary tracklines, ~569km, will be surveyed first. Depending on weather, data quality, and at sea conditions, efforts will be made to survey Secondary tracklines, ~576km

SIO plans to use conventional low-energy seismic methodology to monitor the post-seismic response of the outer accretionary prism, the area where sediments are accreted onto the non-subducting tectonic plate at the convergent plate boundary.

The survey will involve one source vessel, the R/V *Melville*. The *Melville* will deploy as an energy source a pair of 45-105 in^3 GI airguns. The receiving system will consist of a 200-800 m towed hydrophone streamer up to 48 channels with 12.5m channel spacing, and broadband OBSs. The energy to the airguns is compressed air supplied by compressors on board the source vessel. As the GI airgun is towed along the survey line, the towed hydrophone array streamer receives the reflected signals and transfers the data to the on-board processing system. The OBSs acquire the signal, process the data, and log it internally until the instrument is retrieved and the data is recovered.

The program will consist of ~1145 km of seismic survey tracklines (Fig. 1). Water depths within the seismic survey areas are ~1000–5300 m. To provide constraints on the fault structure and seismic stratigraphy in the accretionary wedge, high resolution seismic data will be acquired using two GI-guns shot simultaneously. Simultaneously shots from both airguns will provide penetration to basement in the trench and clearly define fault structures and folds in the slope basin sediments that overlie the accretionary complex.

The Primary tracklines, ~569 km, identified in Figure 1 will be surveyed first. Depending on weather, data quality, and at sea conditions, efforts will be made to survey the Secondary tracklines idenitified in Figure 1, ~576 km. During the survey, OBSs will be deployed and survey profiles will be taken along tracklines that extend from the trench across the accretionary complex to the region of greatest slip. These data will be processed onboard the vessel and will be used to optimize the location of remaining profiles to be collected within the survey site area. 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. An additional 25% of survey contingency has been added in the calculations to accommodate these operations. In addition to the GI airguns, a multibeam echosounder (MBES) and a sub-bottom profiler (SBP) will be used throughout the cruise. All planned geophysical and geochemical data acquisition activities will be conducted by SIO with on-board assistance by the scientists who have proposed the study. The Principal Investigator is Dr. Anne Trehu of Oregon State University. The vessel will be self-contained, and the crew will live aboard the vessel for the entire cruise.

Vessel Specifications

The R/V *Melville* has a length of 85 m, a beam of 14.0 m, and a maximum draft of 5.0 m. The ship is powered by two 1385-hp Propulsion General Electric motors and a 900-hp retracting Azimuthing bow thruster. Operation speeds of ~8-12 km/h (~4-6 knots) and 15–18.5 km/h (8–10 knots) will be used during seismic acquisition within the survey areas and between stations, respectively. When not towing seismic survey gear, the R/V *Melville* cruises at 21.7 km/h (11.7 knots) and has a maximum speed of 25.9 km/h (14 knots). It has a normal operating range of ~18,630 km.

The R/V *Melville* will also serve as the platform from which vessel-based marine mammal observers will watch for marine mammals and sea turtles before and during airgun operations, as described in § II(3), below.

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

Owner:	U.S. Navy
Operator:	Scripps Institution of Oceanography of the University of California
Flag:	United States of America
Date Built:	1969
Gross Tonnage:	2516
Compressors for Air Guns:	1850 psi
Accommodation Capacity:	23 crew plus 38 scientists

Airgun Description

The R/V *Melville* will tow a pair of 45-105-in^3 Sercel GI airguns and a streamer containing hydrophones. Seismic pulses will be emitted at intervals of ~8–12 seconds. At speeds of ~8-12 km/h through the water, the ~8–12 s spacing corresponds to a shot interval of ~25 m over the seafloor.

The generator chamber of each GI airgun, the one responsible for introducing the sound pulse into the ocean, is either 45 in^3. The injector chamber (105 in^3) 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 *Melville*, at a depth of 2 m. The total effective volume will be 90 cubic inches.

As the GI airgun is towed along the survey line, the towed hydrophone array streamer receives the reflected signals and transfers the data to the on-board processing system. The OBSs acquire the signal, process the data, and log it internally until the instrument is retrieved and the data is recovered. 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.

<u>GI Airgun Specifications</u>

Energy Source	Two GI airguns of 45 in^3-105 in^3 each
Source output (downward)	0-pk is 3.4 bar-m (230.7 dB re 1 μPa·m); pk-pk is 6.2 bar-m (235.9 dB re 1 μPa·m)
Towing depth of energy source	2 m
Air discharge volume	~90 in^3 maximum
Dominant frequency components	2–188 Hz
Gun positions used	Two side by side airguns 8 m apart
Gun volumes at each position (in^3)	45, 45

Predicted Sound Levels

Received sound levels have been modeled by Lamont-Doherty Earth Observatory of Columbia University (L-DEO) for a number of airgun configurations, including two Nucleus 45-in^3 G Guns, in relation to distance and direction from the airguns (Fig. 2). The GI gun is essentially two G guns that are joined head to head. The G-gun signal has more energy than the GI-gun signal, but the peak energy levels are equivalent and appropriate for modeling purposes. The L-DEO 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 guns where sound levels of 190, 180, 170, and 160 dB re 1 μParms are predicted to be received in deep (>1000-m) water are shown in Table 1. Because the model results are for G guns, which have more energy than GI guns of the same size, those distances are overestimates of the distances for the 45-in3 GI guns.

Empirical data concerning the 190-, 180-, 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.

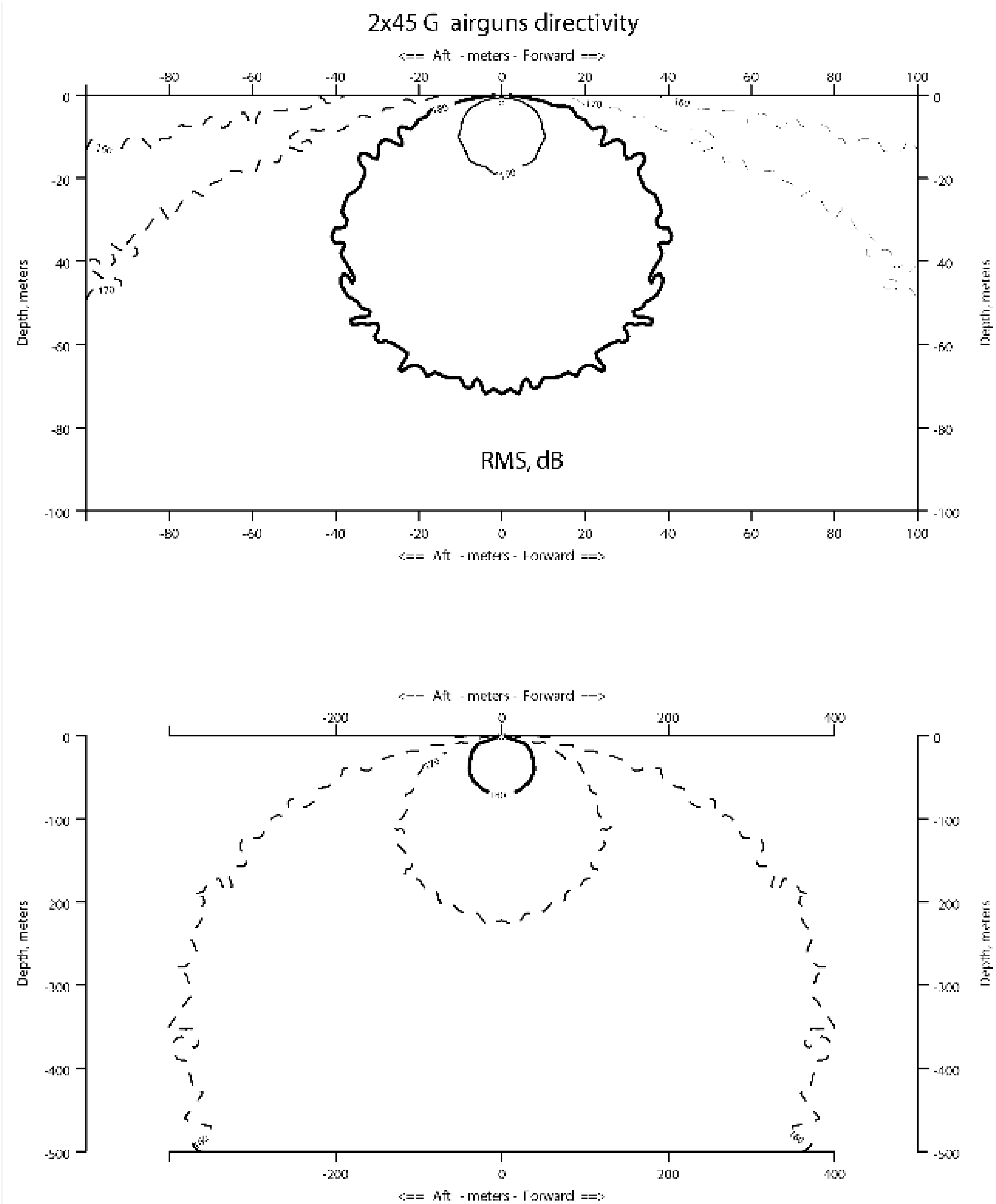

FIGURE 2. Modeled received sound levels from two 45-in^3 Nucleus G guns, similar to the two GI guns that will be used during the SIO survey. Model results provided by the Lamont-Doherty Earth Observatory of Columbia University.

TABLE 1. Distances to which sound levels ≥190, 180, 170, and 160 dB re 1 Parms might be received from two 45-in G guns, similar to the two 45-in GI guns that will be used during the proposed seismic survey in May 2012. Distances are based on model results provided by L-DEO.

Water depth	Estimated Distances at Received Levels (m)			
	190 dB	180 dB	170 dB	160 dB
>1000 m	10	40	125	350
100–1000 m	15	60	188	525
<100 m	147	296	536	1029

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; Holst 2009; Antochiw et al. n.d.). If marine mammals or sea turtles are detected within or about to enter the appropriate exclusion zone, the airguns will be 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.

Description of Operations

The survey will involve one source vessel, the R/V *Melville*. 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 (90 in^3). The receiving system will consist of a 200-800 m towed hydrophone streamer up to 48 channels with 12.5m channel spacing, and broadband OBSs. The energy to the airguns is compressed air supplied by compressors on board the source vessel. As the GI airgun is towed along the survey line, the towed hydrophone array streamer receives the reflected signals and transfers the data to the on-board processing system. The OBSs acquire the signal, process the data, and log it internally until the instrument is retrieved and the data is recovered.

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OBS Description and Deployment

Approximately 10 broadband OBSs will be deployed and recovered by the *Melville* during the survey. LDEO OBS08 model broadband OBSs will be used during the cruise. This type of OBS has a height of ~ 122 cm and a width and depth of 76.2×106.7 cm. The anchor is made of two steel cylinders approximately 15 cm in diameter and 46 cm in length. Each cylinder weighs approximately 75 lbs in air. OBSs will remain on the seafloor to continue to collect data for approximately one year. Once an OBS is ready to be retrieved, an acoustic release transponder interrogates the instrument at a frequency of 9–11 kHz, and a response is received at a frequency of 9–13 kHz. The burn-wire release assembly is then activated, and the instrument is released from the anchor to float to the surface.

Multibeam Echosounder and Sub-bottom Profiler

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

The Knudsen Engineering Model 3260 sub-bottom profiler (SBP) is used in conjunction with the MBES to provide data about the sedimentary features that occur below the sea floor. The SBP is capable of reaching depths of 10,000m. The beam is transmitted as a 27 degree cone, which is directed downward by a 3.5-kHz transducer array mounted in the hull of the R/V *Melville*. The nominal power output is 10 kilowatts or 222 dB re 1μPa-m. The ping duration is up to 64 ms, and the ping interval is 1 s. A common mode of operation is to broadcast five pings at 1-s intervals followed by a 5-s pause. (The 12-kHz section is seldom used in survey mode on *R/V Melville* because of overlap with the operating frequency of the Kongsberg EM 122 MBES.)

II. Dates, Duration, and Region of Activity

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

The survey will occur in the Chile EEZ, south-eastern Pacific Ocean, ~50 km of the coast of Chile 34º–35°S, ~72–74°W (Fig. 1). The seismic survey will take place in water ~1000–5300 m deep. The exact dates of the activities depend on logistics and weather conditions. The ~5-11 days seismic survey will be conducted in the EEZ of Chile, and is scheduled to occur 4 – 18 May 2012. Some minor deviation from these dates is possible, depending on logistics and weather.

III. SPECIES AND NUMBERS OF MARINE MAMMALS IN AREA

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

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

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

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

Sections III and IV are integrated here to minimize repetition.

Twenty-eight cetacean species could occur in the south-eastern Pacific survey area, including odontocetes (toothed cetaceans, such as dolphins) and mysticetes (baleen whales); although considered unlikely, the four pinniped species could also be encountered (Table 2). Information on the occurrence, population size, and conservation status for each of the 32 species is presented in Table 2. The status of these species is based on the ESA, the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2011), and the Convention on International Trade in Endangered Species in Wild Fauna and Flora (CITES; UNEP-WCMC 2011). Five of these species are listed under the ESA as ***Endangered***: the sperm, humpback, fin, sei, and blue whale.

An additional twelve cetacean species, although present in the wider SEP, likely would not be found in the proposed seismic survey area because their ranges in the survey area are extralimital, or they are typically found in coastal water. Southern right whales *(Eubalaena australis*) are listed as endangered, and the IUCN lists the Chile-Peru subpopulation as critically endangered (Reilly 2008). Sightings are seen on rare occasions off the coasts of Peru and Chile (Aguayo et al. 1992, Santillan et al. 2004) although females with calves have been observed between June and October. Given the size of this population, estimated at 50 individuals, in Chile and Peru (IWC 2007, IWC 2007b) and the the rarity of the species in the survey area, it is unlikely that individuals from this subpopulation will be encountered. Pygmy right whales (*Caperea marginata*) are rarely seen at sea, but are known from stranding records off Chile (Cabrera et al. 2005). Little is known about Arnoux's beaked whales (*Berardius arnuxii*) as they are rarely seen, but typically they are found between the Antarctic continent and 34°S. The northernmost limit of their range overlaps with the survey area, but no records of their occurrence exist within the survey area. The spade toothed beaked whales (*Mesoplodon traversii*) and Shepherd's beaked whales *(Tasmacetus shepherdi)* are uncommon species, but individuals have been described from stranding records in the Juan Fernandez Archipelago in Chile (Reyes et al. 1996) approximately 700 km west of the survey site. Ginko toothed beaked whales, (*Mesoplodon ginkgodons*), pygmy beaked whales (*Mesoplodon pervianus*), and long beaked common dolphins *(Delphinus capensis*) are likely extralimital with distributions mostly north of the survey area. Commerson's dolphins (*Cephalorhynchus commersonii),* hourglass dolphins (*Lagenorhynchus cruciger*) and southern bottlenose whales (*Hyperoodon planifrons)* are also extralimital in the survey area, but have a northernmost extent that is south of the survey area.

No cetacean distribution and abundance studies have been conducted in the survey area. The closest distribution studies have been in the Eastern Tropical Pacific and Patagonia, in southern Chile. Several other studies of marine mammal distribution and abundance have been conducted in the wider eastern tropical Pacific (ETP). The most extensive regional distribution and abundance data come primarily from multi-year vessel surveys conducted by NMFS' Southwest Fisheries Science Center

(SWFSC). The surveys were conducted during July–December in an area generally extending from 30ºN to 18ºS from the coastline to 153ºW (Wade and Gerrodette 1993; Ferguson and Barlow 2001; Gerrodette et al. 2008; Jackson et al. 2008).

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

Species	Occurrence in survey area during Apr-May	Habitat	Abundance in the SEP[1]	ESA[2]	IUCN	CITES
Mysticetes						
Humpback whale	Uncommon	Mainly nearshore waters and banks	SE Pacific 2900 [3]	EN	LC	I
Common minke whale	Uncommon	Coastal	338,000 [4]	NL	LC	I
Bryde's whale	Uncommon	Pelagic and coastal	130,008	NL	DD	I
Sei whale	Very rare	Mostly pelagic	11,000 [5]	EN	EN	I
Fin whale	Very rare	Slope, mostly pelagic	15178 [6]	EN	EN	I
Blue whale	Uncommon	Pelagic and coastal	1415 [7]	EN	EN	I
Odontocetes						
Sperm whale	Common	Usually deep pelagic, steep topography	26,053 [8]	EN	VU	I
Pygmy sperm whale	Rare	Deep waters off shelf	150,000[9]	NL	DD	II
Dwarf sperm whale	Very rare	Deep waters off shelf	150,000[9]	NL	DD	II
Cuvier's beaked whale	Uncommon	Slope and pelagic	20,000 [10]	NL	LC	II
Blainville's beaked whale	Uncommon	Pelagic	25300 [11]	NL	DD	II
Rough-toothed dolphin	Common	Mainly pelagic	107,633	NL	LC	II
Bottlenose dolphin	Very Common	Coastal, shelf, pelagic	335,834	NL	LC	II
Spinner dolphin	Very Common	Coastal and pelagic	1,797,716	NL	DD	II
Striped dolphin	Common	Off continental shelf	964,362	NL	LC	II
Short-beaked common dolphin	Common	Shelf, pelagic, high relief	3,127,203	NL	LC	II
Risso's dolphin	Common	Shelf, slope, seamounts	110,457	NL	LC	II
False killer whale	Uncommon	Pelagic	398,009	NL	DD	II
Killer whale	Uncommon	Widely distributed	8500 [12]	NL	DD	II
Long finned pilot whale	Common	Shelf, pelagic	200,000[13]	NL	DD	II
Peale's dolphin	Uncommon	Coastal, shelf	N.A.	NL	DD	II
Dusky dolphin	Common	Shelf, slope	7,252 [14]	NL	DD	II
Southern right whale dolphin	Rare	Pelagic	N.A.	NL	DD	II
Burmeister's porpoise	Rare	Coastal	N.A.	NL	DD	II
Gray's beaked whale	Uncommon	Slope, pelagic	N.A.	NL	DD	II
Hector's beaked whale	Rare	Slope, pelagic	N.A.	NL	DD	II
Strap toothed whale	Rare	Slope, pelagic	N.A.	NL	DD	II
Chilean dolphin	Rare	Coastal, shelf	< 10,000 [15]	NL	NT	II
Pinnipeds						
S. American fur seal	Rare	Coastal, shelf	30,000 [16]	NL	LC	II
Juan Fernandez fur seal	Rare	Coastal, shelf	12,000 [17]	NL	NT	II

S. American sea lion	Very rare	Coastal, shelf	150,000 [18]	NL	LC	II
Southern elephant seal	Very rare	Coastal, Pelagic	650,000 [19]	NL	LC	II

N.A. Not available or not assessed. IUCN: DD = Data deficient, LC = Least Concern, NT = Near Treatened, VU = Vulnerable, EN = Endangered

[1] Abundance from Gerrodette et al. (2008) unless otherwise stated.

[2] U.S. Endangered Species Act: EN = Endangered, T = Threatened, NL = Not listed

[3] Southeast Pacific; Félix et al. (2005)

[4] Estimated from Antarctic and common Minke whales in S Pacific (Reily 2011)

[5] Based on 2007 projection for southern hemisphere (IWC 1996)

[6] Based on 2007 projection for southern hemisphere (Reilly 2011)

[7] ETP (Wade and Gerrodette 1993)* excluded nursing area south of study area estimated at ~ 267 animals

[8] Eastern temperate North Pacific (Whitehead 2002)

[9] This abundance estimate is for both *K. sima* and *K. breviceps* in ETP (Ferguson and Barlow 2001)

[10] ETP (Wade and Gerrodette 1993)

[11] This estimate includes all species of the genus *Mesoplodon* in the ETP (Ferguson and Barlow 2001)

[12] ETP (Ford 2002)

[13] Southern hemisphere population (Waring et al. 1997)

[14] Patagonian coast population (Dans et al. 1997)

[15] SEP (Reeves et al. 2008)

[16] Chile (Arias Shreiber and Rivas 1998)

[17] Juan Fernandez Archipelago population (Aurioles and Trillmich 2008)

[18] Peru and Chile (Campagna 2008a).

[19] Southern hemisphere (Capagna 2009)

Mysticetes

Humpback Whale *(Megaptera novaeangliae)*

The humpback whale is listed as ***Endangered*** under the U.S. ESA and ***Least concern*** on the 2011 IUCN Red List of Threatened Species (IUCN 2011), and is listed in CITES Appendix I (UNEP-WCMC 2011). The worldwide population of humpback whales is divided into various northern and southern ocean populations (Mackintosh 1965). Geographical overlap of these populations has been documented only off Central America (Acevedo and Smultea 1995; Rasmussen et al. 2004, 2007). The humpback whale is one of the most abundant cetaceans off the Pacific coast of Costa Rica during the winter breeding season of northern hemisphere humpbacks, and off the coasts of Ecuador, Columbia, and Panama during the winter breeding period for southern hemisphere humpbacks (e.g., Rasmussen et al. 2004; May-Collado et al. 2005, Félix and Haase 2005). The estimate of abundance for the southeast Pacific stock is ~2900 (Félix et al. 2005)

Humpback whales occur worldwide, migrating from tropical breeding areas to polar or sub-polar feeding areas (Jefferson et al. 2008). Although the humpback whale is considered mainly a coastal species, it often traverses deep pelagic areas while migrating (Clapham and Mattila 1990; Norris et al. 1999; Calambokidis et al. 2001). Some males occur in waters >3000 m deep and up to 57 km from the coast in the Caribbean (Swartz et al. 2003).

Humpback whales are often sighted singly or in groups of two or three, but while on breeding and feeding grounds they may occur in groups of >20 (Leatherwood and Reeves 1983; Jefferson et al. 2008). Based on NMFS vessel-based surveys in the ETP in July–December 2006, Jackson et al. (2008) reported a mean group size of 1.5 (n = 11). The diving behavior of humpback whales is related to time of year and whale activity (Clapham and Mead 1999). 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). On winter breeding grounds, humpback dives have been recorded at depths >100 m (Baird et al. 2000).

Rasmussen et al. (2007) reported 207 humpback whale sightings off Central America during surveys in the austral winters of 2001–2004. Based on eight years (1996–2003) of survey effort off Costa Rica from January to March and three years (2001–2003) off Panama, Rasmussen et al. (2004) reported 177 sightings. Humpback whales were also observed off the coasts of Columbia, Ecuador and Peru, and occasionally in offshore waters >200 km from the coast (Félix and Haase 2005) with a peak in sightings in July. Off the coast of Chile, Humpback whales are known to occur south of the survey area. During opportunistic surveys in 2000-2011 Viddi et al. (2010) made 6 sightings of humpback whales in Patagonia during the austal autumn (between April and June). Group size ranged from 1 to 5 individuals (average 2.8) (Viddi et al. 2010). Migrating humpback whales may occur in the offshore seismic survey areas between April-May, as individuals travel towards their winter breeding grounds farther north.

Minke Whale ***(Balaenoptera acutorostrata)***

The minke whale inhabits all oceans of the world from the high latitudes to near the equator (Jefferson et al. 2008). The common minke whale in the Southern Hemisphere is commonly referred to as the "diminutive" or "dwarf" minke whale (Arnold et al. 1987; Best 1985) and has been considered an undescribed subspecies (Rice 1998). In the Southern Hemisphere common minke whales have been reported for western South Atlantic waters off Brazil (DaRocha and Braga 1982; Zerbini et al. 1996; 1997) and Chilean Patagonia (Acevedo et al. 2006), western South Pacific waters off New Zealand (Baker 1983), central and northern Great Barrier Reef in Australia (Arnold et al. 1987; Arnold 1997), and western Indian Ocean waters off Durban in South Africa (Best 1985). Acevedo et al. (2006) suggested that the population of common minke whales off Brazil may be distributed much farther south in April, some into the Chilean Patagonia Channels, and they postulated that common minke whales from Brazil and Patagonia belong to the same population. However, Pastene et al. (2009) suggest that multiple populations of Minke whales may exist in the southern hemisphere with different populations in the western south Atlantic and western south Pacific oceans.

Minke whales are relatively solitary, but may occur in aggregations of up to 100 when food resources are concentrated (Jefferson et al. 2008). Based on SWFSC vessel surveys from 1991 to 2005, Barlow and Forney (2007) reported mean group sizes of 1.6 (n = 4) off southern California. The mean group size for Minke whales in Patagonia is 1.4 (n=5) (Viddi et al 2010). Little is known about the diving behavior of minke whales, but they are not known to make prolonged deep dives (Leatherwood and Reeves 1983).

The general distribution of minke whales includes the offshore waters of the study area (e.g., Reeves et al. 2002). However, minke whales are likely to be rare in the survey area. Viddi et al. (2010) reported five sightings of Minke whales during a survey in 2000 – 2001 with group sizes ranging from 1to 3 animals. The highest sighting rates for Minke whales in Patagonia, occurred south of the survey site, between April and June (Viddi et al. 2010).

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

Bryde's whale occurs in tropical and subtropical waters, generally between 40°N and 40°S (Jefferson et al. 2008). It is common throughout the ETP, with a concentration near the equator east of 110ºW, decreasing west of 140ºW (Lee 1993; Wade and Gerrodette 1993). They occur off the coasts of Peru and Ecuador but not during July to September (Valdivia *et al.* 1981). Wade and Gerrodette (1993) estimated Bryde's whale population size in the ETP at 13,000, based on data collected during 1986–1990. The International Whaling Commission (IWC) recognizes a cross-equatorial or Peruvian stock of Bryde's whale (Donovan 1991).

Bryde's whales are known to occur in both shallow coastal and deeper offshore waters (Jefferson et al. 2008). It does not undertake long migrations, although there is a general pattern of movement toward the equator in winter and toward higher latitudes in summer (Kato 2002; Miyashita *et al*. 1995). Bryde's whales are usually solitary or in pairs, although groups of 10–20 are known from feeding grounds (Jefferson et al. 2008). Romero et al. (2001) reported that 78% of all sightings off Venezuela were of single animals. Wade and Gerrodette (1993) reported a mean group size of 1.7 (n = 109) for the ETP. The durations of Bryde's whale dives are 1–20 min (Cummings 1985).

Two Bryde's whales were observed north of the survey area during winter surveys between 1993 and 1995 (Aguayo et al. 1998) and they have been sighted off the coast of Chile in an upwelling area between 35°-37°S (Gallardo *et al*. 1983). Bryde's whales are not expected to be common during the May survey period.

Sei Whale (*Balaenoptera borealis*)

The sei whale is listed as ***Endangered*** under the U.S. ESA and on the 2011 IUCN Red List of Threatened Species (IUCN 2011), and is listed in CITES Appendix I (UNEP-WCMC 2011). Sei whale current status is generally uncertain (Horwood 1987) and the global population size is unknown but thought to be small. The sei whale has a nearly cosmopolitan distribution, with a marked preference for temperate oceanic waters, and is rarely seen in coastal waters (Gambell 1985a). In the open ocean, sei whales generally migrate from temperate zones occupied in winter to higher latitudes in the summer, where most feeding takes place (Gambell 1985a). Sei whales appear to prefer regions of steep bathymetric relief such as the continental shelf break, 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. 1999).

Sei whales are frequently seen in groups of 2–5 (Leatherwood et al. 1988; Jefferson et al. 2008), although larger groups sometimes form on feeding grounds (Gambell 1985a). Based on NMFS vessel surveys in the ETP during July–December 2006, Jackson et al. (2008) reported mean group sizes for tentative sei whale sightings (may have been Bryde's whales, see above) of 1.3 (n = 21). Sei whales generally do not dive deeply, and dive durations are 15 min or longer (Gambell 1985a).

Sei whales may have been sighted during surveys in the ETP (Wade and Gerrodette 1993; Kinzey et al. 1999, 2000, 2001); however, it is difficult to distinguish sei whales from Bryde's whales at sea. Because sei whales generally have a more northerly and temperate distribution (Leatherwood et al. 1988), Wade and Gerrodette (1993) classified any tentative sei whale observations in the ETP as Bryde's whale sightings.

Sei whales are likely to be rare in the survey area during the proposed survey period. Rasmussen et al. (2004) did not report sei whales in eight years of surveys off Costa Rica or Panama, and no sei whales were sighted south of the survey area in the fjords of northern Patagonia between 2000 and 2001 (Viddi et al. 2010). Aguayo et al (1998) made three sightings of sei whales in September in the offshore waters of northern and central Chile during surveys between 1993 and 1995, and there is a record of a sei whale ship-strike in 2009. The 2009 incident involved a cruise ship departing from Puerto Montt in southern Chile that struck a baleen whale which was later identified as a sei whale (Brownell et al. 2009). Sei whales are more common north or south of the survey area and are unlikely to be encountered during the survey.

Fin Whale (*Balaenoptera physalus*)

The fin whale is listed as ***Endangered*** under the U.S. ESA and on the 2011 IUCN Red List of Threatened Species (IUCN 2011), and is listed in CITES Appendix I (UNEP-WCMC 2011). Based on 2001 and 2005 surveys, the California/Oregon/Washington Stock of fin whales was estimated at 2636 (Caretta et al. 2010). Fin whales are widely distributed in all the world's oceans in coastal, shelf, and oceanic waters, but typically occur in temperate and polar regions (Gambell 1985b; Perry et al. 1999; Gregr and Trites 2001; Jefferson et al. 2008). The North Pacific population summers from the Chukchi Sea to California, and winters from California southward (Gambell 1985b). Fin whales from the Southern Hemisphere are usually distributed south of 50ºS in the austral summer (Gambell 1985b). The Chile–Peruvian stock of the Southern Hemisphere fin whale population winters west of northern Chile and Peru from 110ºW to 60ºW (Gambell 1985b).

The species appears to have complex seasonal movements, and is likely a seasonal migrant: mating and calving occurs in temperate waters during winter, followed by migration to northern latitudes to feed during the summer (Mackintosh 1966; Gambell 1985b; Jefferson et al. 2008). However, some evidence suggests that there is a resident population of fin whales in the Gulf of California (Tershy et al. 1993). Thus, some individuals or populations may not undertake the typical long-distance migrations that characterize this species. Sergeant (1977) suggested that fin whales tend to follow steep slope contours, either because they detect them readily or because biological productivity is high along steep contours because of tidal mixing and perhaps current mixing.

Fin whales are typically observed alone or in pairs, but also in groups of up to seven or more, with the largest aggregations occurring on feeding grounds (Jefferson et al. 2008). Based on NMFS vessel-based surveys in the ETP in July–December 2006, Jackson et al. (2008) reported a mean group size of 1.2 (n = 8); all sightings were near Baja California. Croll et al. (2001) reported a mean dive depth and time of 98 m and 6.3 min for foraging fin whales, and a mean dive depth and time of 59 m and 4.2 min for non-foraging individuals. Dive depths of >150 m coinciding with the diel migration of krill were reported by Panigada et al. (1999).

Fin whales are considered rare in the proposed survey area during the proposed survey period. No fin whales were sighted in surveys off Patagonia between April – June (Viddi et al. 2010), but ten fin whale sightings were made north of the survey are during winter surveys (June – September) between 1993 and 1995 (Aguayo et a. 1998). Fin whales from the Southern Hemisphere population are likely to be south of the survey area during the proposed May survey period.

Blue Whale (*Balaenoptera musculus*)

The blue whale is listed as ***Endangered*** under the U.S. ESA and on the 2011 IUCN Red List of Threatened Species (IUCN 2011), and is listed in CITES Appendix I (UNEP-WCMC 2011). The world-wide population has been estimated at 15,000, with 10,000 in the Southern Hemisphere (Gambell 1976). Two recognised subspecies of blue whales occur in the Southern Hemisphere: Antarctic (or true) blue whales (*Balaenoptera musculus intermedia*) and pygmy blue whales (*B. m. brevicauda*). During the austral summer, nearly all Antarctic blue whales are in the Southern Ocean south of 55°S, while pygmy blue whales are in more northerly waters, primarily in the Indian Ocean and around Australia and New Zealand (Ichihara, 1966; Kato *et al.*, 1995; Branch *et al.*, 2007; Branch *et al.*, 2009). Blue whales also occur off Chile, Peru and Ecuador, but it is not yet clear whether these blue whales are Antarctic blue whales or pygmy blue whales (Van Waerebeek *et al.*, 1997). The blue whale population estimated off coastal Chile between 18º and 38º S is ~267 (Williams et al. 2009), but this likely underestimates the South Pacific population because it excludes the newly discovered feeding and nursing ground in the

Chiloe-Corcovado region in southern Chile (Williams *et al*. 2009; Hucke-Gaete *et al.*, 2003; Hucke-Gaete *et al.*, 2005; Galletti Vernazzani *et al.*, 2006).

The blue whale is widely distributed throughout most of the world's oceans, occurring in coastal, shelf, and pelagic waters (Jefferson et al. 2008), and are most often found in cool, productive waters where upwelling occurs (Reilly and Thayer 1990). Generally, blue whales are seasonal migrants between high latitudes in the summer, where they feed, and low latitudes in winter, where they mate and give birth (Lockyer and Brown 1981). Little is known about the movements and wintering grounds of the stocks (Mizroch et al. 1984). Some individuals may stay in low or high latitudes throughout the year (Reilly and Thayer 1990; Watkins et al. 2000).

Blue whales are typically found singly or in groups of two or three (Yochem and Leatherwood 1985; Jefferson et al. 2008). They commonly form scattered aggregations on feeding grounds (Jefferson et al. 2008) and apparent single whales are likely part of a large, dispersed group (Wade and Friedrichsen 1979). Based on NMFS vessel surveys in the ETP in July–December 2006, Jackson et al. (2008) reported a mean group size of 1.9 (n = 57). Four satellite-radio-tagged blue whales in the northeast Pacific Ocean spent 94% of their time underwater, 72% of dives were <1 min long, and "true" dives (>1 min) were 4.2–7.2 min long. Shallow (<16-m) dives were most common (75%), and the average depth of deep (>16-m) dives was 105 m (Lagerquist et al. 2000). 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).

Reilly and Thayer (1990) also suggested that the whales seen along the equator are likely part of the southeast Pacific population, which occupies the coastal shelf of South America and the Antarctic (Mackintosh 1966). However, the whales could also be resident in the area, exploiting food resources in the Costa Rica Dome (CRD) and near the South American coastline (Mate et al. 1999; Palacios 1999). Based on call similarities, Stafford et al. (1999b) linked the whales near the CRD to the population that feeds off California at the same time of year. A recent satellite-tag study confirmed that some blue whales off California migrate south in the fall to an area west of the CRD at 9ºN; the area is considered an important winter feeding area for blue whales (Bailey et al. 2009).

Nine blue whales were sighted within the survey area in a boat-based survey between December 1997 and January 1998 (Williams et al. 2009), although higher sighting rates were reported 390 km north (26.5°S to 31°S) (Williams et al. 2009) and 900 km south of the survey area between January and April (Hucke-Gaete *et al.*, 2003). Blue whales may be encountered in the survey area during the May survey period.

Odontocetes

Sperm Whale (*Physeter macrocephalus*)

The sperm whale is listed as ***Endangered*** under the U.S. ESA and as ***Vulnerable*** on the 2011 IUCN Red List of Threatened Species (IUCN 2011), and is listed in CITES Appendix I (UNEP-WCMC 2011). Using the Whitehead (2002) estimate of the worldwide sperm whale population, the NMFS sperm whale recovery plan estimates the sourthern hemisphere population between 150,000 -225,000. The population of sperm whales for he ETP is estimated at 26,053 (Whitehead 2002).

Sperm whales range between the northern and southern edges of the polar pack ice, although they are most abundant in tropical and temperate waters >1000 m deep over the continental shelf edge and slope, and in pelagic waters (e.g., Rice 1989; Gregr and Trites 2001; Waring et al. 2001). Adult females and juveniles generally occur year-round in tropical and subtropical waters, whereas males often move to higher latitudes outside the breeding season to forage (Best 1979; Watkins and Moore 1982; Arnbom and Whitehead 1989; Whitehead and Waters 1990). Sperm whales often associate with areas of high secondary productivity and steep underwater topography, such as volcanic islands (Jacquet and Whitehead 1996). Adult males may occur in water depths <100 m and as shallow as 40 m (Whitehead et al. 1992; Scott and Sadove 1997). Females almost always occur in water depths >1000 m (Whitehead 2002).

Sperm whales undertake some of the deepest-known dives for the longest durations among cetaceans. 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). A recent study of tagged male sperm whales off Norway found that foraging dives extended to highly variable maximum depths, ranging from 14 to 1860 m and with median 175 m (Teloni et al. 2008). During a foraging dive, sperm whales typically travel ~3 km horizontally and 0.5 km vertically (Whitehead 2003). At the Galápagos Islands, sperm whales typically forage at depths of ~400 m (Papastavrou et al. 1989; Whitehead 1989; Smith and Whitehead 2000). Whales typically dove for ~40 min and then spent 10 min at the surface (Papastavrou et al. 1989).

Sperm whales occur singly (older males) or in groups, with mean group sizes of 20–30 but as many as 50 (Whitehead 2003; Jefferson et al. 2008). May-Collado et al. (2005) reported a mean group size of 9.9 whales off Costa Rica. Based on NMFS vessel surveys in the ETP in 2006, Jackson et al. (2008) reported a mean group size of 6.1 (n = 24). Jackson et al. (2008) recorded two sperm whale sightings during surveys in July–December 2006: one ~100 km off the coast of Ecuador and one in deep, offshore waters of the coast of central Peru. Whitehead and Rendell (2004) identified 739 immature and female sperm whales off northern Chile (19^{o} – 23 ^{o}S) in 2000 from photographs, suggesting a higher sighting rate north of the survey site. Several sightings of sperm whales exist within the survey area, and includes one sperm whale stranding reported off Chile in 2009, one sighting during an aerial survey between 36^{o} – 44 ^{o}S in 2009 (Centro de Conservación Cetácea) and 13 sightings in northern and central Chile during winter surveys between 1993 and 1995 (Aguayo et al. 1998).

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

Pygmy sperm whales (*Kogia breviceps*) and dwarf sperm whales (*Kogia sima*) are distributed widely throughout tropical and temperate seas, but their precise distributions are unknown because much of what we know of the species comes from strandings (McAlpine 2002). They are difficult to sight at sea, because of their dive behavior and perhaps because of their avoidance reactions to ships and behavior changes in relation to survey aircraft (Würsig et al. 1998). The two species are often difficult to distinguish from one another when sighted (McAlpine 2002). Wade and Gerrodette (1993) estimated that the population of dwarf sperm whales in the ETP was 11,200.

Both *Kogia* species are sighted primarily along the continental shelf edge and slope and over deeper waters off the shelf (Hansen et al. 1994; Davis et al. 1998; Jefferson et al. 2008). Several studies have suggested that pygmy sperm whales live mostly beyond the continental shelf edge, whereas dwarf sperm whales tend to occur closer to shore, often over the continental shelf (Rice 1998; Wang et al. 2002; MacLeod et al. 2004). Barros et al. (1998), on the other hand, suggested that dwarf sperm whales might be more pelagic and dive deeper than pygmy sperm whales. Another suggestion is that the pygmy sperm whale is more temperate, and the dwarf sperm whale more tropical, based at least partially on live sightings at sea from a large database from the ETP (Wade and Gerrodette 1993). This idea is also supported by the distribution of strandings in South American waters (Muñioz-Hincapié et al. 1998).

Pygmy and dwarf sperm whales are usually found singly or in groups of less than six (Jefferson et al. 2008). Based on NMFS vessel-based surveys in the ETP, Jackson et al. (2008) reported a mean group size of 1.6 (n = 31) for dwarf sperm whales. In the Gulf of California, median dive and surface times for dwarf or unidentified *Kogia* sp. were 8.6 min and 1.2 min, and dives of up to 25 min and surface times up to 3 min were common (J. Barlow, pers. comm. *in* Willis and Baird 1998). However, dive times of up to 45 min have also been recorded in *K. sima* (Willis and Baird 1998). Little is known about dive depths of *Kogia* spp. A satellite-tagged pygmy sperm whale released off Florida made longer dives (> 8 min and up to ~18 min) at night and on overcast days, and shorter dives (usually 2–5 min) on clear days, probably because of the distribution of their prey, vertically-migrating squid (Scott et al. 2001).

Both *Kogia* species have distributions that include the proposed survey area, although dwarf sperm whales are likely to be very rare and pygmy sperm whales are likely to be rare. Rodríguez-Fonseca (2001) reported the presence of *Kogia* sp. off Costa Rica, but only the dwarf sperm whale has been positively identified as occurring in that area (Ferguson and Barlow 2001; Jackson et al. 2008; May-Collado et al. 2005). Similarly, the dwarf sperm whale was the only confirmed *Kogia* species off Costa Rica based on sightings compiled from 1979 to 2001 by May-Collado et al. (2005). Most of the 34 groups of *Kogia* sp. occurred in offshore waters, with frequent sightings ~90–100 km southwest of the Osa Peninsula. Records of pygmy sperm whales along the Chilean coast exist (Huckstadt 2005; Sanino and Yanez 1997), but there are no confirmed sightings of dwarf sperm whales off Chile.

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 high-latitude polar waters (Heyning 1989). There are an estimated 20,000 Cuvier’s beaked whales in the ETP (Wade and Gerrodette 1993).

Cuvier’s beaked whale is found in deep water, but it appears to prefer steep continental slope waters (Jefferson et al. 2008), and is most common in water depths >1000 m (Heyning 1989). Ferguson et al. (2006a) reported that in the ETP, the mean water depth where Cuvier’s beaked whales were sighted was ~3.4 km. It is most commonly seen in groups of 2–7 but also up to 15, with a reported mean group size of 2.3 (MacLeod and D’Amico 2006; Jefferson et al. 2008). In the ETP, group sizes range from one to seven animals (Heyning 1989); Wade and Gerrodette (1993) reported a mean group size of 2.2 (n = 91) and Jackson et al. (2008) reported a mean group size of 1.8 (n = 16). Cuvier’s beaked whales make long (30–60 min), deep dives with reported maximum depths of 1267 m (Johnson et al. 2004) and 1450 m (Baird et al. 2006).

One Cuvier’s beaked whale was observed south of the survey site in Patagonia (Viddi et al. 2010) and was consistent with the observations of beaked whales occurring primarily in offshore deep waters (May-Collado et al. 2005). Cuvier’s beaked whales are likely to be uncommon in the survey area.

Mesoplodont Beaked Whales (*Mesoplodon* spp.)

Mesoplodont beaked whales (*Mesoplodon* spp.) are difficult to distinguish in the field, and confirmed at-sea sightings are rare (Mead 1989; Caretta et al. 2010; Jefferson et al. 2008). Until better methods are developed for distinguishing the different *Mesoplodon* species from one another, the management unit is defined to include all *Mesoplodon* populations (Caretta et al. 2010). Wade and Gerrodette (1993) estimated a population size of Mesoplodont beaked whales at 25,300 for the ETP. No population estimates are available for the SEP.

Mesoplodonts are distributed primarily in deep waters (>2000 m) and along continental slopes at depths 200–2000 m, and are rarely found in continental shelf waters (Pitman 2002). Most mesoplodonts identified to species are known from strandings involving single individuals (Jefferson et al. 2008), thus it is not possible to identify spatial or seasonal patterns in their distribution (Caretta et al. 2010). Dive depths of most of these species are undocumented.

Mean group sizes are unknown for many of the *Mesoplodon* spp. For the ETP, Wade and Gerrodette (1993) reported a mean group size of 3.0 (n = 128) and Jackson et al. (2008) reported a mean group size of 2.4 (n = 30) during July–December surveys in 2006.

MacLeod and Mitchell (2006) identified the ETP as a key area for beaked whales, but little is known about beaked whale distributions in the SEP. Four species are known to occur in or near the survey area: Gray's, Hector's, strap toothed and Blainville's beaked whales.

Blainville's Beaked Whale (*M. densirostris*)

Blainville's beaked whale is the most widely distributed *Mesoplodon* species (Mead 1989), although it is generally limited to pelagic tropical and warmer temperate waters (Jefferson et al. 2008). Occasional occurrences in cooler, higher-latitude waters are presumably related to warm-water incursions (Reeves et al. 2002). Long-term habitat studies in the northern Bahamas found that Blainville's beaked whales preferred continental slope waters 200–1000 m deep characterized by intermediate depth gradients (MacLeod and Zuur 2005), where they spent most of their time along a canyon wall in waters <800 m deep (Claridge 2003; MacLeod et al. 2004; MacLeod and Zuur 2005). Studies elsewhere indicate that Blainville's beaked whales most frequently occurred in waters 300–1400 m deep (Society Islands, Gannier 2000) and 100–500 m deep (Canary Islands, Ritter and Brederlau 1999). This species may also occur in coastal areas, particularly where deep water gullies come close to shore (Jefferson et al. 2008).

The most commonly observed group size for this species is 1–2 individuals, with a maximum of 9 off Hawaii (Baird et al. 2004; Jefferson et al. 2008). MacLeod and D'Amico (2006) reported a mean group size of 3.5 (n = 31), and Ritter and Brederlau (1999) reported a mean group size of 3.4. The maximum known dive depth of tagged Blainville's beaked whales is 1408 m off Hawaii (Baird et al. 2006).

In the ETP, Blainville's beaked whales have been sighted in offshore as well as nearshore areas of Central and South America (Pitman et al. 1987; Pitman and Lynn 2001). Off Costa Rica, May-Collado et al. (2005) reported one sighting of three Blainville's beaked whales in deep offshore waters based on compiled sightings from 1979 to 2001.

Gray's Beaked Whale (M. grayi)

Gray's beaked whale is primarily found in the southern Hemisphere in cool temperate water, where it occurs in deep water beyond the continental shelf (Taylor et al. 2008). It is assumed to have a circum-Antarctic distribution (Mead 1989, MacLeod *et al*. 2006). Most records are from south of 30°S (Taylor et al. 2008). There are many sighting records from Antarctic and sub-Antarctic waters, and in summer months they appear near the Antarctic Peninsula and along the shores of the continent (sometimes in the sea ice). Most of the stranding records are from New Zealand, southern Australia, South Africa, Argentina, Chile, and Peru. The area between the south island of New Zealand and the Chatham Islands has been suggested to be a "hot spot" for sightings of this species (Dalebout *et al*. 2004).

Hector's Beaked Whale (M. grayi)

Hector's beaked whale is also considered a Southern Hemisphere cool temperate species (Mead 1989). The records of this species occur mostly from strandings in southern South America, South Africa, southern Australia, and New Zealand (Taylor et al. 2008). The single confirmed live sighting record is from southwestern Australia (Gales *et al*. 2002). It has been speculated that the species has a continuous distribution in the Atlantic and Indian oceans at least from South America to New Zealand. Although there are no current records from the central and eastern Pacific Ocean, the range may prove to be circumpolar. This species is probably rare in the survey area.

Strap-toothed Whale (M. layardii)

Strap-toothed beaked whales are the largest Mesoplodonts, with recorded lengths of 6.2 m (Pitman 2009). This species likely has a continuous distribution in the cold temperate and sub-Antarctic waters of the Southern Hemisphere, mostly between 35°S and 60°S (Taylor et al. 2008). This suggests that they are primarily distributed south of the proposed survey area. There have been strandings in South Africa, Australia, Tasmania, New Zealand, the Kerguelen Islands, Heard Island, Argentina, Uruguay, Brazil, and the Falkland Islands (MacLeod *et al*. 2006). The seasonality of strandings suggests that this species may migrate. Like all beaked whales, they occur mostly in deep waters beyond the edge of the continental shelf. There is some evidence of sexual segregation in their distribution.

Rough-toothed Dolphin (*Steno bredanensis*)

The rough-toothed dolphin is distributed worldwide in tropical, subtropical, and warm temperate waters (Miyazaki and Perrin 1994). It rarely ranges north of 40°N or south of 35°S (Jefferson 2002). Wade and Gerrodette (1993) estimated rough-toothed dolphin abundance in the ETP at 145,900 based on data collected during 1986–1990. For 2006, the abundance estimate was 107,633 (Gerrodette et al. 2008).

Rough-toothed dolphins are generally seen in deep water and in shallower waters around islands. They are typically found in groups of 10–20 animals, but groups of up to 300 have been seen (Jefferson 2002). They are deep divers and can dive for up to 15 min (Reeves et al. 2002).

In the ETP, sightings of rough-toothed dolphins have been reported by Perrin and Walker (1975), Pitman and Ballance (1992), Wade and Gerrodette (1993), Kinzey et al. (1999, 2000, 2001), Ferguson and Barlow (2001), Jackson et al. (2008), and May-Collado et al. (2005). The mean group size is 15.46 (Ferguson et al. 2006b).

Rough-toothed dolphins are common in the proposed survey area, but are more frequently sighted north of the survey area in the ETP (May-Collado et al., 2005; Rasmussen et al., 2004; Jackson et al., 2008) in both shallow and deep waters. No rough-toothed dolphins were detected during L-DEO seismic surveys off Costa Rica or Nicaragua in February–March 2008 (Holst et al. 2005b; Holst and Smultea 2008) or during winter offshore surveys in northern and central Chile (Aguayo et al. 1998).

Bottlenose Dolphin (*Tursiops truncatus*)

The bottlenose dolphin occurs throughout the world’s tropical, subtropical, and temperate waters, most commonly in coastal and continental shelf waters (Jefferson et al. 2008). Gerrodette et al. (2008) estimated the abundance of bottlenose dolphins in the ETP at 335,834 for 2006.

There are two distinct bottlenose dolphin types: a shallow water type mainly found in coastal waters and a deepwater type mainly found in oceanic waters (Duffield et al. 1983; Hoelzel et al. 1998; Walker et al. 1999). The nearshore dolphins usually inhabit shallow waters along the continental shelf and upper slope, at depths <200 m (Davis et al. 1998). Klatsky et al. (2007) reported that offshore dolphins show a preference for water <2186 m deep. Bottlenose dolphins are reported to regularly dive to depths >450 m for periods of >5 min, and even down to depths of 600–700 m for up to 12 min (Klatsky et al. 2007). Bottlenose dolphins usually occur in groups of 2–20, although groups of >100 are occasionally seen in offshore areas (Shane et al. 1986; Jefferson et al. 2008). Off Costa Rica, May-Collado et al. (2005) reported a mean group size of 21.5 individuals based on sightings from 1979–2001. For the ETP, Ferguson et al. (2006b) reported a mean group size of 24.1 and Jackson et al. (2008) reported a mean group size of 24.2 (n = 149). Bottlenose dolphins in Chile appear to form larger groups in regions close to the proposed survey area and south of it. From two bottlenose dolphin sightings in southern Chile, Zamorano-Abramson (2010) reported a mean group size of 100 animals in the inshore waters of the Aisen Region 43°-45°S, Viddi et al (2010) reported a mean group size of 34.1 animals (n = 8) in Patagonia, southern Chile, and Aguayo et al (1998) reported a mean group size of 71.8 animals (n = 6) in northern and central Chile.

In the ETP, bottlenose dolphins tend to be more abundant close to the coasts and islands (Scott and Chivers 1990); they also seem to occur more inshore than other dolphin species (Wade and Gerrodette 1993). Polacheck (1987) reported that the highest encounter rates for bottlenose dolphins in the ETP tended to be in nearshore areas. Bottlenose dolphins are very common in the proposed survey area, but may be encountered more often close to the coast.

Spinner Dolphin (*Stenella longirostris*)

The spinner dolphin is distributed in oceanic and coastal waters and is associated with warm tropical surface water (Au and Perryman 1985; Reilly 1990; Reilly and Fiedler 1994). The total population of spinner dolphins in the ETP in 1979 was estimated at 0.8–0.9 million (Allen 1985). Wade and Gerrodette (1993) reported an abundance estimate of 1.7 million for spinner dolphins in the ETP based on data collected during 1986–1990. Gerrodette et al. (2008) estimated the abundance for spinner dolphins in the ETP for 2006 at 1,797,716.

In the ETP, three types of spinner dolphins have been identified and two of those are recognized as subspecies: the eastern spinner dolphin, *S. l. orientalis,* considered an offshore species, the Central American spinner, *S. l. centroamericana* (also known as the Costa Rican spinner), considered a coastal species in Costa Rica (Perrin 1990; Dizon et al. 1991), and the ‘whitebelly’ spinner, which is thought to be a hybrid of the eastern spinner and Gray’s spinner (*S. l. longirostris*). Although there is a great deal of overlap between the ranges of eastern and whitebelly spinner dolphins, the eastern form generally occurs in the northeastern portion of the ETP, whereas the whitebelly spinner occurs in the southern portion of the ETP, ranging farther offshore (Wade and Gerrodette 1993; Reilly and Fiedler 1994).

Spinner dolphins in the ETP tend to occur in large groups compared to most other cetaceans. Ferguson et al. (2006b) reported mean group sizes of 108.8, 82.5, and 147.7 for eastern, whitebelly, and unidentified spinner dolphins, respectively, and Gerrodette and Forcada (2005) reported a mean group size of 112 for the eastern stock. Off Costa Rica, May-Collado et al. (2005) reported a mean group size of 97 based on sightings compiled from 1979–2001. Spinner dolphins usually dive to 600 m or deeper to feed (Perrin and Gilpatrick 1994).

Rasmussen et al. (2004) reported only one sighting of spinner dolphins in eight years of surveys from 1996 to 2003 off Costa Rica and from 2001 to 2003 off Panama. May-Collado et al. (2005) reported spinner dolphins primarily in oceanic waters off Costa Rica during 1979–2001, with small numbers in coastal waters. One sighting of a group of 50 spinner dolphins was reported by the UK Navy near the proposed survey area in 1997 (iOBIS 2011), but no spinner dolphins were observed during winter surveys between 1993 and 1995 (Aguayo et al. 1998). The whitebelly is expected to be very common in the proposed survey area.

Striped Dolphin (*Stenella coeruleoalba*)

The striped dolphin has a cosmopolitan distribution in tropical to warm temperate waters from ~50°N to 40°S (Perrin et al. 1994a; Jefferson et al. 2008). Wade and Gerrodette (1993) estimated that the population in the ETP numbered 1.9 million based on data collected during 1986–1990. The population has declined; Gerrodette et al. (2008) estimated the abundance of striped dolphins in the ETP at 964,362 for 2006.

The striped dolphin's preferred habitat seems to be cool, deep, oceanic waters (Davis et al. 1998) along the edge and seaward of the continental shelf, particularly convergence zones and upwelling areas (Au and Perryman 1985). Striped dolphin group sizes are typically several dozen to 500 animals, although groups of thousands sometimes form (Jefferson et al. 2008). For the ETP, Wade and Gerrodette (1993) reported a mean group size of 61, and Jackson et al. (2008) reported a mean group size of 51.8 (n = 137). Off Costa Rica, May-Collado et al. (2005) reported a mean group size of 48.9. Striped dolphins are believed to be capable of diving to depths of 200–700 m based on stomach content analyses (Archer and Perrin 1999).

Multiple sightings of striped dolphins were recorded in offshore waters off Ecuador and northern Peru, and to the southwest of the Galápagos Islands (Jackson et al. 2008). Mayo-Collado et al. (2005) reported this species nearly exclusively from oceanic waters. The occurrence of this species is known primarily in the ETP, north of the proposed survey area, but it may be common in the offshore survey area.

Short-beaked Common Dolphin (*Delphinus delphis*)

Common dolphins are found in tropical and temperate oceans around the world (Evans 1994). There are two species of common dolphin, the more coastal long-beaked dolphin (*Delphinus capensis*) and the more offshore short-beaked dolphin (*D. delphis*). The short-beaked common dolphin is more widely distributed compared to the long-beaked common dolphin (Heyning and Perrin 1994). Only the short-beaked common dolphin is expected to occur in the SEP. Three stocks of *D. delphis* are recognized in the ETP: northern, central, and southern (Perrin et al. 1985; Perryman and Lynn 1993). Individuals present in the proposed study area would likely be from the central and southern stocks.

Gerrodette et al. (2005) reported an abundance estimate for short-beaked common dolphins of 1.1 million for 2003. However, abundance estimates of common dolphins have fluctuated from <1 million to >3 million from 1986 to 2000 (Gerrodette and Forcada 2002). The abundance estimate for 2006 was 3,127,203 (Gerrodette et al. 2008).

The common dolphin's distribution is associated with prominent underwater topography, such as sea mounts (Evans 1994). Short-beaked common dolphins are widely distributed from the coast to at least 550 km from shore (Carretta et al. 2010). In the ETP, common dolphin distribution is associated with cool, upwelling areas along the equator and off Baja California, Central America, and Peru (Au and Perryman 1985; Reilly 1990; Reilly and Fiedler 1994). Reilly (1990) reported no seasonal changes in common dolphin distribution, although Reilly and Fiedler (1994) observed interannual changes in distribution that were likely attributable to El Niño events. Most dives of a radio-tagged common dolphin off southern California were to depths 9–50 m, and maximum depth was ~200 m (Evans 1994).

Common dolphins travel in group of ~10 to >10,000 (Jefferson et al. 2008). For the ETP, Ferguson et al. (2006b) reported a mean group size of 230, and Jackson et al. (2008) reported a mean group size of 217 (n = 123). The mean group size reported between Valparaiso (just east of the survey site) and Easter Island, Chile was 210.1 (n=8) (Aguayo et al. 1998).

Short beaked common dolphins are very common north of the study area, and although the survey area is in the southern-most extent of their range, they are also expected to be common in the proposed study area.

Risso's Dolphin (*Grampus griseus*)

Risso's dolphin is primarily a tropical and mid-temperate species distributed worldwide between 60ºN and 60ºS, where surface water temperatures are ~10ºC (Kruse et al. 1999). Gerrodette et al. (2008) reported an abundance estimate of 110,457 Risso's dolphins for the ETP.

Risso's dolphins usually occur over steeper sections of the upper continental slope in waters 400–1000 m deep (Baumgartner 1997; Davis et al. 1998), and are known to frequent seamounts and escarpments (Kruse et al. 1999; Baird et al. 2002a). Risso's dolphins occur individually or in small- to moderate-sized groups, normally ranging in numbers from 10 to 100 but up to as many as 4000 (Jefferson et al. 2008). May-Collado et al. (2005) reported a mean group size of 11.6 off Costa Rica. For the ETP, Ferguson et al. (2006b) reported a mean group size of 18.64, and Jackson et al. (2008) reported a mean group size of 18.5 (n = 48). Risso's dolphin can remain underwater up to 30 min (Kruse et al. 1999).

Risso's dolphins are common north of the proposed survey area; based on the SWFSC surveys. Eight Risso's dolphins were reported during July–December ETP surveys in 2006 (Jackson et al. 2008). Six of these sightings were reported off the coasts of Costa Rica and Panama, at various depths, and two were reported in offshore waters between Ecuador and the Galápagos Islands. Seventeen sightings of Risso's dolphins were recorded from historical sources along the Chilean coast between 33º and 40ºS (iOIBS 2011 from Argentina RON), making it one of the most common species in the survey area.

False Killer Whale (*Pseudorca crassidens*)

The false killer whales is widely distributed, though not abundant anywhere (Jefferson et al. 2008). It is found in all tropical and warmer temperate oceans, especially in deep offshore waters (Odell and McClune 1999). Wade and Gerrodette (1993) estimated their abundance in the ETP at 39,800 based on data collected during 1986–1990.

False killer whales have been sighted in the ETP, where they chase or attack *Stenella* and *Delphinus* dolphins during tuna fishing operations (Perryman and Foster 1980). They travel in groups of 20–100 (Baird 2002b), although groups of several hundred are sometimes observed. For the ETP, Wade and Gerrodette (1993) and Ferguson et al. (2006b) reported a mean group size of 11, and Jackson et al. (2008) reported a mean group size of 11.8 (n = 16). Off Costa Rica, May-Collado et al. (2005) reported a mean group size of 36.2, and Martínez-Fernandez et al. (2005) reported a mean group size of 13.2. Smaller numbers of false killer whales have been reported south of the survey area, with mean group sizes of 5 animals (n = 2) reported in Patagonia during 2000 – 2001 surveys (Viddi et al. 2010). False killer whales are usually seen far offshore, although sightings have been reported for both shallow (<200 m) and deep (>2000 m) waters (Wade and Gerrodette 1983).

Aguayo et al. (1998) sighted one false killer whale during winter surveys in 1993–1995 between Valparaiso, east of the survey site, and Easter Island, northwest of the survey site. Sightings occur more often north of the survey area. Off Costa Rica, May-Collado et al. (2005) reported nine sightings of 253 animals in 1979–2000. Martínez-Fernandez et al. (2005) observed four groups off Costa Rica during monthly strip-transect surveys during December 2004–June 2005. Rasmussen et al. (2004) reported eight sightings of false killer whales in eight years of surveys (1996–2003) off Costa Rica and in 2001–2003 off Panama. During L-DEO seismic surveys off Costa Rica and Nicaragua, one sighting was made of 12 false killer whales (off the coast of Nicaragua in waters <2000 m deep) in November–December 2004 (Holst et al. 2005b), but none were observed in February–March 2008 (Holst and Smultea 2008). False killer whales are uncommon in the proposed survey area.

Killer Whale (*Orcinus orca*)

The killer whale is cosmopolitan and globally abundant; it has been observed in all oceans of the world (Ford 2002). Killer whales are segregated socially, genetically, and ecologically into three distinct groups: resident, transient, and offshore animals. Offshore whales do not appear to mix with the other types of killer whales (Black et al. 1997; Dahlheim and Heyning 1999). The abundance of killer whales in the ETP was estimated at 8500 (Ford 2002).

Groups sizes of killer whales are 1–75, though offshore transient groups generally contain <10 (Dahlheim et al. 1982; Jefferson et al. 2008). Off Costa Rica, May-Collado et al. (2005) reported that the mean group size was the smallest among the delphinids seen, at 3.5. For the ETP, Ferguson et al. (2006b) reported a mean group size of 5.5, and Jackson et al. (2008) reported a mean group size of 8.1 (n = 15). Viddi et al. (2010) reported mean group sizes of 5 animals (n=2) in Patagonia, south of the survey area. The maximum depth to which seven tagged free-ranging killer whales dove off British Columbia was 228 m, but only an average of 2.4 % of their time was spent below 30 m in depth (Baird et al. 2003).

Killer whales are found throughout the ETP (Pitman and Ballance 1992; Wade and Gerrodette 1993), but are most densely distributed near the coast from 35ºN to 5ºS (Dahlheim et al. 1982). Dahlheim et al. (1982) reported the occurrence of a cluster of sightings at two offshore locations in the ETP. One location was bounded by 7–14ºN and 127–139ºW, and the other was within a band between the equator and 5ºN and from the Galápagos Islands to 115ºW; both well north of the proposed study area.

Jackson et al. (2008) reported four sighting of killer whales north of the study area during July–December surveys in 2006; one sighting was in Panama and the other three sightings were in the offshore waters of central Peru, to the southwest of the Galápagos Islands. Off Costa Rica, May-Collado et al. (2005) reported seven sightings of 25 animals in offshore oceanic waters in 1979–2000. Rasmussen et al. (2004) reported three sightings in eight years of surveys (1996–2003) off Costa Rica and in 2001–2003 off Panama. A group of 20–22 was seen preying on a blue whale calf in the Costa Rica Dome in 2003, ~230 km west of Nicaragua (Gilpatrick et al. 2005).

Aguayo et al. (1998) made 3 sightings of killer whales between Valparaiso and the Easter Islands, in north and central Chile with a mean group size of 2.7 animals. All sightings of killer whales have occurred at least 100 km north or south of the proposed survey area, and killer whales are likely uncommon in the proposed survey area.

Long-finned Pilot Whale (*Globicephala melas*)

Long-finned pilot whales occur in temperate and subpolar zones (Olson and Reilly 2002). They are found in oceanic waters and some coastal waters of the North Atlantic Ocean, including the Mediterranean Sea and North Sea. In the North Atlantic, the species occurs in deep offshore waters, including those inside the western Mediterranean Sea, North Sea, and Gulf of St. Lawrence (Abend and Smith 1999). The circum-Antarctic subpopulation in the Southern Hemisphere occur as far south as the Antarctic Convergence, sometimes to 68°S, and this subpopulation is likely isolated from the population of pilot whales in the Northern Hemisphere (Bernard and Reilly 1999).

There are estimated to be about 200,000 long-finned pilot whales in the summer south of the Antarctic Convergence in the Southern Hemisphere, and approximately 31,000 (CV = 0.27) in the western North Atlantic (Waring *et al*. 2006), but some of these are short-finned pilot whales. The typical temperature range for the species is 0 - 25°C (Martin 1994).

Aguayo et al. (1998) made three sightings of long-finned pilot whales between Valparaiso and 76°W, just off the Chilean coast during a 3-year survey period. Individuals were sighted mainly near the edge of the continental shelf. Tracking studies of long finned pilot whales around the Faroe islands showed a preference for waters over the borders of the continental shelf (Bloch *et al*. 2003). The mean group size reported off coastal Chile was 4 animals (Aguayo et al. 1998). An additional 26 sightings were made of long finned pilot whales between 33° and 40° S off the coast of Chile (iOBIS 2011 from Argentina RON). Long-finned pilot whales are likely common in the proposed survey area.

Peale's Dolphin (*Lagenorhynchus australis*)

Peale's dolphins occupy two major habitats: open, wave-washed coasts over shallow continental shelves to the north; and deep, protected bays and channels to the south and west. It is typically associated with rocky coasts and riptides at the openings to fjords in the channels. Peale's dolphins show a high degree of association with kelp beds (*Macrocystis pyrifera*), especially in the channel regions (Viddi and Lescrauwaet 2005). Although Peale's dolphins have been observed in waters at least 300 m deep, they appear to prefer shallower coastal waters (Brownell et al. 1999). Over much of its range Peale's dolphin is sympatric with the dusky dolphin although they differ slightly in their habitat use. These two species are often difficult to differentiate at sea (Goodall et al. 1997; de Haro and Iniguez 1997). Peale's dolphins are known to associate with other cetacean species, especially Commerson's dolphins. Calves have been reported from spring through autumn.

Throughout the northern part of their range, Peale's dolphins inhabit waters of the wide continental shelf off Argentina and the narrower shelf off Chile. Aguayo et al (1998) did not observe any Peale's dolphins off coastal Chile near the study site during winter surveys between 1993 and 1995. Zamorano-Abramson et al (2010) observed a mean group size of 6 Peale's dolphins (n=55) during summer surveys (February-March 2009) in Patagonia south of the survey site, and Viddi et al (2010) observed a mean group size of 4.3 animals (n = 42) during surveys in southern Chile in 2000-2001. Peale's dolphins were observed most frequently during surveys in southern Chile during spring and winter (Viddi et al. 2010) although no other studies suggest a seasonal migration for this species. Although this species has a distribution that extends north of the study area, only one record of a sighting exists north of the proposed survey area (iOBIS 2011 from Argentian RON). Peale's dolphins are unlikely to be encountered in the survey area during May.

Dusky Dolphin (*Lagernorhynchus obscures*)

This coastal species is usually found over the continental shelf and slope (Jefferson *et al*. 1993; Aguayo *et al*. 1998). The distribution of dusky dolphins along the west coast of South Africa and both coasts of South America is associated with the continental shelves and cool waters of the Benguela, Humboldt and Falkland Currents. Around New Zealand, these dolphins are associated mainly with various cold water currents (Brownell and Cipriano 1999). Van Waerebeek et al. (1995) suggested that dusky dolphins may be limited to water shallower than 200 m. Off Argentina, dusky dolphins have been sighted from the coast to almost 200 nautical miles offshore (Crespo et al. 1997). They appear to prefer water with sea surface temperatures between 10°C and 18°C (Brownell and Cipriano 1999). Inshore to offshore shifts in abundance have been noted for Argentina and New Zealand, and individuals are known to move over deep waters in some areas, but always along continental slopes.

There are few abundance estimates available for any significant portion of the range (Brownell and Cipriano 1999). The total number of dusky dolphins in one area off the Patagonian cost was estimated to be close to 7,252 individuals (Dans et al. 1997). Individuals from some subpopulations are typically reported as bycatch, such as in fishing-related mortalities in Peru (Van Waerebeek 1994; Van Waerebeek et al. 1997), and midwater trawling in Patagonia (Dans et al. 1997).

There is a gap in the distribution of dusky dolphins in South America, spanning about 1,000 km along the Chilean coast. Animals off Patagonia tend to be smaller than those off northern Chile and Peru, suggesting that the subpopulations in western and eastern South America are separate (Hammond et al. 2008). Aguayo et al. (1998) made only one dusky dolphin sighting of 2 individuals during surveys in 1993-1995 north of the survey site (33ºN), and an additional eight records of dusky dolphins exist south of the survey site, off the coast of Chile (iOBIS 2011 from Argentinean RON). Shiavini et al. (1999) found that 95% of dusky dolphin groups encountered consisted of 10 animals or less in the north and central Patagonia waters, off Argentina indicating smaller group sizes around Chile and Argentina. Dusky dolphins may be common in the survey site, although they are unlikely to be encountered in the deep offshore waters of the proposed survey area.

Southern Right Whale Dolphin (*Lissodelphis peronii*)

Southern right whale dolphins are observed most often in cool, deep, offshore waters with temperatures ranging from 1-20°C. They are only occasionally seen nearshore, generally where deep water approaches the coast (Jefferson *et al*. 1994; Rose and Payne 1991). There are no estimates of abundance for the southern right whale dolphin, and virtually nothing is known of the subpopulation structure or status of the species. Preliminary boat surveys and the rapid accumulation of stranding and fishery interaction records in northern Chile suggest that the southern right whale dolphin may be one of the most common cetaceans in that region (Jefferson *et al*. 1994; Van Waerebeek *et al*., 1991). Aguayo *et al*. (1998) reported one sighting of *L. peronii* between Valparaiso and 76°W, i.e. just off the Chilean coast during a survey in September 1994, consisting of five individuals.

The distribution of southern right whale dolphins is poorly known, though it appears to be circumpolar and fairly common throughout its range (Jefferson *et al*. 1994, Lipsky 2002). Southern right whale dolphins are found only in cool temperate to subantarctic waters of the Southern Hemisphere, mostly between about 30°S and 65°S. The southern limit appears generally to be bounded by the Antarctic Convergence. The range extends furthest north along the west coast of continents, due to the cold counter clockwise currents of the Southern Hemisphere. The northernmost record is at 12°S, off northern Peru (Hammond et al. 2008). Southern right whale dolphins are not unlikely to be encountered during the proposed survey.

Burmeister's porpoise *(Phocoena spinipinnis)*

Very little is known about this species. Most sightings are of less than six individuals, but aggregations of up to 70 have been reported (Goodall et al. 1995a; 1995b). This species is difficult to observe because it is inconspicuous at the surface. There appears to be a protracted summer birth peak with most births in Peru apparently occurring in late summer to fall (Reyes et al. 1995). Burmeister's porpoise have not been sighted within the survey area, and are primarily found south of the survey area, between 44 ºS to 46ºS. Zamorano-Ambramson et al. (2010) sighted 8 groups of Burmeister's porpoise over a six-day period in February 2009 in Patagonia, south of the survey site. Group size ranged from 2 to 7 animals. Aguayo et al. (1998) made no sightings of this species between Valparaiso and Easter Island during winter surveys in 1993 – 1995.

Burmeister's porpoise are essentially a coastal species, which sometimes frequents inshore bays, channels, and the fjords of Tierra del Fuego. It is also occasionally observed inside the kelp line. Individuals are typically found shoreward of the 60 m isobath, but occasionally animals are recorded in deeper water up to 1,000 m (Brownell and Clapham 1999). There have also been records from offshore waters 50 km from the coast of Argentina, however it is unlikely what this species will be encountered in the survey area during the proposed survey period.

Chilean dolphin *(Cephalorhynchus eutropia)*

This dolphin is endemic along the Chilean coast (and possibly in southern Argentina), from about 30°S to Cape Horn, at the southern tip of South America. It is found in shallow coastal waters, and sometimes enters estuaries and rivers. It occurs in the channels and fjords of southern Chile, and to a lesser extent along the west coast of Tierra del Fuego, such as in the Strait of Magellan. Its distribution appears to be continuous, although there may be areas of local abundance, such as Golfo de Arauco, the coast off Valdivia and the eastern side of Isla de Grande Chiloé (Goodall *et al*. 1988).

Sightings of Chilean dolphins are restricted to cold shallow coastal waters where they feed on shallow-water fish (Goodall 1994). According to Goodall (1994) it inhabits two distinct areas: the channels from Cape Horn to Isla Grande de Chiloé and open coasts, bays and river mouths north of Isla Chiloé. Its habitat preference includes areas with rapid tidal flow, tide rips, and shallow waters over banks at the entrance to fjords. Chilean dolphins represented 16% of the cetacean sightings, captures, and strandings in an 8-year study between Coquimbo (30°S) and Tome (36.5°S), but most sightings occurred on an opportunistic basis (Goodall, 1994). Perez-Alvarez et al. (2007) saw Chilean dolphins in 83% of the surveys north of the Maule River (36 °N), in a zone more influenced by the estuarine system, but no sightings were made in central Chile during offshore surveys (Aguayo et al. 1998).

Most sightings have been near shore and therefore the Chilean dolphin is considered a coastal species. Their movements appear limited, with most dolphins resident in only a small area. Individuals identified from natural markings on their dorsal fins have been shown to concentrate their activities in specific bays and channels (Heinrich, 2006). Groups tend to be small (between 1 and 15), but relatively large aggregations (20-50) have been reported (Goodall 1994; Viddi et al. 2010). Although mixed groups of Chilean and Peale's dolphins have been observed, a clear pattern of spatial and temporal partitioning of coastal habitat by the two species was documented during a six-year study at Isla Grande de Chiloé (Heinrich 2006). Chilean dolphins are rare in the offshore survey area.

Pinnipeds

Four species of pinnipeds are known to occur within the SEP: the South American sea lion (*Otaria flavescens*), Juan Fernandez fur seal (*Arctocephalus philippii*), South American fur seal (*A. australis*) and southern elephant seal (*Mirounga leonina*). Of the four species, three have the potential to occur within the survey area, although any occurrence is likely to be rare as they are mainly coastal species.

South American sea lions and South American fur seals are distributed along the coast of South America. The northernmost breeding colony of South American sea lions occurs on the Peruvian coast (Vaz-Ferreira 1981), but vagrant individuals have been seen along the coast of Colombia (Capella et al. 2002) and as far north as Panama (Méndez and Rodriguez 1984). South American sea lions are considered non-migratory, although some may wander long distances away from rookeries during the non-breeding season. Most rookeries are continuously occupied by at least some animals. Campagna et al. (2001) used satellite tracking to examine the foraging behaviour of lactating females and pre-breeding males in the southwest Atlantic Ocean. Although mean foraging trips covered an average of 206 km in the case of females and 591 km in the case of males, tagged animals remained on the continental shelf and never ventured in waters deeper than 150 m. South American fur seals have a discontinuous distribution off the coast of Chile, with no records of occurrence between 28-43°S (Campagna 2008), however a few sightings have been made of animals 600 km offshore and in the Juan Fernandez islands, west of the proposed survey area. However, as the survey area is mainly well offshore and these two species are most common in the coastal habitat, sightings in the study area are not expected, although rare encounters could occur.

The Juan Fernandez fur seal is only found ashore regularly in the Juan Fernandez Archipelago in the eastern South Pacific, west of mainland Chile. The Archipelago includes the Juan Fernandez Island group, and the San Felix Islands, approximately 600 km to the north. They have a seasonal presence in the rookeries with a peak occurring during the breeding period between November-January. Vagrant Juan Fernandez fur seals have been found on the west coast of South America from southern Peru to southern Chile (Aurioles and Trillmich 2008). Juan Fernandez fur seal females travel long distances to forage. Based on geolocating time-depth recorders, the mean distance travelled away from the breeding colony is 653 km, and all tagged females traveled at least 550 km to forage (Aurioles and Trillmich 2008). Most trips were southwest and west of the Juan Fernandez Islands, far offshore to deep oceanic areas. Given the distance of the survey site from the Juan Fernandez Archipelago and the tendency for foraging animals to travel away from coastal Chile, no Juan Fernandez fur seals are expected to be encountered in the survey area.

Southern elephant seals have a nearly circumpolar distribution in the southern Hemisphere. A breeding population occurs at Península Valdes on the Argentinan coast of South America that is thought to be a distinct population from the South Georgia population (Campagna et al. 2008). Historically, southern elephant seals have also been recorded in the Juan Fernandez archipelago (Bourne et al. 1992). Individuals are known to travel long distances and an individual tagged in Tierra del Fuego in southern Chile was recorded to travel 18,000 miles in 11 months (Wildlife Conservation Society 2011). Although southern elephant seals are known to undertake long migrations, and spend 9-10 months at sea, their typical range is in the higher latitudes south of the survey site. Southern elephant seals are rare in the proposed survey area and are not expected to be encountered.

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 Marine Mammal Protection Act (MMPA) for incidental take by harassment during its planned seismic survey in the south-eastern Pacific Ocean during May 2012.

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

VI. NUMBERS OF MARINE MAMMALS THAT COULD BE TAKEN

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

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

VII. ANTICIPATED IMPACT ON SPECIES OR STOCKS

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

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

- First we summarize the potential impacts on marine mammals of airgun operations, as called for in § VII. A more comprehensive review of the relevant background information appears in Appendix A of the EA.
- Then we discuss the potential impacts of operations by the echosounders.
- Finally, we estimate the numbers of marine mammals that could be affected by the proposed survey in the south-eastern Pacific Ocean during May 2012. This section includes a description of the rationale for the estimates of the potential numbers of harassment "takes" during the planned survey, as called for in § VI.

Summary of Potential Effects of Airgun Sounds

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

Tolerance

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

Masking

Masking effects of pulsed sounds (even from large arrays of airguns) on marine mammal calls and other natural sounds are expected to be limited, although there are very few specific data on this. Because of the intermittent nature and low duty cycle of seismic pulses, animals can emit and receive sounds in the relatively quiet intervals between pulses. However, in exceptional situations, reverberation occurs for much or all of the interval between pulses (e.g., Simard et al. 2005; Clark and Gagnon 2006), which could mask calls. Some baleen and toothed whales are known to continue calling in the presence of seismic pulses, and their calls usually can be heard between the seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999a,b; Nieukirk et al. 2004; Smultea et al. 2004; Holst et al. 2005a,b, 2006; Dunn and Hernandez 2009). However, Clark and Gagnon (2006) reported that fin whales in the northeast Pacific Ocean went silent for an extended period starting soon after the onset of a seismic survey in the area. Similarly, there has been one report that sperm whales ceased calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994). However, more recent studies found that they continued calling in the presence of seismic pulses (Madsen et al. 2002; Tyack et al. 2003; Smultea et al. 2004; Holst et al. 2006; Jochens et al. 2008). Dolphins and porpoises commonly are heard calling while airguns are operating (e.g., Gordon et al. 2004; Smultea et al. 2004; Holst et al. 2005a,b; Potter et al. 2007). The sounds important to small odontocetes are predominantly at much higher frequencies than are the dominant components of airgun sounds, thus limiting the potential for masking. In general, masking effects of seismic pulses are expected to be minor, given the normally intermittent nature of seismic pulses. Masking effects on marine mammals are discussed further in Appendix 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. 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 160–170 dB re 1 μPa_{rms} seem to cause obvious avoidance behavior in a substantial fraction of the animals exposed (Richardson et al. 1995). In many areas, seismic pulses from large arrays of airguns diminish to those levels at distances ranging from 4 to 15 km from the source. A substantial proportion of the baleen whales within those distances may show avoidance or other strong behavioral reactions to the airgun array. Subtle behavioral changes sometimes become evident at somewhat lower received levels, and studies summarized in Appendix 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; 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). Based on a single observation, Aguilar-Soto et al. (2006) suggested that foraging efficiency of Cuvier's beaked whales may be reduced by close approach of vessels. In any event, it is likely that most beaked whales would also show strong avoidance of an approaching seismic vessel, although this has not been documented explicitly. In fact, Moulton and Holst (2010) reported 15 sightings of beaked whales during seismic studies in the Northwest Atlantic; seven of those sightings were made at times when at least one airgun was operating. There was little evidence to indicate that beaked whale behavior was affected by airgun operations; sighting rates and distances were similar during seismic and non-seismic periods (Moulton and Holst 2010).

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

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

Pinnipeds.—Pinnipeds are not likely to show a strong avoidance reaction to the airgun array. Visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds, and only slight (if any) changes in behavior—see Appendix 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).

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. TTS has been demonstrated and studied in certain captive odontocetes and pinnipeds exposed to strong sounds (reviewed in Southall et al. 2007). However, there has been no specific documentation of TTS let alone permanent hearing damage, i.e., permanent threshold shift (PTS), in free-ranging marine mammals exposed to sequences of airgun pulses during realistic field conditions. Current NMFS policy regarding exposure of marine mammals to high-level sounds is that cetaceans should not be exposed to impulsive sounds with received levels ≥180 dB re 1 μPa_{rms} (NMFS 2000). This criterion has been used in establishing the exclusion (=shut-down) zones planned for the proposed seismic survey. However, this criterion was established before there was any information about minimum received levels of sounds necessary to cause auditory impairment in marine mammals. As discussed in Appendix 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 have been published (Southall et al. 2007). Those recommendations have not, as of 2011, been formally adopted by NMFS for use in regulatory processes and during mitigation programs associated with seismic surveys. However, some aspects of the recommendations have been taken into account in certain environmental impact statements and small-take authorizations. NMFS has indicated that it may issue new noise exposure criteria for marine mammals that account for the now-available scientific data on TTS, the expected offset between the TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive (e.g., M-weighting or generalized frequency weightings for various groups of marine mammals, allowing for their functional bandwidths), and other relevant factors. Preliminary information about possible changes in the regulatory and mitigation requirements, and about the possible structure of new criteria, was given by Wieting (2004) and NMFS (2005).

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

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

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

For toothed whales exposed to single short pulses, the TTS threshold appears to be, to a first approximation, a function of the energy content of the pulse (Finneran et al. 2002, 2005). Based on these data, the received energy level of a single seismic pulse (with no frequency weighting) might need to be ~186 dB re 1 $\mu Pa^2 \cdot s$ (i.e., 186 dB SEL or ~196–201 dB re 1 μPa_{rms}) in order to produce brief, mild TTS[1]. Exposure to several strong seismic pulses that each have received levels near 190 dB re 1 μPa_{rms} might result in cumulative exposure of ~186 dB SEL and thus slight TTS in a small odontocete assuming the TTS threshold is (to a first approximation) a function of the total received pulse energy; however, this 'equal-energy' concept is an oversimplification. The distances from the *Melville'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 planned study area at the time of the survey; (2) the strong likelihood that baleen whales would avoid the approaching airguns (or vessel) before being exposed to levels high enough for TTS to occur; and (3) the mitigation measures that are planned.

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

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

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

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

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

Relationships between TTS and PTS thresholds have not been studied in marine mammals, but are assumed to be similar to those in humans and other terrestrial mammals. PTS might occur at a received sound level at least several decibels above that inducing mild TTS if the animal were exposed to strong sound pulses with rapid rise time—see Appendix 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. (2007:441-4) 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 μ$Pa^2 \cdot s$ (15 dB higher than the M_{mf}-weighted TTS threshold, in a beluga, for a watergun impulse), where the SEL value is cumulated over the sequence of pulses. Additional assumptions had to be made to derive a corresponding estimate for pinnipeds, as the only available data on TTS-thresholds in pinnipeds pertain to non-impulse sound. Southall et al. (2007) estimate that the PTS threshold could be a cumulative M_{pw}-weighted SEL of ~186 dB re 1 μ$Pa^2 \cdot s$ in the harbor seal exposed to impulse sound. The PTS threshold for the California sea lion and northern elephant seal would probably be higher, given the higher TTS thresholds in those species.

Southall et al. (2007) also note that, regardless of the SEL, there is concern about the possibility of PTS if a cetacean received one or more pulses with peak pressure exceeding 230 or 218 dB re 1 μPa (peak), respectively. Thus, PTS might be expected upon exposure of cetaceans to *either* SEL ≥198 dB re 1 μ$Pa^2 \cdot s$ *or* peak pressure ≥ 230 dB re 1 μPa. Corresponding pro posed dual criteria for pinnipeds (at least harbor seals) are ≥ 186 dB SEL and ≥ 218 dB peak pressure (Southall et al. 2007). These estimates are all first approximations, given the limited underlying data, assumptions, species differences, and evidence that the "equal energy" model may not be entirely correct. A peak pressure of 230 dB re 1 μPa

(3.2 bar·m, 0-pk) would only be found within a few meters of the GI airguns planned for this survey (e.g., Caldwell and Dragoset 2000). A peak pressure of 218 dB re 1 μPa could be received somewhat farther away; to estimate that specific distance, one would need to apply a model that accurately calculates peak pressures in the near-field around an array of airguns.

Given the higher level of sound necessary to cause PTS as compared with TTS, it is considerably less likely that PTS would occur. Baleen whales generally avoid the immediate area around operating seismic vessels, as do some other marine mammals and sea turtles. The planned monitoring and mitigation measures, including visual monitoring, 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.

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

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

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

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

Possible Effects of Multibeam Echosounder Signals

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

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

Masking

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

Behavioral Responses

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

Captive bottlenose dolphins and a white whale exhibited changes in behavior when exposed to 1-s tonal signals at frequencies similar to those that will be emitted by the MBES used by 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 echosounder sounds at frequencies similar to those used during seismic operations. Hastie and Janik (2007) conducted a series of behavioral response tests on two captive gray seals to determine their reactions to underwater operation of a 375-kHz multibeam imaging echosounder that included significant signal components down to 6 kHz. Results indicated that the two seals reacted to the signal by significantly increasing their dive durations. Because of the likely brevity of exposure to the MBES sounds, pinniped reactions are expected to be limited to startle or otherwise brief responses of no lasting consequence to the animals.

Hearing Impairment and Other Physical Effects

Given recent stranding events that have been associated with the operation of naval sonar, there is concern that mid-frequency sonar sounds can cause serious impacts to marine mammals (see above). However, the MBES proposed for use by 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 242 dB re 1 μPa·m_{rms} the received level for an animal within the MBES beam 100 m below the ship would be ~202 dB re 1 μPa_{rms}, assuming 40 dB of spreading loss over 100 m (circular spreading). Given the narrow beam, only one pulse is likely to be received by a given animal as the ship passes overhead. The received energy level from a single pulse of duration 15 ms would be about 184 dB re 1 $\mu Pa^2 \cdot s$, i.e., 202 dB + 10 log (0.015 s). That is below the TTS threshold for a cetacean receiving a single non-impulse sound (195 dB re 1 $\mu Pa^2 \cdot s$) and even further below the anticipated PTS threshold (215 dB re 1 $\mu Pa^2 \cdot s$) (Southall et al. 2007). In contrast, an animal that was only 10 m below the MBES when a ping is emitted would be expected to receive a level ~20 dB higher, i.e., 204 dB re 1 $\mu Pa^2 \cdot s$ in the case of the EM 122. That animal might incur some TTS (which would be fully recoverable), but the exposure would still be below the anticipated PTS threshold for cetaceans. As noted by Burkhardt et al. (2007, 2008), cetaceans are very unlikely to incur PTS from operation of scientific sonars on a ship that is underway.

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

Possible Effects of the Sub-bottom Profiler Signals

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

Masking

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

Behavioral Responses

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

Hearing Impairment and Other Physical Effects

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

Possible Effects of Acoustic Release Signals

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

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

All anticipated takes would be "takes by harassment", involving temporary changes in behavior. The mitigation measures to be applied will minimize the possibility of injurious takes. (However, as noted earlier, there is no specific information demonstrating that injurious "takes" would occur even in the absence of the planned mitigation measures.) In the sections below, we describe methods to estimate the number of potential exposures to various received sound levels, and present estimates of the numbers of marine mammals that could be affected during the proposed seismic program. The estimates are based on consideration of the number of marine mammals that could be disturbed appreciably by ~1810.5 km^2 (includes primary and secondary lines and an additional 25% contingency) of seismic surveys in the SEP. 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 SBP 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 SBP given their characteristics (e.g., narrow downward-directed beam) and other considerations described in previously. 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 airguns.

Basis for Estimating "Take by Harassment"

Extensive systematic ship-based surveys have been conducted by NMFS SWFSC for marine mammals in the ETP. We used densities from five sources: (1) SWFSC has recently developed habitat modeling as a method to estimate cetacean densities on a finer spatial scale than traditional line-transect analyses by using a continuous function of habitat variables, e.g., sea surface temperature, depth, distance from shore, and prey density (Barlow et al. 2009). For the ETP, the models are based on data from 12 SWFSC ship-based cetacean and ecosystem assessment surveys conducted during July–December from

1986 to 2006. The models have been incorporated into a web-based Geographic Information System (GIS) developed by Duke University's Department of Defense Strategic Environmental Research and Development Program (SERDP) team in close collaboration with the SWFSC SERDP team (Read et al. 2009). For 11 cetacean species in the model, we used the GIS to obtain mean densities near the proposed survey area, i.e., in a rectangle bounded by 4° to 12 °S and 75° to 85° W which was the SE extent of the model; (2) For species sighted in SWFSC surveys whose sample sizes were too small to model density, we used densities from the surveys conducted during summer and fall 1986–1996, as summarized by Ferguson and Barlow (2001). Densities were calculated from Ferguson and Barlow (2003) for 5° x 5° blocks that include the proposed survey areas and corridors: Blocks 139, 159, 160, 200, 201, 202, 212, 213, and 219. Those blocks included 27,275 km of survey effort in Beaufort sea states 0–5, and 2564 km of survey effort in Beaufort sea states 0–2. Densities were obtained for an additional 5 species that were sighted in one or more of those blocks; (3) For dusky dolphins, we used the mean densities reported for Area A from aerial surveys in North and Central Patagonia (Shiavini et al. 1999), corrected for f(0), but not g(0). Since the closest density estimates were taken south of the proposed survey area, where dusky dolphin abundance is higher, we used 10% of the reported density to account for the decreased abundance of dusky dolphins in the proposed survey area; (4) For Chilean dolphins we used the estimated density of Chilean dolphins in Patagonia from Heinrich (2006). The extralimital, offshore distribution of Chilean dolphins in the proposed survey area was corrected for by taking 1% of the densities reported by Heinrich (2006); (5) For blue whales we used the densities reported by Gallettti-Vernazzani and Cabrera (2009) from aerial surveys in Patagonia in March 2007 and April in 2009 that took place south of the survey site (39°S-44°S). The density estimates were corrected for f(0) and g(0). Given the higher abundance of blue whales south of the survey site, we corrected the reported density for the proposed survey area by reducing the density by 50%.

For two endangered species for which there are only unconfirmed sightings in the region, the sei and fin whales, arbitrary low densities (equal to the density of the species with the lowest calculated density) were assigned. The same arbitrary low density was assigned to southern right whale dolphins and Burmeister's porpoise where no confirmed sightings were made within the survey region. In addition, there were no density estimates available for Humpback whales, minke whales, and Peale's dolphins but confirmed sightings have been made near the survey area. We arbitrarily assigned a density estimate of 0.8 animals/1000 km^2, which was similar to the densities reported for uncommon species in the area.

Oceanographic conditions, including occasional El Niño and La Niña events, influence the distribution and numbers of marine mammals present in the ETP and SEP, resulting in considerable year-to-year variation in the distribution and abundance of many marine mammal species (e.g., Escorza-Treviño 2009). Thus, for some species the densities derived from recent surveys may not be representative of the densities that will be encountered during the proposed seismic survey.

Table 3 gives the estimated densities for each cetacean species likely to occur in the study area, i.e., species for which we obtained or assigned densities. The densities have been corrected for both detectability and availability bias by the authors. Detectability bias is associated with diminishing sightability with increasing lateral distance from the trackline [f(0)]. Availability bias refers to the fact that there is less-than-100% probability of sighting an animal that is present along the survey trackline, and it is measured by *g*(0). Corrections for f(0) and g(0) were made where mentioned above.

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

It should be noted that the following estimates of exposures to various sound levels assume that the surveys will be fully completed; in fact, the planned number of line-kilometers has been increased to accommodate lines that may need to be repeated, equipment testing, etc. As is typical during ship surveys, inclement weather and equipment malfunctions are likely to cause delays and may limit the number of useful line-kilometers of seismic operations that can be undertaken. Furthermore, any marine mammal sightings within or near the designated exclusion zone will result in the shutdown of seismic operations as a mitigation measure. Thus, the following estimates of the numbers of marine mammals potentially exposed to 160-dB re 1 μPa_{rms} sounds are precautionary, and probably overestimate the actual numbers of marine mammals that might be involved. These estimates assume that there will be no weather, equipment, or mitigation delays, which is highly unlikely.

Number of Cetaceans that could be 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 are not in close proximity, which minimizes the number of times an individual mammal may be exposed during the survey; the area including overlap is only 1.2x the area excluding overlap.

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 for the appropriate water depth (see Table 1) around each seismic line, and then calculating the total area within the buffers. Areas where overlap occurred (because of crossing lines) were included only once when estimating the number of individuals exposed.

Applying the approach described above, ~1448.4 km^2 would be within the 160-dB isopleth on one or more occasions during the surveys (including primary and secondary lines). The total ensonified area used to calculate estimated numbers exposed was 1810.5 km^2 and includes an additional 25% increase in the calculated area for contingency. Because this approach does not allow for turnover in the mammal populations in the study area during the course of the survey, the actual number of individuals exposed 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 *Melville* 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 3 also shows 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 3. For Endangered Species the ***Requested Take Authorization*** has been increased to the mean group size listed in southern Chile where available (Viddi et al 2010) or the ETP (Wade and Gerodette 1993) where the calculated number of individuals exposed was between 0.05 and the mean group size (i.e., for sei, fin, humpback and sperm whales). For non-listed species, the ***Requested Take Authorization*** has been increased to the mean group size in the ETP (Wade and Gerodette 1993) or southern Chile (Viddi et al 2010; Zamorano-Abramson et al. 2010) in cases where the calculated number of individuals exposed was between 1 and the mean group size. For delphinids where typically large groups are encountered the ***Requested Take Authorization*** was increased to the mean group size in southern Chile (Aguauo et. Al 1998; Viddi et al 2010; Zamorano-Abramson et al. 2010) if the calculated number was greater than 1, but less than the mean group size.

The best estimate of the number of individual cetaceans that could be exposed to seismic sounds with received levels ≥160 dB re 1 µPa_{rms} during the survey is 561 (Table 3). That total includes 12 ***endangered*** whales: 4 blue whales (0.03%), 1 humpback whale (0.05%) and 7 sperm whales (0.03%) (Table 3). Most (96.4%) of the cetaceans potentially exposed are delphinids; rough-toothed, short-beaked common, striped, spinner, bottlenose, Risso's, and Dusky dolphins, and long-finned pilot whales are estimated to be the most common species in the area.

Number of Pinnipeds that could be Exposed to ***□160 dB.***— Due to the extralimital distribution of pinnipeds in the study area, no pinnipeds are expected to be encountered during the proposed survey.

TABLE 3. Densities of marine mammals in the SEP near the proposed survey area. Cetacean densities are based on the sources listed (see text for details).Species listed as "Endangered" under the ESA are in italics. Calculated take of different individuals that might be exposed during SIO's proposed seismic survey in SEP in May 2012 calculated from the estimated density (reported density x correction factor) multiplied by the 160dB ensonified area (1810.5 km^2 includes primary and secondary lines and 25% contingency). The column numbers in boldface shows the numbers of "takes" for which authorization is requested. Regional population estimates taken from Table 2; NA = Not available.

	Reported density (#/1000 km^2)										
Species	Read et al (2009)	Ferguson and Barlow (2003)	Shiavini et al. (1999)	Heinrich (2006)	Galletti-Vernazzani and Cabrera (2009)	Correction factor	**Estimated Density (#/1000 km^2)[1]**	**Ensonified area (km^2)**	**Calculated Take**	**% of Regional Pop'n**	**Requested Take Authorization**
Mysticetes											
Humpback whale							0.8[2]	1810.5	1	0.05	**3***
Minke whale							0.8[2]	1810.5	1	NA	**2***
Bryde's whale	0.96						0.96	1810.5	2	0.00	**2**
Sei whale							0.01[3]	1810.5	0	NA	**0**
Fin whale							0.01[3]	1810.5	0	0.00	**0**
Blue whale					4.87	0.5	2.44	1810.5	4	0.03	**4**
Odontocetes											
Sperm whale		3.95					3.95	1810.5	7	0.03	**8***
Pygmy and dwarf sperm whales	0.03						0.03	1810.5	0	0.00	**0**
Cuvier's beaked whale	0.801						0.80	1810.5	1	0.01	**1**
Blainville's beaked	0.801						0.80	1810.5	1	0.00	**1**
Mesoplodon spp.	0.36						0.36	1810.5	1	0.00	**1**
Rough-toothed dolphin	4.19						4.19	1810.5	8	0.01	**15***
Bottlenose dolphin	17.06						17.06	1810.5	31	0.01	**72***
Spinner dolphin	35.7						35.70	1810.5	65	0.00	**134***
Striped dolphin	67.8						67.80	1810.5	123	0.01	**123**
Short-beaked common dolphin	110.89						110.90	1810.5	201	0.01	**254***
Risso's dolphin		10.21					10.21	1810.5	18	0.02	**18**
False killer whale		0.39					0.39	1810.5	1	0.00	**1**
Killer whale		0.85					0.85	1810.5	2	0.02	**2**
Long finned pilot whale	11.88						11.88	1810.5	22	0.01	**22**
Peale's dolphin							0.8[2]	1810.5	1	NA	**4***
Dusky dolphin			368			0.1	37	1810.5	67	0.92	**67**
Southern right whale dolphin							0.01[3]	1810.5	0	NA	**0**
Burmeister's porpoise							0.01[3]	1810.5	0	NA	**0**
Chilean dolphin				222.2		0.01	11.11	1810.5	4	0.2	**4**

[1] Densities of other species included in Table 2 (e.g. pinnipeds) presumably would be lower than the lowest density in this table. [2]Densities assigned an arbitrary density similar to densities reported for species that area uncommon in the survey area. [3]Densities assigned an arbitrarily low number for rare species with unconfirmed sightings in the survey area. *Requested take authorization was increased

to mean group size for delphinids if calculated numbers were between 1 and mean group size, and increased to the mean group size if calculated values were >0.05 for endangered species.

Conclusions

The proposed seismic survey will involve towing an airgun array that introduces pulsed sounds into the ocean, along with simultaneous operation of an MBES, and SBP. The survey will employ a pair of 45-in^3 GI airguns similar to the airguns used for typical low-energy seismic surveys. The total airgun discharge volume is ~90 in^3. Routine vessel operations, other than the proposed airgun operations, are conventionally assumed not to affect marine mammals sufficiently to constitute "taking". No "taking" of marine mammals is expected in association with echosounder or OBS operations given the considerations discussed, i.e., sounds are beamed downward, the beam is narrow, and the pulses are extremely short.

Cetaceans.—Several species of mysticetes show strong avoidance reactions to seismic vessels at ranges up to 6–8 km and occasionally as far as 20–30 km from the source vessel when medium-large airgun arrays have been used. However, reactions at the longer distances appear to be atypical of most species and situations. If mysticetes are encountered, the numbers estimated to occur within the 160-dB isopleth in the survey area are expected to be relatively low.

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

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

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

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

Pinnipeds.— Four species of pinnipeds have the potential to occur in the proposed survey area. However, given the extralimital distribution of all the pinnipeds in the offshore survey location and their main habitat, pinnipeds area unlikely to be encountered during the proposed survey.

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

Effects on Fish

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

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

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

Pathological Effects

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

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

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

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

Physiological Effects

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

Behavioral Effects

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

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

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

Effects on Invertebrates

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

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

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

Pathological Effects

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

Some studies have suggested that seismic survey sound has a limited pathological impact on early developmental stages of crustaceans (Pearson et al. 1994; Christian et al. 2003; DFO 2004). However, the impacts appear to be either temporary or insignificant compared to what occurs under natural conditions. Controlled field experiments on adult crustaceans (Christian et al. 2003, 2004; DFO 2004) and adult cephalopods (McCauley et al. 2000a,b) exposed to seismic survey sound have not resulted in any significant pathological impacts on the animals. It has been suggested that giant squid strandings were caused by exposure to commercial seismic survey activities (Guerra et al. 2004), but there was little evidence to support the claim. André et al. (2011) exposed cephalopods, primarily cuttlefish, to continuous 50–400 Hz sinusoidal wave sweeps for two hours while captive in relatively small tanks, and reported morphological and ultrastructural evidence of massive acoustic trauma (i.e., permanent and substantial alterations of statocyst sensory hair cells). The received SPL was reported as 157±5 dB re 1µPa, with peak levels at 175 dB re 1µPa. As in the McCauley et al. (2003) paper on sensory hair cell damage in pink snapper as a result of exposure to seismic sound, the cephalopods were subjected to higher sound levels than they would be under natural conditions, and they were unable to swim away from the sound source.

Physiological Effects

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

Behavioral Effects

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

OBS deployment

A total of ~10 OBSs will be deployed during the proposed survey. LDEO OBS08 model broadband OBSs will be used during the cruise. This type of OBS has a height of ~ 122 cm and a width and depth of 76.2×106.7 cm. The anchor is made of two steel cylinders approximately 15 cm in diameter and 46 cm in length. Each cylinder weighs approximately 75 lbs in air. OBSs will remain on the seafloor to continue to collect data for approximately one year. Once an OBS is ready to be retrieved, an acoustic release transponder interrogates the instrument at a frequency of 9–11 kHz, and a response is received at a frequency of 9–13 kHz. The burn-wire release assembly is then activated, and the instrument is released from the anchor to float to the surface. OBS anchors will be left behind upon equipment recovery. Although OBS placement will disrupt a very small area of seafloor habitat and could disturb benthic invertebrates, the impacts are expected to be localized and transitory.

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

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

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

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

XI. Mitigation Measures

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

Marine mammals and sea turtles are known to occur in the proposed study area year-round. To minimize the likelihood that impacts will occur to the species and stocks, airgun operations will be conducted in accordance with the MMPA and the ESA, including obtaining permission for incidental harassment or incidental ‘take’ of marine mammals and other endangered species. The proposed activities will take place in the Chile EEZ.

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

Planning Phase

The PIs worked with SIO and NSF to identify potential time periods to carry out the survey taking into consideration key factors such as environmental conditions (i.e., the seasonal presence of marine mammals, sea turtles, and seabirds), weather conditions, equipment, and optimal timing for other proposed seismic surveys using the R/V *Melville*. Most marine mammal species are expected to occur in the area year-round, so altering the timing of the proposed project likely would result in no net benefits for those species. Baleen whales are most common south of the survey area between February and June, whereas odontocetes were most commonly observed between October and November. After considering what energy source level was necessary to achieve the research goals, the PIs determined the use of the 2 GI airgun array with a maximum total volume of 90 in^3 would be required. Given the research goals, location of the survey and associated deep water, this energy source level was viewed appropriate. The location of the survey was informed and adjusted based on the latest scientific information on the epicenter of the February 27, 2010 earthquake; survey location is critical for collecting the data for the overall research activity and meeting research objectives.

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 45-in^3 Nucleus G 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-, 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; Holst 2009; Antochiw et al. n.d.). If marine mammals or sea turtles are detected within or about to enter the appropriate exclusion zone, the airguns will be 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.

Mitigation During Operations

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

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 GI airguns 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) or 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 (45 in^3). The second GI airgun (45 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 the south-eastern Pacific Ocean, and no activities will take place in or near a traditional Arctic subsistence hunting area.

XIII. MONITORING AND REPORTING PLAN

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

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 IHA.

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 protected species observers (PSOs) will be based on board the seismic source vessel, and they will watch for marine mammals and turtles near the vessel during seismic operations. PSOs will also watch for marine mammals and turtles near 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. Based on PSO observations, the seismic source will be shut down when marine mammals are observed within or about to enter a designated exclusion zone (EZ). The EZ is a region in which a possibility exists of adverse effects on animal hearing or other physical effects.

PSOs will be appointed by the academic institution conducting the research cruise, 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.

Standard equipment for PSOs 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

PSO Data and Documentation

PSOs will record data to estimate the numbers of marine mammals and turtles exposed to various received sound levels and to document apparent disturbance reactions or lack thereof. Data will be used to estimate numbers of animals potentially 'taken' by harassment (as defined in the MMPA). They will also provide information needed to order a shutdown of the seismic source when a marine mammal or sea turtle is within or near the EZ.

When a sighting is made, the following information about the sighting will be recorded:

1. Species, group size, age/size/sex categories (if determinable), behavior when first sighted and after initial sighting, heading (if consistent), bearing and distance from seismic vessel, sighting cue, apparent reaction to the 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 and sea turtles 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.

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 any potential "take" of marine mammals and sea turtles by harassment or in other ways. After acceptance by NMFS, the report will be publicly available on the NSF website

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 with other parties that may have interest in this area. SIO and NSF have coordinated, and will continue to coordinate, with other applicable Federal agencies as required, and will comply with their requirements. Pursuant to the IHA requirements, SIO will submit a PSO report to NMFS 90 days after the proposed survey. PSO data collected during the survey will be submitted to OBIS Seamap and will be made available on the NSF website for interested parties and researchers.

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