negligible impact on this species. In addition, NMFS has determined that bearded and spotted seals, if present within the vicinity of the project area could also be taken incidentally, by no more than Level B harassment and that such taking would have a negligible impact on such species or stocks. Although there is not a specfic number assessed for the taking of bearded and spotted seals due to their rare occurrence in the project area, NMFS believes that any take would be significantly lower than those of ringed seals. NMFS also finds that the action will not have an unmitigable adverse impact on the availability of such species or stocks for taking for subsistence uses.

In addition, no take by Level A harassment (injury) or death is anticipated or authorized, and harassment takes should be at the lowest level practicable due to incorporation of the mitigation measures described in this document.

Authorization

NMFS has issued an IHA to SOI for the potential Level B harassment of small number of ringed seals, and potential Level B harassment of bearded and spotted seals incidental to conducting on-ice seismic R&D program in the U.S. Beaufort Sea, provided the previously mentioned mitigation, monitoring, and reporting requirements are incorporated.

Dated: March 30, 2007.

Angela Somma,

Acting Director, Office of Protected Resources, National Marine Fisheries Service.

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DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

[I.D. 040307B]

Small Takes of Marine Mammals Incidental to Specified Activities; Low-Energy Marine Seismic Survey in the Northeastern Indian Ocean, May-August 2007

AGENCY: National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Commerce.

ACTION: Notice; proposed incidental take authorization; request for comments.

SUMMARY: NMFS has received an application from Scripps Institute of Oceanography (SIO) for an Incidental Harassment Authorization (IHA) to take marine mammals incidental to conducting a low-energy marine seismic survey in the northeastern Indian Ocean during May-August 2007. Pursuant to the Marine Mammal Protection Act (MMPA), NMFS is requesting comments on its proposal to issue an IHA to SIO to incidentally take, by Level B harassment only, several species of marine mammals during the aforementioned activity.

DATES: Comments and information must be received no later than May 10, 2007.

ADDRESSES: Comments on the application should be addressed to Michael Payne, Chief, Permits, Conservation and Education Division, Office of Protected Resources, National Marine Fisheries Service, 1315 East-West Highway, Silver Spring, MD 20910–3225. The mailbox address for providing email comments is PR1.040307B@noaa.gov. NMFS is not responsible for e-mail comments sent to addresses other than the one provided here. Comments sent via e-mail, including all attachments, must not exceed a 10–megabyte file size.

A copy of the application containing a list of the references used in this document may be obtained by writing to the address specified above, telephoning the contact listed below (see **FOR FURTHER INFORMATION CONTACT**), or visiting the internet at: *http://www.nmfs.noaa.gov/pr/permits/incidental.htm#applications*.

Documents cited in this notice may be viewed, by appointment, during regular business hours, at the aforementioned address.

FOR FURTHER INFORMATION CONTACT: Jolie Harrison, Office of Protected Resources, NMFS, (301) 713–2289, ext 166.

SUPPLEMENTARY INFORMATION:

Background

Sections 101(a)(5)(A) and (D) of the MMPA (16 U.S.C. 1361 *et seq.*) direct the Secretary of Commerce to allow, upon request, the incidental, but not intentional, taking of marine mammals by U.S. citizens who engage in a specified activity (other than commercial fishing) within a specified geographical region if certain findings are made and either regulations are issued or, if the taking is limited to harassment, a notice of a proposed authorization is provided to the public for review.

Authorization shall be granted if NMFS finds that the taking will have a negligible impact on the species or stock(s), will not have an unmitigable adverse impact on the availability of the species or stock(s) for subsistence uses (where relevant), and if the permissible methods of taking and requirements pertaining to the mitigation, monitoring and reporting of such takings are set forth. NMFS has defined ''negligible impact'' in 50 CFR 216.103 as ''...an impact resulting from the specified activity that cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival.''

Section 101(a)(5)(D) of the MMPA established an expedited process by which citizens of the United States can apply for an authorization to incidentally take small numbers of marine mammals by harassment. Except with respect to certain activities not pertinent here, the MMPA defines ''harassment'' as:

> any act of pursuit, torment, or annoyance which (i) has the potential to injure a marine mammal or marine mammal stock in the wild [Level A harassment]; or (ii) has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering [Level B harassment].

Section 101(a)(5)(D) establishes a 45–day time limit for NMFS review of an application followed by a 30–day public notice and comment period on any proposed authorizations for the incidental harassment of marine mammals. Within 45 days of the close of the comment period, NMFS must either approve or deny the authorization.

Summary of Request

On January 5, 2007, NMFS received an application from SIO for the taking, by Level B harassment only, of 32 species of marine mammals incidental to conducting, with research funding from the National Science Foundation (NSF), a low-energy marine seismic survey in the northeastern Indian Ocean from May-August 2007. The purpose of the research program is to conduct a scientific rock-dredging, magnetic, bathymetric, and seismic survey program at nine sites on the Ninety East Ridge in the northeastern Indian Ocean. The results will be used to (1) determine the morphology, structure, and tectonics of ridge volcanoes to see whether they reflect centralized (plume) or distributed (crack) eruptions; (2) infer the magmatic evolution of the ridge, whether it fits the plume hypothesis, and its connection to existing hotspots; (3) examine the duration of volcanism at the various sites and along the ridge to see whether the age progression fits the simple plume model; and (4) survey broad characteristics of subseafloor in order to refine the planning of the IODP drilling proposal. Included in the research planned for 2007 are scientific rock dredging at all nine sites, high-resolution seismic methods to image the subsea floor at five of the sites, and the use of a magnetometer, gravimeter, multi-beam sonar, and sub-bottom profiler throughout the cruise.

Description of the Activity

The seismic surveys will involve one vessel, the *R/V Roger Revelle* (*Roger Revelle*), which is scheduled to depart from Fremantle, Australia, between May 22 and June 19, 2007. The *Roger Revelle* will conduct the cruise in the Indian Ocean and arrive at Colombo, Sri Lanka, between July 16 and August 13, 2007. The exact dates of the activities may vary by a few days because of weather conditions, repositioning, streamer operations and adjustments, airgun deployment, or the need to repeat some lines if data quality is substandard. Additional seismic operations may be occasionally needed to investigate significant new findings as revealed by the other survey systems. The overall area within which the seismic surveys will occur is located between approximately 5° N. and 25° S., along approximately 90o E. (Figure 1 in the application), in the Indian Ocean. The surveys will be conducted entirely in International Waters.

The *Roger Revelle* will deploy a pair of low-energy Generator-Injector (GI) airguns as an energy source (each with a discharge volume of 45 in^3), plus a 800 m-long (2625–ft long), 48–channel, towed hydrophone. The program will consist of approximately 2700 km (1678 mi) of surveys, including turns. Water depths within the seismic survey areas are 1600–5100 m (1750–5577 yd). The GI guns will be operated on a small grid for approximately 49 hours at each of 5 sites over a approximately 50–day period during May-August 2007, commencing between May 22 and June 19. There will be additional seismic operations associated with equipment testing, start-up, and repeat coverage of any areas where initial data quality is sub-standard.

In addition to the operations of the GI guns, a 3.5–kHz sub-bottom profiler , a Kongsberg-Simrad EM–120 multi-beam sonar, and a gravimeter will be used continuously throughout the cruise, and passive geophysical sensors will be deployed to conduct magnetic surveys at all times except during dredging.

Vessel Specifications

The *Roger Revelle* has a length of 83 m (272 ft), a beam of 16 m (52 ft), and a maximum draft of 5.2 m. The ship is powered by two 3,000 hp Propulsion General Electric motors and an 1180–hp Azimuthing jet bow thruster. An operation speed of 11.1 km/h (6 knots) is used during seismic acquisition. When not towing seismic survey gear, the *Roger Revelle* cruises at 22.2–23.1 km/h (12–12.5 knots) and has a maximum speed of 27.8 km/h (15 knots). It has a normal operating range of approximately 27,780 km (17,262 mi).

Acoustic Source Specifications

Seismic Airguns

The vessel *Roger Revelle* will tow a pair of GI airguns and an 800 m-long (2624–ft), 48–channel hydrophone streamer. Seismic pulses will be emitted at intervals of 6–10 seconds, which corresponds to a shot interval of approximatley 18.5–31 m (61–102 ft) (at a speed of 6 knots (11.1 km/h). The generator chamber of each GI gun, the one responsible for introducing the sound pulse into the ocean, is 45 in^3 (total air discharge approximately 90 in^3). The larger (105 in^3) injector chamber injects air into the previously-generated bubble to maintain its shape, and does not introduce more sound into the water. The two 45 in^3 GI guns will be towed 8 m (26 ft) apart side by side, 21 m (69 ft) behind the *Roger Revelle*, at a depth of 2 m (6.6 ft). The dominant frequency components are 0–188 Hz.

The sound pressure field of that GI gun variation has not been modeled, but that for two 45 in^3 Nucleus G guns (which actually have more energy than GI guns of the same size) has been modeled by the Lamont-Doherty Earth Observatory (L-DEO) in relation to distance and direction from the airguns. This source, which is directed downward, was found to have an output (0–peak) of 230.6 dB re 1 μPa m. The nominal downward-directed source levels indicated above do not represent actual sound levels that can be measured at any location in the water. Rather, they represent the level that would be found 1 m from a hypothetical point source emitting the same total amount of sound as is emitted by the combined GI guns. The actual received level at any location in the water near the GI guns will not exceed the source level of the strongest individual source. In this case, that will be about 224.6 dB re 1 μPa-m peak, or 229.8 dB re 1 μPa-m peak-to-peak. Actual levels experienced by any organism more than 1 m from either GI gun will be significantly lower.

A further consideration is that the rms (root mean square) received levels that are used as impact criteria for marine mammals are not directly comparable to the peak or peak to peak values normally used to characterize source levels of airgun arrays. The measurement units used to describe airgun sources, peak or peak-to-peak decibels, are always higher than the ‘‘root mean square’’ (rms) decibels referred to in biological literature. A measured received level of 160 dB rms in the far field would typically correspond to a peak measurement of approximately 170 to 172 dB, and to a peak-to-peak measurement of approximately 176 to 178 dB, as measured for the same pulse received at the same location (Greene 1997; McCauley *et al.*, 1998, 2000). The precise difference between rms and peak or peak-to-peak values depends on the frequency content and duration of the pulse, among other factors. However, the rms level is always lower than the peak or peak-to-peak level for an airgun-type source.

Bathymetric Sonar

The *Roger Revelle* will utilize the Kongsberg-Simrad EM120 multi-beam sonar, which operates at 11.25–12.6 kHz and is mounted in the hull. It operates in several modes, depending on water depth. In the proposed survey, it will be used in deep (>800–m (2625 ft)) water, and will operate in ‘‘Deep’’ mode. The beam width is 1° or 2° fore-aft and a total of 150° athwartship. Estimated maximum source levels are 239 and 233 dB at 1° and 2° beam widths, respectively. Each ‘‘ping’’ consists of nine successive fan-shaped transmissions, each ensonifying a sector that extends 1° or 2° fore-aft. In the ‘‘Deep’’ mode, the total duration of the transmission into each sector is 15 ms. The nine successive transmissions span an overall cross-track angular extent of about 150 degrees, with 16 ms gaps between the pulses for successive sectors. A receiver in the overlap area between two sectors would receive two 15–ms pulses separated by a 16–ms gap. The ‘‘ping’’ interval varies with water depth, from approximately 5 s at 1000 m (3280 ft) to 20 s at 4000 m (13120 ft).

Sub-bottom Profiler

The *Roger Revelle* will utilize the Knudsen Engineering Model 320BR sub-bottom profiler, which is a dual-frequency transceiver designed to operate at 3.5 and/or 12 kHz. It is used in conjunction with the multi-beam sonar to provide data about the sedimentary features that occur below the sea floor. The energy from the sub-bottom profiler is directed downward (in an 80–degree cone) via a 3.5–kHz transducer array mounted in the hull. The maximum power output of the

320BR is 10 kilowatts for the 3.5–kHz section and 2 kilowatts for the 12–kHz section. (The 12–kHz section is seldom used in survey mode on *Roger Revelle* because of overlap with the operating frequency of the Kongsberg Simrad EM–120 multi-beam sonar.)

The pulse length for the 3.5 kHz section of the 320BR is 0.8–24 ms, controlled by the system operator in regards to water depth and reflectivity of the bottom sediments, and will usually be 12 or 24 ms in this survey. The system produces one sound pulse and then waits for its return before transmitting again. Thus, the pulse interval is directly dependent upon water depth, and in this survey is 4.5–8 sec. Using the Sonar Equations and assuming 100 percent efficiency in the system (impractical in real world applications), the source level for the 320BR is calculated to be 211 dB re 1 μPa-m. In practice, the system is rarely operated above 80 percent power level.

Safety Radii

NMFS has determined that for acoustic effects, using acoustic thresholds in combination with corresponding safety radii is the most effective way to consistently apply measures to avoid or minimize the impacts of an action, and to quantitatively estimate the effects of an action. Thresholds are used in two ways: (1) to establish a mitigation shut-down or power down zone, i.e., if an animal enters an area calculated to be ensonified above the level of an established threshold, a sound source is powered down or shut down; and (2) to calculate take, in that a model may be used to calculate the area around the sound source that will be ensonified to that level or above, then, based on the estimated density of animals and the distance that the sound source moves, NMFS can estimate the number of marine mammals that may be ''taken''. NMFS believes that to avoid permanent physiological damage (Level A Harassment), cetaceans and pinnipeds should not be exposed to pulsed underwater noise at received levels exceeding, respectively, 180 and 190 dB re 1 μPa (rms). NMFS also assumes that cetaceans or pinnipeds exposed to levels exceeding 160 dB re 1 μPa (rms) may experience Level B Harassment.

Received sound levels have been modeled by 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. 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 guns where sound levels of 190, 180, and 160 dB re 1 μPa (rms) are predicted to be received in deep (≤1000–m (3280–ft)) water are 10, 40, and 400 m (33, 131, and 1312 ft), respectively. 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–in^3 GI guns.

Empirical data concerning the 180- and 160- dB distances have been acquired based on measurements during the acoustic verification study conducted by L-DEO in the northern Gulf of Mexico from 27 May to 3 June 2003 (Tolstoy *et al.*, 2004). Although the results are limited, the data showed that radii around the airguns where the received level would be 180 dB re 1 μPa (rms) vary with water depth. Similar depth-related variation is likely in the 190–dB distances applicable to pinnipeds. Correction factors were developed for water depths 100–1000 m (328–3280 ft) and <100 m (328 ft). The proposed survey will occur in depths 1600–5100 m (5249–16732 ft), so the correction factors are not relevant here.

The empirical data indicate that, for deep water (>1000 m (3280 ft)), the L-DEO model tends to overestimate the received sound levels at a given distance (Tolstoy *et al.*, 2004). However, to be precautionary pending acquisition of additional empirical data, it is proposed that safety radii during airgun operations in deep water will be the values predicted by L-DEO's model (above). Therefore, the assumed 180- and 190–dB radii are 40 m and 10 m (131 and 33 ft), respectively.

Airguns will be shut down immediately when cetaceans or pinnipeds are detected within or about to enter the appropriate 180–dB (rms) or 190–dB (rms) radius, respectively.

Description of Marine Mammals in the Activity Area

Thirty-two species of cetacean, including 25 odontocete (dolphins and small and large toothed whales) species and seven mysticete (baleen whales) species, are thought to occur in the proposed seismic survey areas along the Ninety East Ridge in the northeastern Indian Ocean (Table 1). Several are listed under the U.S. Endangered Species Act (ESA) as Endangered: the sperm whale, humpback whale, blue whale, fin whale, and sei whale.

Although there have been several surveys of marine mammals in the Indian Ocean (e.g., Keller *et al.*, 1982; Leatherwood *et al.*, 1984; Eyre 1995; Baldwin *et al.*, 1998; de Boer 2000; de Boer *et al.*, 2003), data on the occurrence, distribution, and abundance of odontocetes and mysticetes in the northeastern Indian Ocean, encompassing the proposed seismic survey area along the Ninety East Ridge, are limited or lacking. Commercial whaling severely depleted all the large whale populations in this region, and subsequently, in 1979, the International Whaling Commission declared the Indian Ocean north of 55° S. latitude a whale sanctuary. The majority of recent detailed information on whales within the Indian Ocean Sanctuary (IOS) comes from

(1) A United Nations Environment Programme (UNEP) Report summarizing cetacean research in the western IOS (Leatherwood and Donovan 1991);

(2) A compilation of sightings for the entire IOS produced by the Whale and Dolphin Conservation Society (de Boer *et al.*, 2003); and

(3) A review of marine mammals records in India (Sathasivam 2004); and

(4) A series of research cruises within the IOS (Keller *et al.*, 1982; Leatherwood *et al.*, 1984; Corbett 1994; Eyre 1995; Ballance and Pitman 1998; de Boer 2000).

Because the proposed survey area spans such a wide range of latitudes (approximately 5° N.-25° S.), tropical and temperate species are found there. The survey area is all in deep-water habitat but is close to oceanic island habitats (i.e., Andaman, Nicobar, and Cocos (Keeling) Islands), so both coastal and oceanic species might be encountered, although species that stay in very shallow water (e.g., Indian hump-backed dolphin, Irrawaddy dolphin, and finless porpoise) would not. Abundance and density estimates of cetaceans found in areas other than the northeastern and central Indian Ocean are provided for reference only, and are not necessarily the same as those in the survey area. Table 1 also shows the estimated abundance of the marine mammals likely to be encountered during the *Roger Revelle*'s cruise. Additional information regarding the distribution of these species and how the estimated densities were calculated may be found in SIO's application.

Species	Habitat	Occurrence	Rqstd Take
Mysticetes			
Humpback whale (Megaptera novaeangliae)*	Mainly nearshore waters and banks	Common	5(0)**
Minke whale (Balaenoptera acutorostrata)	Pelagic and coastal	Uncommon	5
Antarctic minke whale (Balaenoptera bonaerensis)	Coastal and oceanic	Uncommon	5
Bryde's whale (Balaenoptera edeni)	Pelagic and coastal	Very common	5
Sei whale (Balaenoptera borealis) *	Primarily offshore, pelagic	Uncommon	5(0)**
Fin whale (Balaenoptera physalus)*	Continental slope, mostly pelagic	Common	5(0)**
Blue whale (Balaenoptera musculus)*	Pelagic and coastal	Very common	5(1)**
Odontocetes			
Sperm whale (Physeter macrocephalus)*	Usually pelagic and deep seas	Common	5(1)**
Pygmy sperm whale (Kogia breviceps)	Deep waters off the shelf	Common	5
Dwarf sperm whale (Kogia sima)	Deep waters off the shelf	Common	5
Cuvier's beaked whale (Ziphius cavirostris)	Pelagic	Common	5
Shepherd's beaked whale (Tasmacetus shepherdi))	Pelagic	Rare	5
Longman's beaked whale (Indopacetus pacificus)	Pelagic	Common?	1
Southern bottlenose whale (Hyperoodon planifrons)	Pelagic	Uncommon	5
True's beaked whale (Mesoplodon mirus)	Pelagic	Rare	5
Gray's beaked whale (Mesoplodon grayi)	Pelagic	Uncommon	5
Ginkgo-toothed whale (Mesoplodon ginkgodens)	Pelagic	Common	5
Blainville's beaked whale (Mesoplodon densirostris)	Pelagic	Very common	5
Rough-toothed dolphin (Steno bredanensis)	Deep water	Uncommon	69
Bottlenose dolphin (Tursiops truncatus)	Coastal and oceanic, shelf break	Common	129
Pantropical spotted dolphin (Stenella attenuata)	Coastal and pelagic	Uncommon	65
Spinner dolphin (Stenella longirostris)	Coastal and pelagic	Abundant	215
Striped dolphin (Stenella coeruleoalba)	Off continental shelf	Common	86
Fraser's dolphin (Lagenodelphis hosei)	Waters >1000 m	Rare	22
Common dolphin (Delphinus delphis)	Shelf and pelagic, seamounts	Very common	151
Risso's dolphin (Grampus griseus)	Waters >1000 m, seamounts	Very common	151
Melon-headed whale (Peponocephala electra)	Oceanic	Very common	50
Pygmy killer whale (Feresa attenuata)	Deep, pantropical waters	Common	25
False killer whale (Pseudorca crassidens)	Pelagic	Common	15
Killer whale (Orcinus orca)	Widely distributed	Common	5
Long-finned pilot whale (Globicephala melas)	Mostly pelagic	Rare	30

Species	Habitat	Occurrence	Rqstd Take
Short-finned pilot whale (Globicephala macrorhynchus)	Mostly pelagic, high-relief topography	Very common	15

Table 1. Species expected to be encountered (and potentially harassed) during SIO's Indian Ocean cruise
*Species are listed as endangered under the Endangered Species Act
**Parenthetical numbers represent numbers of takes NMFS proposes to authorize (we may not authorize take ofspecies, or take of numbers of species, that we are not exempted pursuant to our internal ESA consultation)

Potential Effects on Marine Mammals

Potential Effects of Airguns

The effects of sounds from airguns might include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and temporary or permanent hearing impairment (Richardson *et al.*, 1995). Given the small size of the GI guns planned for the present project, effects are anticipated to be considerably less than would be the case with a large array of airguns. It is very unlikely that there would be any cases of temporary or, especially, permanent hearing impairment. Also, behavioral disturbance is expected to be limited to relatively short distances.

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 of SIO's application. However, it should be noted that most of the measurements of airgun sounds that have been reported concerned sounds from larger arrays of airguns, whose sounds would be detectable considerably farther away than the GI guns planned for use in the present project.

Numerous 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 (e) of SIO's application. That is often true even in cases when the pulsed sounds must be readily audible to the animals based on measured received levels and the hearing sensitivity of that mammal group. Although various baleen whales, toothed whales, and (less frequently) pinnipeds have been shown to react behaviorally to airgun pulses under some conditions, at other times mammals of all three types have shown no overt reactions. In general, pinnipeds and small odontocetes seem to be more tolerant of exposure to airgun pulses than are baleen whales. Given the relatively small and low-energy airgun source planned for use in this project, mammals (and sea turtles) are expected to tolerate being closer to this source than might be the case for a larger airgun source typical of most seismic surveys.

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. Some whales are known to continue calling in the presence of seismic pulses. Their calls can be heard between the seismic pulses (e.g., Richardson *et al.*, 1986; McDonald *et al.*, 1995; Greene *et al.*, 1999; Nieukirk *et al.*, 2004). Although there has been one report that sperm whales cease calling when exposed to pulses from a very distant seismic ship (Bowles *et al.*, 1994), a recent study reports that sperm whales off northern Norway continued calling in the presence of seismic pulses (Madsen *et al.*, 2002c). That has also been shown during recent work in the Gulf of Mexico (Tyack *et al.*, 2003). Given the small source planned for use here, there is even less potential for masking of baleen or sperm whale calls during the present study than in most seismic surveys. Masking effects of seismic pulses are expected to be negligible in the case of the smaller odontocete cetaceans, given the intermittent nature of seismic pulses and the relatively low source level of the airguns to be used here. Also, the sounds important to small odontocetes are predominantly at much higher frequencies than are airgun sounds. Masking effects, in general, are discussed further in Appendix A (d) of SIO's application.

Disturbance Reactions

Disturbance includes a variety of effects, including subtle changes in behavior, more conspicuous changes in activities, and displacement. Disturbance is one of the main concerns in this project. Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors. If a marine mammal responds to an underwater sound by changing its behavior or moving a small distance, the response may or may not rise to the level of harassment, let alone affect the stock or the species as a whole. Alternatively, if a sound source displaces marine mammals from an important feeding or breeding area, effects on the stock or species could potentially be more than negligible. 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 are likely to be present within a particular distance of industrial activities, or exposed to a particular level of industrial sound. This practice potentially overestimates the numbers of marine mammals that are 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 on behavioral observations during studies of several species. However, information is lacking for many species. Detailed studies have been done on humpback, gray, and bowhead whales, and on ringed seals. Less detailed data are available for some other species of baleen whales, sperm whales, and small toothed whales. Most of those studies have focused on the impacts resulting from the use of much larger airgun sources than those planned for use in the present project. Thus, effects are expected to be limited to considerably smaller distances and shorter periods of exposure in the present project than in most of the previous work concerning marine mammal reactions to airguns.

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 (e) of SIO's application, baleen whales exposed to strong noise pulses from airguns often react by deviating from their normal migration route and/or interrupting their feeding activities and moving away from the sound source. In the case of the 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 determined that received levels of pulses in the 160–170 dB re 1 μPa rms range seem to cause obvious avoidance behavior in a substantial fraction of the animals exposed. In many areas, seismic pulses from large arrays of airguns diminish to those levels at distances ranging from 4.5–14.5 km (2.8–9 mi) from the source. A substantial proportion of the baleen whales within those distances may show avoidance or other strong disturbance reactions to the airgun array. Subtle behavioral changes sometimes become evident at somewhat lower received levels, and recent studies, reviewed in Appendix A (e) of SIO's application, have shown that some species of baleen whales, notably bowheads and humpbacks, at times show strong avoidance at received levels lower than 160–170 dB re 1 μPa rms. Reaction distances would be considerably smaller during the present project, in which the 160–dB radius is predicted to be approximately 0.40 km (0.9 mi), as compared with several kilometers when a large array of airguns is operating.

Humpback whales summering 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 on an approximate rms basis. 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 (approximately rms). More detailed information on responses of humpback whales to seismic pulses during studies in Australia can be found in Appendix A (a) of SIO's application.

Malme *et al.* (1986, 1988) studied the responses of feeding eastern gray whales to pulses from a single 100 in3 airgun off St. Lawrence Island in the northern Bering Sea. They estimated, based on small sample sizes, that 50 percent of feeding gray whales ceased feeding at an average received pressure level of 173 dB re 1 μPa on an (approximate) rms basis, and that 10 percent of feeding whales interrupted feeding at received levels of 163 dB. Those findings were generally consistent with the results of experiments conducted on larger numbers of gray whales that were migrating along the California coast.

Data on short-term reactions (or lack of reactions) of cetaceans to impulsive noises do not necessarily provide information about long-term effects. It is not known whether impulsive noises affect reproductive rate or distribution and habitat use in subsequent days or years. However, gray whales continued to migrate annually along the west coast of North America despite intermittent seismic exploration and much ship traffic in that area for decades (Appendix A in Malme *et al.*, 1984). Bowhead whales continued to travel to the eastern Beaufort Sea each summer despite seismic exploration in their summer and autumn range for many years (Richardson *et al.*, 1987). In any event, the brief exposures to sound pulses from the present small airgun source are highly unlikely to result in prolonged effects.

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 have been reported for toothed whales. However, systematic work on sperm whales is underway (Tyack *et al.*, 2003).

Seismic operators sometimes see dolphins and other small toothed whales near operating airgun arrays, but in general there seems to be a tendency for most delphinids to show some limited avoidance of seismic vessels operating large airgun systems. However, 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. Nonetheless, there have been indications that small toothed whales sometimes 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., Goold, 1996; Calambokidis and Osmek, 1998; Stone, 2003). Similarly, captive bottlenose dolphins and beluga whales exhibit changes in behavior when exposed to strong pulsed sounds similar in duration to those typically used in seismic surveys (Finneran *et al.*, 2000, 2002). However, the animals tolerated high received levels of sound (pk-pk level >200 dB re 1 μPa) before exhibiting aversive behaviors. With the presently-planned small airgun system, such levels would only be found within a few meters of the airguns.

There are no specific data on the behavioral reactions of beaked whales to seismic surveys. A few beaked whale sightings have been reported from seismic vessels (Stone, 2003), however, based on limited observations most beaked whales tend to avoid approaching vessels of other types (e.g., Kasuya, 1986; Wursig *et al.*, 1998). Several beaked whale strandings have been associated with naval mid-frequency sonar exercises, however, the sounds produced by seismic airguns are quite different from tactical sonar (see Appendix A (g) of SIO's application). The strandings mentioned above are apparently at least in part a disturbance response, although auditory or other injuries may also be a factor. Whether beaked whales would ever react similarly to seismic surveys is unknown (see ''Strandings and Mortality'', below).

Sperm whales have been reported to show avoidance reactions to standard vessels not emitting airgun sounds, and it is to be expected that they would tend to avoid an operating seismic survey vessel. There were some limited early observations suggesting that sperm whales in the Southern Ocean and Gulf of Mexico might be fairly sensitive to airgun sounds from distant seismic surveys. However, more extensive data from recent studies in the North Atlantic suggest that sperm whales in those areas show little evidence of avoidance or behavioral disruption in the presence of operating seismic vessels (McCall Howard, 1999; Madsen *et al.*, 2002c; Stone, 2003).

Odontocete reactions to large arrays of airguns are variable and, at least for small odontocetes, seem to be confined to a smaller radius than has been observed for mysticetes. Thus, behavioral reactions of odontocetes to the small airgun source to be used here are expected to be very localized, probably to distances <0.40 km (.25 mi).

Pinnipeds – Pinnipeds are not likely to show a strong avoidance reaction to the small airgun source that will be used. Visual monitoring from seismic vessels, usually employing larger sources, has shown only slight (if any) avoidance of airguns by pinnipeds, and only slight (if any) changes in behavior-see Appendix A (e) of SIO's application. Those studies show that pinnipeds frequently do not avoid the area within a few hundred meters of operating airgun arrays, even for arrays much larger than the one to be used here (e.g., Harris *et al.*, 2001). However, initial telemetry work suggests that avoidance and other behavioral reactions to small airgun sources may be stronger than evident to date from visual studies of pinniped reactions to airguns (Thompson *et al.*, 1998). Even if reactions of the species occurring in the present study area are as strong as those evident in the telemetry study, reactions are expected to be confined to relatively small distances and durations, with no long-term effects on pinnipeds.

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 (e) of SIO's application.

Hearing Impairment and Other Physical Effects

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds, but there has been no specific documentation of this for marine mammals exposed to sequences of airgun pulses. Current NMFS policy regarding exposure of marine mammals to high-level sounds is that cetaceans and pinnipeds should not be exposed to impulsive sounds of 180 and 190 dB re 1 μPa (rms), respectively. Those criteria have been used in defining the safety (shut-down) radii planned for the proposed seismic survey. The precautionary nature of these criteria is discussed in Appendix A (f) of SIO's application, including the fact that the minimum sound level necessary to cause permanent hearing impairment is higher, by a variable and generally unknown amount, than the level that induces barely-detectable temporary threshold shift (TTS) (which NMFS' criteria are based on) and the level associated with the onset of TTS is often considered to be a level below which there is no danger of permanent damage. NMFS is presently developing new noise exposure criteria for marine mammals that take account of the now-available data on TTS in marine (and terrestrial) mammals.

Because of the small size of the airgun source in this project (two 45–in^3 GI guns), along with the planned monitoring and mitigation measures, there is little likelihood that any marine mammals will be exposed to sounds sufficiently strong to cause hearing impairment. Several aspects of the planned monitoring and mitigation measures for this project are designed to detect marine mammals occurring near the two GI airguns (and multi-beam bathymetric sonar), and to avoid exposing them to sound pulses that might, at least in theory, cause hearing impairment. In addition, many cetaceans are likely to show some avoidance of the area with high received levels of airgun sound (see above). 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 theoretically might occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, resonance effects, 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 pulsed 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 especially unlikely that any effects of these types would occur during the present project given the small size of the source, the brief duration of exposure of any given mammal, and the planned monitoring and mitigation measures (see below). The following subsections discuss in somewhat more detail the possibilities of TTS, permanent threshold shift (PTS), and non-auditory physical effects.

Temporary Threshold Shift (TTS) – TTS is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter, 1985). While experiencing TTS, the hearing threshold rises and a sound must be stronger in order to be heard. 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 recovers rapidly after exposure to the noise ends. Only a 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.

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). Given the available data, the received level of a single seismic pulse might need to be approximately 210 dB re 1 μPa rms (approximately 221–226 dB pk-pk) in order to produce brief, mild TTS. Exposure to several seismic pulses at received levels near 200–205 dB (rms) might result in slight TTS in a small odontocete, assuming the TTS threshold is (to a first approximation) a function of the total received pulse energy. Seismic pulses with received levels of 200–205 dB or more are usually restricted to a radius of no more than 100 m (328 ft) around a seismic vessel operating a large array of airguns. Such levels would be limited to distances within a few meters of the small GI-gun source to be used in this project.

For baleen whales, there are no data, direct or indirect, on levels or properties of sound that are required to induce TTS. However, no cases of TTS are expected given the small size of the source, and, as mentioned previously, there is a strong likelihood that baleen whales would avoid the approaching GI gun (or vessel), with the sound source operating, before being exposed to levels high enough for there to be any possibility of TTS.

In pinnipeds, TTS thresholds associated with exposure to brief pulses (single or multiple) of underwater sound have not been measured. Initial evidence from prolonged exposures suggested that some pinnipeds may incur TTS at somewhat lower received levels than do small odontocetes exposed for similar durations (Kastak *et al.*, 1999; Ketten *et al.*, 2001; cf. Au *et al.*, 2000). However, more recent indications are that TTS onset in the most sensitive pinniped species studied (harbor seal) may occur at a similar sound exposure level as in odontocetes (Kastak *et al.*, 2004).

A marine mammal within a radius of 100 m (328 ft) around a typical large array of operating airguns might be exposed to a few seismic pulses with levels of 205 dB, and possibly more pulses if the mammal moved with the seismic vessel. (As noted above, most cetacean species tend to avoid operating airguns, although not all individuals do so.) In addition, ramping up airgun arrays, which is standard operational protocol for large airgun arrays, provides an opportunity for cetaceans to move away from the seismic source and to avoid being exposed to the full acoustic output of the airgun array. However, several of the considerations that are relevant in assessing the impact of typical seismic surveys with arrays of airguns are not directly applicable here:

(1) The planned GI gun source is much smaller, with correspondingly smaller radii within which received sound levels could exceed any particular level of concern.

(2) With a large airgun array, it is unlikely that cetaceans would be exposed to airgun pulses at a sufficiently high level for a sufficiently long period to cause more than mild TTS, given the relative movement of the vessel and the marine mammal. In this project, the gun source is much smaller, so the radius of influence and duration of exposure to strong pulses is much smaller, especially in deep and intermediate-depth water.

(3) With a large array of airguns, TTS would be most likely in any odontocetes that bow-ride or otherwise linger near the airguns. In the present project, the

anticipated 180–dB distance in deep water is 40 m (131 ft), and the waterline at the bow of the *Roger Revelle* will be approximately 97 m (318 ft) ahead of the GI gun.

To avoid injury, NMFS has determined 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). The predicted 180- and 190–dB distances for the GI guns operated by SIO are 40 m (131 ft) and 10 m (33 ft), respectively, in water depths >1000 m (3280 ft). [Those distances actually apply to operations with two 45–in^3 G guns, and smaller distances would be expected for the two 45–in^3 GI guns to be used here.] These sound levels are the received levels above which, in the view of a panel of bioacoustics specialists convened by NMFS, one cannot be certain that there will be no injurious effects, auditory or otherwise, to marine mammals. More recent TTS data imply that, at least for dolphins, TTS is unlikely to occur unless the dolphins are exposed to airgun pulses notably stronger than 180 dB re 1 μPa rms. However NMFS utilizes a precautionary approach of requiring shut down at received levels above which we cannot be certain there will be no injurious effects to the most sensitive species.

Permanent Threshold Shift (PTS) – When PTS occurs, there is physical damage to the sound receptors in the ear. In some cases, there can be total or partial deafness, while in other cases, the animal has an impaired ability to hear sounds in specific frequency ranges. 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 TTS, there has been further speculation about the possibility that some individuals occurring very close to airguns might incur PTS. Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage in terrestrial mammals. 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 20 dB or more above that inducing mild TTS if the animal were exposed to the strong sound for an extended period, or to a strong sound with rather rapid rise time-see Appendix A (f) of SIO's application.

It is highly unlikely that marine mammals could receive sounds strong enough to cause permanent hearing impairment during a project employing two 45–in^3 GI guns. In the present project, marine mammals are unlikely to be exposed to received levels of seismic pulses strong enough to cause TTS, as they would probably need to be within a few meters of the airguns for that to occur. Given the higher level of sound necessary to cause PTS, it is even less likely that PTS could occur. In fact, even the levels immediately adjacent to the airguns may not be sufficient to induce PTS, especially since a mammal would not be exposed to more than one strong pulse unless it swam immediately alongside an airgun for a period longer than the inter-pulse interval (6–10 s). Baleen whales generally avoid the immediate area around operating seismic vessels. The planned monitoring and mitigation measures, including visual monitoring, ramp ups, and shut downs of the airguns when mammals are seen within the ''safety radii'', will minimize the already-minimal probability of exposure of marine mammals to sounds strong enough to induce PTS.

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 effects, and other types of organ or tissue damage. There is no evidence that any of these effects occur in marine mammals exposed to sound from airgun arrays (even large ones) and there have been no direct studies of the potential for airgun pulses to elicit any of those effects. NMFS does not anticipate that marine mammals would experience any of these effects in response to being exposed to the airguns in this proposed study, especially considering the small size of the airguns. If any such effects do occur, they would probably be limited to unusual situations when animals might be exposed at close range for unusually long periods.

Exposure of laboratory animals, wildlife, and humans to strong noise often results in significant increases in adrenal activity, including cortisol and/or catecholamine release and related measures of stress (see Appendix A of SIO's application). However, it is doubtful that any single marine mammal would be exposed to strong seismic sounds for sufficiently long that significant physiological stress would develop. That is especially so in the case of the present project where the airguns are small, the ship's speed is relatively fast (5–8 knots or 9.3–14.8 km/h), and each survey does not encompass a large area.

Gas-filled structures in marine animals have an inherent fundamental resonance frequency. If stimulated at that frequency, the ensuing resonance could cause damage to the animal. A workshop (Gentry [ed.] 2002) was held to discuss whether the stranding of beaked whales in the Bahamas in 2000 (Balcomb and Claridge, 2001; NOAA and USN, 2001) might have been related to air cavity resonance or bubble formation in tissues caused by exposure to noise from naval sonar. A panel of experts concluded that resonance in air-filled structures was not likely to have caused this stranding. Opinions were less conclusive about the possible role of gas (nitrogen) bubble formation/growth in the Bahamas stranding of beaked whales.

Until recently, it was assumed that diving marine mammals are not subject to the bends or air embolism. However, a short paper concerning beaked whales stranded in the Canary Islands in 2002 suggests that cetaceans might be subject to decompression injury in some situations (Jepson *et al*., 2003). If so, that might occur if they ascend quickly when exposed to aversive sounds. However, the interpretation that the effect was related to decompression injury is unproven (Piantadosi and Thalmann 2004; Fernandez *et al*., 2004). Even if that effect can occur during exposure to mid-frequency sonar, there is no evidence that this type of effect occurs in response to airgun sounds. It is especially unlikely in the case of the proposed survey, involving only two GI guns.

In general, little is known about the potential for seismic survey sounds to cause auditory impairment or other physical effects in marine mammals. Available data suggest that such effects, if they occur at all, would be limited to short distances and probably to projects involving large arrays of airguns. However, the available data do not allow for 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 auditory impairment or other physical effects. Also, the planned mitigation measures, including ramp ups and shut downs, will reduce any such effects that might otherwise occur.

Strandings and Mortality

Marine mammals close to underwater detonations of high explosives can be killed or severely injured, and their auditory organs are especially susceptible to injury (Ketten *et al.*, 1993; Ketten 1995). Airgun pulses are less energetic and have slower rise times, and there is no proof that they can cause serious injury, death, or stranding even in the case of large airgun arrays. However, the association of several strandings of beaked whales with naval exercises and, in one case, an L-DEO seismic survey, 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. Appendix A (g) of SIO's application provides additional details.

Seismic pulses and mid-frequency sonar pulses are quite different. Sounds produced by airgun arrays are broadband with most of the energy below 1 kHz. Typical military mid-frequency sonars operate at frequencies of 2–10 kHz, generally with a relatively narrow bandwidth at any one time. 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 pulses can, in special circumstances, lead to physical damage and mortality (NOAA and USN 2001; Jepson *et al.*, 2003), even if only indirectly, suggests that caution is warranted when dealing with exposure of marine mammals to any high-intensity pulsed sound.

In May 1996, 12 Cuvier's beaked whales stranded along the coasts of Kyparissiakos Gulf in the Mediterranean Sea. That stranding was subsequently linked to the use of low- and medium-frequency active sonar by a North Atlantic Treaty Organization (NATO) research vessel in the region (Frantzis 1998). In March 2000, a population of Cuvier's beaked whales being studied in the Bahamas disappeared after a U.S. Navy task force using mid-frequency tactical sonars passed through the area; some beaked whales stranded (Balcomb and Claridge, 2001; NOAA and USN, 2001).

In September 2002, a total of 14 beaked whales of various species stranded coincident with naval exercises in the Canary Islands (Martel n.d.; Jepson *et al.*, 2003; Fernandez *et al.*, 2003). Also in Sept. 2002, there was a stranding of two Cuvier's beaked whales in the Gulf of California, Mexico, when the L-DEO vessel *Maurice Ewing* was operating a 20–gun, 8490–in^3 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, that plus the incidents involving beaked whale strandings near naval exercises suggests a need for caution in conducting seismic surveys in areas occupied by beaked whales.

The present project will involve a much smaller sound source than used in typical seismic surveys. That, along with the monitoring and mitigation measures that are planned, are expected to minimize any possibility for strandings and mortality.

Potential Effects of Other Acoustic Devices

Bathymetric Sonar Signals

A multi-beam bathymetric sonar (Simrad EM120, 11.25–12.6 kHz) will be operated from the source vessel during much of the planned study. Sounds from the multi-beam sonar are very short pulses. Most of the energy in the sound pulses emitted by the multi-beam is at moderately high frequencies, centered at 12 kHz. The beam is narrow (1° or 2°) in fore-aft extent, and wide (150°) in the cross-track extent. Each ping consists of nine successive transmissions (segments) at different cross-track angles. Any given mammal at depth near the track line would be in the main beam for only a fraction of a second.

Tactical Navy sonars that have been linked to avoidance reactions and stranding of cetaceans (1) generally are more powerful than the Simrad EM120, (2) have a longer pulse duration, and (3) are directed close to omnidirectionally, vs. downward for the Simrad EM120. The area of possible influence of the Simrad EM120 is a much smaller narrow band oriented in the cross-track direction below the source vessel. Marine mammals that encounter the Simrad EM120 at close range 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. In assessing the possible impacts of the 15.5 kHz Atlas Hydrosweep (a similar model), Boebel *et al.* (2004) noted that the critical sound pressure level at which TTS may occur is 203.2 dB re 1 µPa (rms). The critical region included an area of 43 m (141 ft) in depth, 46 m (151 ft) wide athwartship, and 1 m (3.3 ft) fore-and-aft (Boebel *et al.*, 2004).

Behavioral reactions of free-ranging marine mammals to military and other sonars 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. However, all of those observations are of limited relevance to the present situation. Pulse durations from those sonars were much longer than those of the SIO multi-beam sonar, and a given mammal would have received many pulses from the naval sonars. 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.

Captive bottlenose dolphins and a white whale exhibited changes in behavior when exposed to 1 s pulsed sounds at frequencies similar to those that will be emitted by the multi-beam sonar 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). The relevance of those data to free-ranging odontocetes is uncertain, and in any case, the test sounds were quite different in either duration or bandwidth as compared with those from a bathymetric sonar.

Because of the shape of the beam, NMFS believes it unlikely that marine mammals will be exposed to the bathymetric sonar at levels at or above those likely to cause harassment. Further, NMFS believes that the brief exposure of cetaceans or pinnipeds to one pulse, or small numbers of signals, from the multi-beam bathymetric sonar system are not likely to result in the harassment of marine mammals.

Sub-bottom Profiler Signals

A sub-bottom profiler will be operated from the source vessel at all times during the planned study. Sounds from the sub-bottom profiler are very short pulses, occurring for 12 or 24 ms once every 4.5–8 seconds. Most of the energy in the sound pulses emitted by this sub-bottom profiler is at mid frequencies, centered at 3.5 kHz. The beam width is approximately 80o (cone-shaped) and is directed downward.

The sub-bottom profiler on the *Roger Revelle* has a stated maximum source level of 211 dB re 1 µPa m (see section I of SIO's application). Thus, the received level would be expected to decrease to 180 dB and 160 dB approximately 35 m and 350 m below the transducer, respectively, assuming spherical spreading. Corresponding distances in the horizontal plane would be substantially lower, given the directionality of this source.

Marine mammal behavioral reactions to other pulsed sound sources are discussed above, and responses to the sub-bottom profiler are likely to be similar to those for other pulsed sources if received at the same levels. However, the pulsed signals from the sub-bottom profiler are weaker than those from both the multi-beam sonar and the two GI guns. Behavioral responses are not expected unless marine mammals are very close to the source, e.g., within approximately 350 m below the vessel, or a lesser distance to the side. It is unlikely that the sub-bottom profiler 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 sub-bottom profiler 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 sub-bottom profiler. 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 the higher-power sources would further reduce or eliminate any minor effects of the sub-bottom profiler.

Because of the shape of the conical beam and the power of the source, NMFS believes it unlikely that marine mammals will be exposed to the bathymetric sonar at levels at or above those likely to cause harassment. Further, NMFS believes that the brief exposure of cetaceans or pinnipeds to small numbers of signals from the multi-beam bathymetric sonar system are not likely to result in the harassment of marine mammals.

Estimated Take by Incidental Harassment

All anticipated takes would be ''takes by harassment'', involving temporary changes in behavior. The proposed mitigation measures are expected to 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 ''take by harassment'', and present estimates of the numbers of marine mammals that might be affected during the proposed seismic survey in the northeast Indian Ocean. The estimates are based on the best available data concerning marine mammal densities (numbers per unit area) and estimates of the size of the area where effects potentially could occur.

Because there is very little information on marine mammal densities in the proposed survey area, densities were used from two of Longhurst's (2007) biogeographic provinces in the ETP that are oceanographically similar to the two provinces in which the seismic activities will take place (see further, below).

SIO's application presents two types of estimates: estimates of the number of potential ''exposures'', and estimates of the number of different individual marine mammals that might potentially be exposed to sound levels ≥160 dB re 1 μPa (rms). The distinction between ''exposures'' and ''number of different individuals exposed'' is marginally relevant in this project, because the plan does not call for repeated GI gun operations through the same or adjacent waters, and the 2 GI guns that will be used ensonify a relatively small area. Estimates of the number of exposures are considered precautionary overestimates of the actual numbers of different individuals potentially exposed to seismic sounds, because in all likelihood, exposures represent repeated exposures of some of the same individuals as discussed in the sections that follow. Because of their precautionary nature, the fact that they are the numbers SIO requested authorization for, and the fact that they differ only slightly from the estimated number of individuals, NMFS will use the estimated number of exposures for the take estimate.

The following estimates are based on a consideration of the number of marine mammals that might be disturbed appreciably by operations with the 2 GI guns to be used during approximately 2700 line-km of surveys at five sites on the Ninety East Ridge in the northeastern Indian Ocean. The anticipated radii of influence of the multi-beam sonar and sub-bottom profiler are less than those for the GI guns. It is assumed that, during simultaneous operations of the multi-beam sonar and airguns, any marine mammals close enough to be affected by the sonar would already be affected by the airguns. No animals are expected to exhibit more than short-term and inconsequential responses to the multi-beam sonar and sub-bottom profiler, given their characteristics (e.g., narrow downward-directed beam) and other considerations described previously. Therefore, no additional allowance is included for animals that might be affected by those sources. Any effects of the multi-beam sonar and sub-bottom profiler during times when they are operating but the airguns are silent are not considered.

Few systematic aircraft- or ship-based surveys have been conducted for marine mammals in offshore waters of the Indian Ocean, and the species of marine mammals that occur there are not well known. The density estimates used in this assessment are from two sources, as noted above. The most comprehensive and recent density data available for cetaceans of the ETP are from 1986 1996 NMFS ship surveys reported by Ferguson and Barlow (2001).

(1) Some of those waters are in Longhurst's (2007) Pacific Equatorial Divergence Province (PEQD), which is similar to the Indian Monsoon Gyres Province (MONS), in which 3 of the 5 proposed seismic surveys in the northeastern Indian Ocean will occur. The similarities are that they are both high-nitrate, low-chlorophyll regions of the oceans that support relatively large populations of yellowfin, bigeye, and skipjack tuna. SIO used the 1986 1996 data from blocks 162–170, 202–209, and 213–216 of Ferguson and Barlow (2001) for the species group density estimates given in Table 3 of SIO's application (and used to calculate the take estimates in Table 1 here).

(2) Some of the surveys conducted by Ferguson and Barlow (2001) in the ETP are in Longhurst's (2007) North Pacific Tropical Gyre Province (NPTG), which is similar to the Indian South Subtropical Gyre Province (ISSG), in which 2 of the 5 proposed seismic surveys will occur. The similarities are that they are both low-nitrate, low-chlorophyll regions of the oceans that support relatively large bigeye and yellowfin tuna populations. SIO used the 1986 1996 data from blocks 105, 106, 111, 112, and 125 131 of Ferguson and Barlow (2001) to compute the species group densities in Table 4 of their application (and used to calculate the take estimates in Table 1 here).

The species that will be encountered during the Indian Ocean survey will be different than those sighted during the surveys in the ETP. However, the overall abundance of species groups with generally similar habitat requirements are expected to be roughly similar. No density data were available for any cetacean species in the proposed seismic survey area. Thus, data from offshore areas of the ETP to estimate the densities of beaked whales, delphinids, small whales, and mysticetes in the northeastern Indian Ocean were used. SIO then estimated the relative abundance of individual species within the species groups on a scale of 1 (rare) to 10 (abundant) using various surveys and other information from areas near the study area, and general information on species such as latitudinal ranges, water depth preferences, and group sizes (see Column 1 in Tables 3 and 4 of SIO's application). Finally, SIO estimated the density of each species expected to occur in the survey area from the densities for species groups in Tables 3 and 4 of their application by multiplying their relative abundance/ the relative abundance for all species in the species group times the density for the species group.

Tables 3 and 4 in SIO's application give the average and maximum densities for each species group of marine mammals reported in the PEQD and NPTG provinces of the ETP, corrected for effort, based on the densities reported in Ferguson and Barlow (2001). The densities from those studies had been corrected, by the original authors, for both detectability bias and availability bias. Detectability bias is associated with diminishing sightability with increasing lateral distance from the track line [f(0)]. Availability bias refers to the fact that there is less-than 100 percent probability of sighting an animal that is present along the survey track line, and it is measured by g(0).

It should be noted that the following estimates of ''takes by harassment'' assume that the seismic surveys will be undertaken and completed; in fact, the planned number of line-kms has been increased by 25 percent to accommodate lines that may need to be repeated, equipment testing, etc. As is typical on offshore ship surveys, inclement weather, equipment malfunctions, and other survey priorities (rock dredging, magnetic surveys) may cause delays and may limit the number of useful line-kms of seismic operations that can be undertaken. Furthermore, any marine mammal sightings within or near the designated safety zones will result in the shut down of seismic operations as a mitigation measure. Thus, the following estimates of the numbers of marine mammals potentially exposed to 160–dB sounds are precautionary, and probably overestimate the actual numbers of marine mammals that might be involved. The estimates assume that there are no conflicts in survey priorities or weather, equipment, or mitigation delays, which is unlikely, particularly given the complexity of the tasks and equipment involved.

There is some uncertainty about the representativeness of the data and the assumptions used in the take calculations. However, the approach used here is believed to be the best available approach. Also, to provide some allowance for the uncertainties, ''maximum estimates'' as well as ''best estimates'' of the numbers potentially affected have been derived. Best and maximum estimates are based on the average and maximum estimates of densities reported in the selected datasets that were used from Ferguson and Barlow (2001) described above. SIO has requested authorization for the take of the maximum estimates and NMFS has analyzed the maximum estimate for it's effect on the species or stock.

The potential number of occasions when members of each species might be exposed to received levels ≥160 dB re 1 μPa (rms) was calculated by multiplying

- Its expected density, either ''average'' (i.e., best) or ''maximum'', corrected as described above, times
- The anticipated total line-kilometers of operations with the 2 GI guns (including turns and additional buffer line km to allow for repeating of lines due to equipment malfunction, bad weather, etc.), times
- The cross-track distances within which received sound levels are predicted to be ≥160 dB.

For the 2 GI guns, that cross track distance is 2x the predicted 160–dB radii of 400 m (1312 ft) in water depths >1000 m (3280 ft).

Based on that method, the ''best'' and ''maximum'' estimates of the number of marine mammal exposures to airgun sounds ≥160 dB re 1 μPa (rms) were obtained for each of the ecological provinces using the reported average and maximum densities from Tables 3 and 4 of SIO's application. The two estimates were then added to give totals. Of the five endangered cetacean species that could be present, the best and maximum estimates show that only one blue whale and one sperm whale may be exposed to such noise levels (Table 5 of SIO's application). The vast majority of the best and maximum exposures to seismic sounds ≥160 dB would involve delphinids. Maximum estimates of exposures for the species with the highest numbers are, in descending order, spinner dolphin (215 exposures), common and Risso's dolphins (151 exposures), and bottlenose dolphin (129 exposures). Estimates for other species are lower (Table 1).

The far right column in Table 1, ''Requested Take Authorization'', shows the numbers for which ''take authorization'' is requested. The requested take authorization numbers are calculated as indicated above based on the maximum densities reported by Ferguson and Barlow (2001) in any of the survey blocks included in the average density estimates. For those species for which very low numbers to none are estimated to be exposed to seismic sounds ≥160 dB, SIO included allowance for encountering one group based on the mean group size. Where group sizes are less than five, SIO assigned a group size of five. However, for endangered species, NMFS only plans to authorize take for one sperm whale and one blue whale.

The best and maximum estimates are based on 160–dB distances predicted from the acoustic model applied by L-DEO. Based on the empirical calibration data collected in the Gulf of Mexico in 2003 for L-DEO's 2 GI guns in deep water (510 m (1673 ft)), actual 160–dB distances in deep water are likely to be less than predicted (Tolstoy *et al.*, 2004). Additionally, the requested take is based on maximum exposure estimates (based on maximum density estimates). Given these considerations, the predicted numbers of marine mammals that might be exposed to sounds ≥160 dB may be somewhat overestimated.

The stock structures of the marine mammals present in the Indian Ocean have not been identified by NMFS; therefore, NMFS must make the necessary findings based on the species as a whole. The species anticipated to be affected during the proposed activities are wide-ranging species. Though worldwide abundance (or abundance outside of that estimated for the U.S. stocks) has not been estimated, localized surveys in the west tropical Indian Ocean and elsewhere have been conducted. Since the take estimates proposed in this document fall largely within 6 percent (all but common dolphin (21 percent) and rough-toothed dolphin (14 percent)) of the numbers estimated to be present during a localized survey of the west tropical Indian Ocean, and the species range far beyond the Indian Ocean (i.e., the abundance of the species is notably larger), NMFS believes that the estimated take numbers for these are small relative both to the worldwide abundance of these species and to numbers taken in other activities that have been authorized for incidental take of these species.

Potential Effects on Habitat

The proposed airgun operations 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 activities will be temporarily elevated noise levels and the associated direct effects on marine mammals, as discussed above.

One of the reasons for the adoption of airguns as the standard energy source for marine seismic surveys was that they (unlike the explosives used in the distant past) do not result in any appreciable fish kill. However, the existing body of information relating to the impacts of seismic on marine fish and invertebrate species is very limited. The various types of potential effects of exposure to seismic on fish and invertebrates can be considered in three categories: (1) pathological, (2) physiological, and (3) behavioral. Pathological effects include lethal and sub-lethal damage to the animals, physiological effects include temporary primary and secondary stress responses, and behavioral effects refer to changes in exhibited behavior of the fish and invertebrates. The three categories are interrelated in complex ways. For example, it is possible that certain physiological and behavioral changes could potentially lead to the ultimate pathological effect on individual animals (i.e., mortality).

The available information on the impacts of seismic surveys on marine fish and invertebrates provides limited insight on the effects only at the individual level. Ultimately, the most important knowledge in this area relates to how significantly seismic affects animal populations.

The following sections provide an overview of the information that exists on the effects of seismic surveys on fish and invertebrates. The information comprises results from scientific studies of varying degrees of soundness and some anecdotal information.

Pathological Effects – 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 (Hubbs and Rechnitzer, 1952 in Wardle *et al.*, 2001). Generally, the higher the received pressure and the less time it takes for the pressure to rise and decay, the greater the chance of acute pathological effects. Considering the peak pressure and rise/decay time characteristics of seismic airgun arrays used today, the pathological zone for fish and invertebrates would be expected to be within a few meters of the seismic source (Buchanan *et al.*, 2004). For the proposed survey, any injurious effects on fish would be limited to very short distances, especially considering the small source planned for use in this project (two 45–in^3 GI guns).

Matishov (1992) reported that some cod and plaice died within 48 hours of exposure to seismic pulses 2 m (6.5 ft) from the source. No other details were provided by the author. On the other hand, there are numerous examples of no fish mortality as a result of 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, 2000b; Bjarti, 2002; IMG, 2002; McCauley *et al.*, 2003; Hassel *et al.*, 2003).

There are examples of damage to fish ear structures from exposure to seismic airguns (McCauley *et al.*, 2000a, 2000b, 2003), but it should be noted the experimental fish were caged and exposed to high cumulative levels of seismic energy. Atlantic salmon were exposed within 1.5 m (4.9 ft) of underwater explosions (Sverdrup *et al.*, 1994). Compared to airgun sources, explosive detonations are characterized by higher peak pressures and more rapid rise and decay times, and are considered to have greater potential to damage marine biota. In spite of this, no salmon mortality was observed immediately after exposure or during the seven-day monitoring period following exposure.

Some studies have also provided some information on the effects of seismic exposure on fish eggs and larvae (Kostyuchenko, 1972; Dalen and Knutsen, 1986; Holliday *et al.*, 1987; Matishov, 1992; Booman *et al.*, 1996; Dalen *et al.*, 1996). Overall, impacts appeared to be minimal and any mortality was generally not significantly different from the experimental controls. Generally, any observed larval mortality occurred after exposures within 0.5 3 m (1.6–9.8 ft) of the airgun source. Matishov (1992) did report some retinal tissue damage in cod larvae exposed at 1 m (3.3 ft) from the airgun source. Saetre and Ona (1996) applied a 'worst-case scenario' mathematical model to investigate the effects of seismic energy on fish eggs and larvae, and concluded that mortality rates caused by exposure to seismic are so low compared to natural mortality that the impact of seismic surveying on recruitment to a fish stock must be regarded as insignificant.

The pathological impacts of seismic energy on marine invertebrate species have also been investigated. Christian *et al.* (2003) exposed adult male snow crabs, egg-carrying female snow crabs, and fertilized snow crab eggs to energy from seismic airguns. Neither acute nor chronic (12 weeks after exposure) mortality was observed for the adult male and female crabs. There was a significant difference in development rate noted between the exposed and unexposed fertilized eggs. The egg mass exposed to seismic energy had a higher proportion of less-developed eggs than the unexposed mass. It should be noted that both egg masses came from a single female and that any measure of natural variability was unattainable. However, a result such as this does point to the need for further study.

Pearson *et al.* (1994) exposed Stage II larvae of the Dungeness crab to single discharges from a seven-airgun seismic array and compared their mortality and development rates with those of unexposed larvae. For immediate and long-term survival and time to molt, this field experiment did not reveal any statistically-significant differences between the exposed and unexposed larvae, even those exposed within 1 m (3.3 ft) of the seismic source.

Bivalves of the Adriatic Sea were also exposed to seismic energy and subsequently assessed (LaBella *et al.*, 1996). No effects of the exposure were noted.

To date, there have not been any well-documented cases of acute post-larval fish or invertebrate mortality as a result of exposure to seismic sound under normal seismic operating conditions. Sub-lethal injury or damage has been observed, but generally as a result of exposure to very high received levels of sound, significantly higher than the received levels generated by the single GI gun sound source to be used in the proposed study. Acute mortality of eggs and larvae have been demonstrated in experimental exposures, but only when the eggs and larvae were exposed very close to the seismic sources and the received pressure levels were presumably very high. Limited information has not indicated any chronic mortality as a direct result of exposure to seismic.

*Physiological Effect*s – Biochemical responses by marine fish and invertebrates to acoustic stress have also been studied, although in a limited way. Studying the variations in the biochemical parameters influenced by acoustic stress might give some indication of the extent of the stress and perhaps forecast eventual detrimental effects. Such stress could potentially affect animal populations by reducing reproductive capacity and adult abundance.

McCauley *et al.* (2000a, 2000b) used various physiological measures to study the physiological effects of exposure to seismic energy on various fish species, squid, and cuttlefish. No significant physiological stress increases attributable to seismic energy were detected. Sverdrup *et al.* (1994) found that Atlantic salmon subjected to acoustic stress released primary stress hormones, adrenaline and cortisol, as a biochemical response although there were different patterns of delayed increases for the different indicators. Caged European sea bass were exposed to seismic energy and numerous biochemical responses were indicated. All returned to their normal physiological levels within 72 hours of exposure.

Stress indicators in the haemolymph of adult male snow crabs were monitored after exposure of the animals to seismic energy (Christian *et al*., 2003). No significant differences between exposed and unexposed animals were found in the stress indicators (e.g., proteins, enzymes, cell type count).

Primary and secondary stress responses of fish after exposure to seismic energy all appear to be temporary in any studies done to date. The times necessary for these biochemical changes to return to normal are variable depending on numerous aspects of the biology of the species and of the sound stimulus.

Summary of Physical (Pathological and Physiological) Effects – As indicated in the preceding general discussion, there is a relative lack of knowledge about the potential physical (pathological and physiological) effects of seismic energy on marine fish and invertebrates. Available data suggest that there may be physical impacts on egg, larval, juvenile, and adult stages at very close range. Considering typical source levels associated with commercial seismic arrays, close proximity to the source would result in exposure to very high energy levels. Again, this study will employ a sound source that will generate low energy levels. Whereas egg and larval stages are not able to escape such exposures, juveniles and adults most likely would avoid it. In the case of eggs and larvae, it is likely that the numbers adversely affected by such exposure would not be that different from those succumbing to natural mortality. Limited data regarding physiological impacts on fish and invertebrates indicate that these impacts are short term and are most apparent after exposure at close range.

The proposed seismic program for 2007 is predicted to have negligible to low physical effects on the various life stages of fish and invertebrates for its short duration (approximately 49 hours at each of five sites on the Ninety East Ridge) and 2700–km extent. Therefore, physical effects of the proposed program on the fish and invertebrates would be not significant.

Fish and Invertebrate Acoustic Detection and Production – Hearing in fishes was first demonstrated in the early 1900s through studies involving cyprinids (Parker, 1903 and Bigelow, 1904 in Kenyon *et al*., 1998). Since that time, numerous methods have been used to test auditory sensitivity in fishes, resulting in audiograms of over 50 species. These data reveal great diversity in fish hearing ability, mostly attributable to various peripheral modes of coupling the ear to internal structures, including the swim bladder. However, the general auditory capabilities of <0.2 percent of fish species are known so far.

For many years, studies of fish hearing have reported that the hearing bandwidth typically extends from below 100 Hz to approximately 1 kHz in fishes without specializations for sound detection, and up to approximately 7 kHz in fish with specializations that enhance bandwidth and sensitivity. Recently there have been suggestions that certain fishes, including many clupeiforms (herring, shads, anchovies, etc.) may be capable of detecting ultrasonic signals with frequencies as high as 126 kHz (Dunning *et al*., 1992; Nestler *et al*., 1992). Studies on Atlantic cod, a non-clupeiform fish, suggested that this species could detect ultrasound at almost 40 kHz (Astrup and M hl, 1993).

Mann *et al.* (2001) showed that the American shad is capable of detecting sounds up to 180 kHz. They also demonstrated that the gulf menhaden is also able to detect ultrasound, whereas other species such as the bay anchovy, scaled sardine, and Spanish sardine only detect sounds with frequencies up to approximately 4 kHz.

Among fishes, at least two major pathways for sound transmission to the ear have been identified. The first and most primitive is the conduction of sound directly from the water to tissue and bone. The fish's body takes up the sound's acoustic particle motion and subsequent hair cell stimulation occurs because of the difference in inertia between the hair cells and their overlying otoliths. These species are known as 'hearing generalists' (Fay and Popper, 1999). The second sound pathway to the ears is indirect. The swim bladder or other gas bubble near the ears expands and contracts in volume in response to sound pressure fluctuations, and the motion is then transmitted to the otoliths. While present in most bony fishes, the swim bladder is absent or reduced in many other fish species. Only some species of fish with a swim bladder appear to be sound-pressure sensitive via this indirect pathway to the ears; they are called 'hearing specialists'. Hearing specialists have some sort of connection with the inner ear, either via bony structures known as Weberian ossicles, extensions of the swim bladder, or a swim bladder more proximate to the inner ear. Hearing specialists' sound-pressure sensitivity is high and their upper frequency range of detection is extended above those species that hear only by the direct pathway. Typically, most fish detect sounds of frequencies up to 2,000–Hz but, as indicated, others have detection ranges that extend to much higher frequencies.

Fish also possess lateral lines that detect water movements. The essential stimulus for the lateral line consists of differential water movement between the body surface and the surrounding water. The lateral line is typically used in concert with other sensory information, including hearing (Sand, 1981; Coombs and Montgomery, 1999).

Elasmobranchs (sharks and skates) lack any known pressure-to-displacement transducers such as swim bladders. Therefore, they presumably must rely on the displacement sensitivity of their mechanoreceptive cells. Unlike acoustic pressure, the kinetic stimulus is inherently directional but its magnitude rapidly decreases relative to the pressure component as it propagates outward from the sound source in the near field. It is believed that elasmobranches are most sensitive to low frequencies, those <1 kHz (Corwin 1981).

Because they lack air-filled cavities and are often the same density as water, invertebrates detect underwater acoustics differently than fish. Rather than being pressure sensitive, invertebrates appear to be most sensitive to particle displacement. However, their sensitivity to particle displacement and hydrodynamic stimulation seem poor compared to fish. Decapods, for example, have an extensive array of hair-like receptors both within and upon the body surface that could potentially respond to water- or substrate-borne displacements. They are also equipped with an abundance of proprioceptive organs that could serve secondarily to perceive vibrations. Crustaceans appear to be most sensitive to sounds of low frequencies, those <1000 Hz (Budelmann, 1992; Popper *et al*., 2001).

Many fish and invertebrates are also capable of sound production. It is believed that these sounds are used for communication in a wide range of behavioral and environmental contexts. The behaviors most often associated with acoustic communication include territorial behavior, mate finding, courtship, and aggression. Sound production provides a means of long-distance communication and communication when underwater visibility is poor (Zelick *et al*., 1999).

Behavioral Effects – Because of the apparent lack of serious pathological and physiological effects of seismic energy on marine fish and invertebrates, most concern now centers on the possible effects of exposure to seismic surveys on the distribution, migration patterns, and catchability of fish. There is a need for more information on exactly what effects such sound sources might have on the detailed behavior patterns of fish and invertebrates at different ranges. Studies investigating the possible effects of seismic energy on fish and invertebrate behavior have been conducted on both uncaged and caged animals. Studies of change in catch rate regard potential effects of seismic energy on larger spatial and temporal scales than are typical for close-range studies that often involve caged animals (Hirst and Rodhouse, 2000). Hassel *et al.* (2003) investigated the behavioral effects of seismic pulses on caged sand lance in Norwegian waters. The sand lance did exhibit responses to the seismic, including an increase in swimming rate, an upwards vertical shift in distribution, and startle responses. Normal behaviors were resumed shortly after cessation of the seismic source. None of the observed sand lance reacted by burying into the sand.

Engas *et al.* (1996) assessed the effects of seismic surveying on Atlantic cod and haddock behavior using acoustic mapping and commercial fishing techniques. Results indicated that fish abundance decreased at the seismic survey area, and that the decline in abundance and catch rate lessened with distance from the survey area. Fish abundance and catch rates had not returned to pre-shooting levels five days after cessation of shooting. In other airgun experiments, catch per unit effort (CPUE) of demersal fish declined when airgun pulses were emitted, particularly in the immediate vicinity of the seismic survey (Dalen and Raknes, 1985; Dalen and Knutsen, 1986; L kkeborg, 1991; Skalski *et al.*, 1992). Reductions in the catch may have resulted from a change in behavior of the fish. The fish schools descended to near the bottom when the airgun was firing, and the fish may have changed their swimming and schooling behavior. Fish behavior returned to normal minutes after the sounds ceased.

Marine fish inhabiting an inshore reef off the coast of Scotland were monitored by telemetry and remote camera before, during, and after airgun firing (Wardle *et al.*, 2001). Although some startle responses were observed, the seismic gun firing had little overall effect on the day-to-day behavior of the resident fish.

Other species involved in studies that have indicated fish behavioral responses to underwater sound include rockfish (Pearson *et al.*, 1992), Pacific herring (Schwarz and Greer, 1984), and Atlantic herring (Blaxter *et al.*, 1981). The responses observed in these studies were relatively temporary. What is not known is the effect of exposure to seismic energy on fish and invertebrate behaviors that are associated with reproduction and migration.

Studies on the effects of sound on fish behavior have also been conducted using caged or confined fish. Such experiments were conducted in Australia using fish, squid, and cuttlefish as subjects (McCauley *et al.* (2000a,b). Common observations of fish behavior included startle response, faster swimming, movement to the part of the cage furthest from the seismic source (i.e., avoidance), and eventual habituation. Fish behavior appeared to return pre-seismic state 15 30 min after cessation of seismic shooting. Squid exhibited strong startle responses to the onset of proximate airgun firing by releasing ink and/or jetting away from the source. The squid consistently made use of the 'sound shadow' at the surface, where the sound intensity was less than at 3–m (9.8 ft) depth. These Australian experiments provided more evidence that fish and invertebrate behavior will be modified at some received sound level. Again, the behavioral changes seem to be temporary.

Christian *et al.* (2003) conducted an experimental commercial fishery for snow crab before and after the area was exposed to seismic shooting. Although the resulting data were not conclusive, no drastic decrease in catch rate was observed after seismic shooting commenced. Another behavioral investigation by Christian *et al.* (2003) involved caging snow crabs, positioning the cage 50 m (164 ft) below a seven-gun array, and observing the immediate responses of the crabs to the onset of seismic shooting by remote underwater camera. No obvious startle behaviors were observed. Anecdotal information from Newfoundland, Canada, indicated that snow crab catch rates showed a significant reduction immediately following a pass by a seismic survey vessel. Other anecdotal information from Newfoundland indicated that a school of shrimp showing on a fishing vessel sounder shifted downwards and away from a nearby seismic source. Effects were temporary in both the snow crab and shrimp anecdotes (Buchanan *et al.*, 2004).

Summary of Behavioral Effects – As is the case with pathological and physiological effects of seismic on fish and invertebrates, available information is relatively scant and often contradictory. There have been well-documented observations of fish and invertebrates exhibiting behaviors that appeared to be responses to exposure to seismic energy (i.e., startle response, change in swimming direction and speed, and change in vertical distribution), but the ultimate importance of those behaviors is unclear. Some studies indicate that such behavioral changes are very temporary, whereas others imply that fish might not resume pre-seismic behaviors or distributions for a number of days. There appears to be a great deal of inter- and intra-specific variability. In the case of finfish, three general types of behavioral responses have been identified: startle, alarm, and avoidance. The type of behavioral reaction appears to depend on many factors, including the type of behavior being exhibited before exposure, and proximity and energy level of sound source.

During the proposed study, only a small fraction of the available habitat would be ensonified at any given time, and fish species would return to their pre-disturbance behavior once the seismic activity ceased. The proposed seismic program is predicted to have negligible to low behavioral effects on the various life stages of the fish and invertebrates during its short duration (approximately 49 hours at each of 5 sites on the Ninety East Ridge) and 2700–km extent.

Changes in behavior in fish near the airguns might have short-term impacts on the ability of cetaceans to feed near the survey area. However, only a small fraction of the available habitat would be ensonified at any given time, and fish species would return to their pre-disturbance behavior once the seismic activity ceased. Thus, the proposed survey would have little impact on the abilities of marine mammals to feed in the area where seismic work is planned. Some of the fish that do not avoid the approaching airguns (probably a small number) may be subject to auditory or other injuries.

Zooplankters that are very close to the source may react to the shock wave. These animals have an exoskeleton and no air sacs. Little or no mortality is expected. Many crustaceans can make sounds and some crustaceans and other invertebrates have some type of sound receptor. However, the reactions of zooplankters to sound are not known. Some mysticetes feed on concentrations of zooplankton. A reaction by zooplankton to a seismic impulse would only be relevant to whales if it caused a concentration of zooplankton to scatter. Pressure changes of sufficient magnitude to cause this type of reaction would probably occur only very close to the source. Impacts on zooplankton behavior are predicted to be negligible, and this would translate into negligible impacts on feeding mysticetes.

Because of the reasons noted above and the nature of the proposed activities (small airguns and limited duration), the proposed operations are not expected to have any habitat-related effects that could cause significant or long-term consequences for individual marine mammals or their populations or stocks.

Monitoring

Either dedicated marine mammal observers (MMOs) or other vessel-based personnel will watch for marine mammals near the seismic source vessel during all daytime and nighttime airgun operations. GI airgun operations will be suspended when marine mammals are observed within, or about to enter, designated safety radii where there is a possibility of significant effects on hearing or other physical effects. At least one dedicated vessel-based MMO will watch for marine mammals near the seismic vessel during daylight periods when shooting is being conducted, and two MMOs will watch for marine mammals for at least 30 min prior to start-up of airgun operations. Observations of marine mammals will also be made and recorded during any daytime periods without airgun operations. At night, the forward-looking bridge watch of the ship's crew will look for marine mammals that the vessel is approaching, and execute avoidance maneuvers; the 180dB/190dB safety radii around the airguns will be continuously monitored by an aft-looking member of the scientific party, who will call for shutdown of the guns if mammals are observed within the safety radii. Nighttime observers will be aided by (aft-directed) ship's lights and night vision devices (NVDs).

Observers will be appointed by SIO with NMFS concurrence. Two observers will be on the vessel, and both will have gone through NOAA/NMFS training for marine mammal observations. Observers will be on duty in shifts usually of duration no longer than two hours. Use of two simultaneous observers prior to start up will increase the detectability of marine mammals present near the source vessel, and will allow simultaneous forward and rearward observations. Bridge personnel additional to the dedicated marine mammal observers will also assist in detecting marine mammals and implementing mitigation requirements, and before the start of the seismic survey will be given instruction in how to do so.

The *Roger Revelle* is a suitable platform for marine mammal observations, and has been used for that purpose during the routine CalCOFI (California Cooperative Oceanic Fisheries Investigations). Observing stations will be at the 02 level, with observers' eyes approximately 10.4 m (34 ft) above the waterline: one forward on the 02 deck commanding a forward-centered, approximately 240° view, and one atop the aft hangar, with an aft-centered view that includes the 60–m radius area around the airguns. The eyes of the bridge watch will be at a height of approximately 15 m (49 ft); marine mammal observers will repair to the enclosed bridge and adjoining aft steering station during any inclement weather (unlikely at this place and season), and as necessary to use the 50 X ''big-eye'' binoculars that are mounted there.

Standard equipment for marine mammal observers will be 7 X 50 reticle 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 airgun power-down or shut-down.

The vessel-based monitoring will provide data required to estimate the numbers of marine mammals exposed to various received sound levels, to document any apparent disturbance reactions, and thus to estimate the numbers of mammals potentially ''taken'' by harassment. It will also provide the information needed in order to shut down the GI airguns at times when mammals are present in or near the safety zone. When a mammal 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 seismic vessel (e.g., none, avoidance, approach, paralleling, etc.), and behavioral pace.

(2) Time, location, heading, speed, activity of the vessel (shooting or not), sea state, visibility, cloud cover, 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 mammal observations and airgun shutdowns will be recorded in a standardized format. Data will be entered into a custom database using a notebook computer when observers are off duty. The accuracy of the data entry will be verified by computerized data validity checks as the data are entered, and by subsequent manual checking of the database. Those procedures will allow initial summaries of data to be prepared during and shortly after the field program, and will facilitate transfer of the data to statistical, graphical, or other programs for further processing and archiving.

Results from the vessel-based observations will provide:

- The basis for real-time mitigation (airgun shut down).
- Information needed to estimate the number of marine mammals potentially taken by harassment, which must be reported to NMFS.
- Data on the occurrence, distribution, and activities of marine mammals in the area where the seismic study is conducted.
- Information to compare the distance and distribution of marine mammals relative to the source vessel at times with and without seismic activity.
- Data on the behavior and movement patterns of marine mammals seen at times with and without seismic activity.

Mitigation

For the proposed seismic surveys in the Northeastern Indian Ocean during May August 2007, SIO will deploy two GI airguns as an energy source, with a total discharge volume of 90 in3. The energy from the airguns will be directed mostly downward. The small size of the airguns to be used during the proposed study will reduce the potential for effects relative to those that might occur with a large airgun arrays.

In addition to marine mammal monitoring, the following mitigation measures will be adopted during the proposed seismic program, provided that doing so will not compromise operational safety requirements. Although power-down procedures are often standard operating practice for seismic surveys, it will not be used here because powering down from two guns to one gun would make only a small difference in the 180- or 190–dB radius – probably not enough to allow continued one-gun operations if a mammal came within the safety radius for two guns. Mitigation measures that will be adopted are:

(1) Speed or course alteration;

(2) Ramp-up and shut-down procedures; and

(3) Night operations;

Speed or Course Alteration – If a marine mammal is detected outside the safety radius and, based on its position and the relative motion, is likely to enter the safety radius, the vessel's speed and/or direct course may, when practical and safe, be changed in a manner that also minimizes the effect to the planned science objectives. The marine mammal activities and movements relative to the seismic vessel will be closely monitored to ensure that the animal does not approach within the safety radius. If the animal appears likely to enter the safety radius, further mitigative actions will be taken, i.e. either further course alterations or shut down of the airguns.

Shut-down Procedures - If a marine mammal is detected outside the safety radius but is likely to enter the safety radius, and if the vessel's course and/or speed cannot be changed to avoid having the animal enter the safety radius, the airguns will be shut down before the animal is within the safety radius (10 m (33 ft) for pinnipeds (190–dB isopleth) or 40 m (131 ft) for cetaceans (180–dB isopleth)). Likewise, if a marine mammal is already within the safety radius when first detected, the airguns will be shut down immediately.

Airgun activity will not resume until the animal has cleared the safety radius. The animal will be considered to have cleared the safety radius if it is visually observed to have left the safety radius, or if it has not been seen within the radius for 15 min (small odontocetes and pinnipeds) or 30 min (mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, beaked, and bottlenose whales).

Ramp-up Procedures – A ''ramp-up'' procedure will be followed when the airguns begin operating after a period without airgun operations. The two GI guns will be added in sequence 5 minutes apart. During ramp-up procedures, the safety radius for the two GI guns will be maintained.

Night Operations – At night, vessel lights and/or night vision devices (NVDs) could be useful in sighting some marine mammals at the surface within a short distance from the ship (within the safety radii for the two GI guns in deep water). Start up of the airguns will only occur in situations when the entire safety radius is visible with vessel lights and NVDs.

Reporting

A report will be submitted to NMFS within 90 days after the end of the cruise. The end of the northeastern Indian Ocean cruise is predicted to occur between July 16 and August 13, 2007. The report will describe the operations that were conducted and the marine mammals that were detected 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, marine mammal sightings (dates, times, locations, activities, associated seismic survey activities), and estimates of the amount and nature of potential ''take'' of marine mammals by harassment or in other ways.

Endangered Species Act

Under section 7 of the Endangered Species Act (ESA) the NSF has begun consultation on this proposed seismic survey. NMFS will also consult on the issuance of an IHA under section 101(a)(5)(D) of the MMPA for this activity. Consultation will be concluded prior to a determination on the issuance of the IHA.

National Environmental Policy Act (NEPA)

NSF prepared an Environmental Assessment of a Planned Low-Energy Marine Seismic Survey by the Scripps Institution of Oceanography in the Northeast Indian Ocean, May July 2007. NMFS will either adopt NSF's EA or conduct a separate NEPA analysis, as necessary, prior to making a determination on the issuance of the IHA.

Preliminary Determinations

NMFS has preliminarily determined that the impact of conducting the seismic survey in the northeast Indian Ocean may result, at worst, in a temporary modification in behavior (Level B Harassment) of small numbers of 29 species of cetaceans. Further, this activity is expected to result in a negligible impact on the affected species or stocks. The provision requiring that the activity not have an unmitigable adverse impact on the availability of the affected species or stock for subsistence uses does not apply for this proposed action.

For reasons stated peviously in this document, this determination is supported by: (1) the likelihood that, given sufficient notice through relatively slow ship speed and rampup, marine mammals are expected to move away from a noise source that is annoying prior to its becoming potentially injurious; (2) the fact that marine mammals would have to be closer than 40 m from the vessel to be exposed to levels of sound (180 dB) believed to have even a minimal chance of causing TTS; and (3) the likelihood that marine mammal detection ability by trained observers is high at that short distance from the vessel. As a result, no take by injury or death is anticipated and the potential for temporary or permanent hearing impairment is very low and will be avoided through the incorporation of the proposed mitigation measures.

While the number of potential incidental harassment takes will depend on the distribution and abundance of marine mammals in the vicinity of the survey activity, the number of potential harassment takings is estimated to be small, less than a few percent of any of the estimated population sizes, and has been mitigated to the lowest level practicable through incorporation of the measures mentioned previously in this document.

Proposed Authorization

As a result of these preliminary determinations, NMFS proposes to issue an IHA to SIO for conducting a low-energy seismic survey in the Indian Ocean from May - August, 2007, provided the previously mentioned mitigation, monitoring, and reporting requirements are incorporated.

Dated: April 4, 2007.

David Cottingham,

Acting Deputy Director, Office of Protected Resources, National Marine Fisheries Service.

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DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

[I.D. 010207B]

Small Takes of Marine Mammals Incidental to Specified Activities; Seismic Surveys in the Beaufort and Chukchi Seas off Alaska

AGENCY: National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Commerce.

ACTION: Notice of receipt of application and proposed incidental take authorization; request for comments.

SUMMARY: NMFS has received an application from Shell Offshore, Inc. (SOI) for an Incidental Harassment Authorization (IHA) to take small numbers of marine mammals, by harassment, incidental to conducting open-water offshore exploratory drilling on Outer Continental Shelf (OCS) oil lease blocks in the Beaufort Sea off Alaska. Under the Marine Mammal Protection Act (MMPA), NMFS is requesting comments on its proposal to