Request by Rice University for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during a Low-Energy Marine Seismic Survey in the Northwest Atlantic Ocean, August 2009

submitted by

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SUMMARY

Rice University (Rice), Department of Earth Sciences, plans to conduct a marine seismic survey in the Northwest Atlantic Ocean (NWA) during August 2009, with research funding from the National Science Foundation (NSF). The oceanographic research vessel R/V *Endeavor* will be used for the survey. The *Endeavor* is owned by NSF and operated by the University of Rhode Island (RI). The survey will use two generator-injector (GI) guns with a total discharge volume of ~90 in^3. Rice requests that it be issued an Incidental Harassment Authorization (IHA) allowing non-lethal takes of marine mammals incidental to the planned seismic survey. This request is submitted pursuant to Section 101 (a) (5) (D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371 (a) (5). The seismic survey will be conducted within the Exclusive Economic Zone (EEZ) of the U.S.A.

Numerous species of cetaceans and pinnipeds inhabit the NWA. Several of these species are listed as ***endangered*** under the U.S. Endangered Species Act (ESA), including the North Atlantic right, humpback, sei, fin, blue, and sperm whales. Rice is proposing a marine mammal monitoring and mitigation program to minimize the impacts of the proposed activity on marine mammals present during conduct of the proposed research, and to document the nature and extent of any effects.

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

I. OPERATIONS TO BE CONDUCTED

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

Overview of the Activity

Rice University (Rice), Department of Earth Sciences, plans to conduct a high-resolution multichannel seismic survey (MCS) in the Northwest Atlantic Ocean (NWA). The survey will take place off New England within the U.S. Exclusive Economic Zone (EEZ). Seismic operations will occur over the continental shelf southeast of the island of Martha's Vineyard (MV), Massachusetts (MA), and likely also in Nantucket Sound (Fig. 1). The cruise is currently scheduled to occur ~12–25 August 2009.

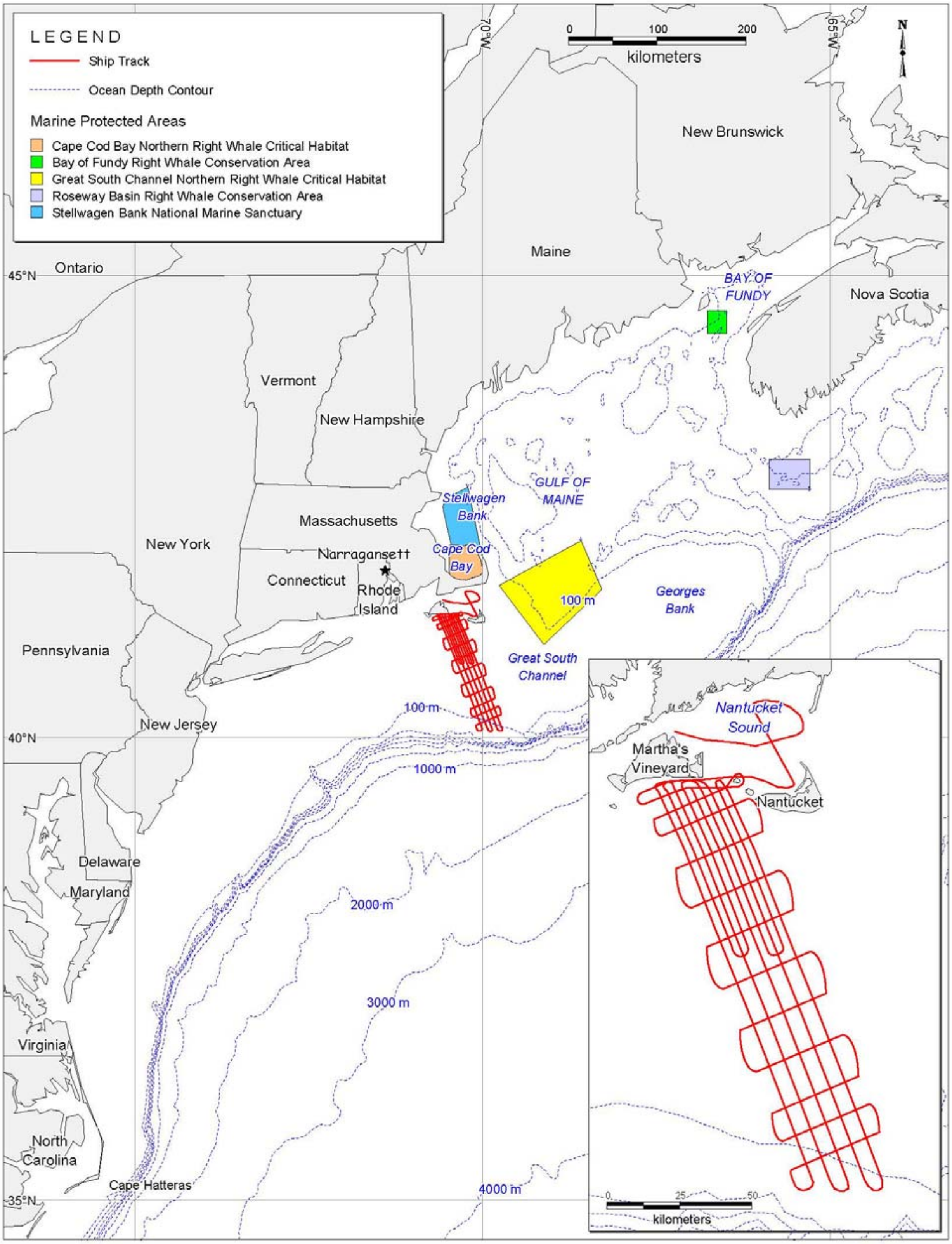

FIGURE 1. Study area and proposed seismic transect lines for the survey in the Northwest Atlantic Ocean, August 2009. For illustrative purposes, U.S. federal and Canadian protected areas are also shown (see § III).; the survey will not occur in those protected areas.

The proposed survey will examine stratigraphic controls on freshwater beneath the continental shelf off the U.S. east coast. In coastal settings worldwide, large freshwater volumes are sequestered in permeable continental shelf sediments. Freshwater storage and discharge have been documented off North and South America, Europe, and Asia. The proposed survey will investigate the Atlantic continental shelf off New England, where freshwater extends up to 100 km offshore. Using high-resolution mathematical models and existing data, it is estimated that ~1300 km^3 of freshwater is sequestered in the continental shelf from New York to Maine. However, the models indicate that the amount of sequestered freshwater is highly dependent on the thickness and distribution of aquifers and aquicludes. The proposed survey will provide imaging of the subsurface and characterize the distribution of aquifers and aquicludes off MV.

The study will provide data integral to improved models to estimate the abundance of sequestered freshwater and will provide site survey data for an Integrated Ocean Drilling Program (IODP) proposal to drill these freshwater resources for hydrogeochemical, biological, and climate studies. Combined seismic and drilling data could help identify undeveloped freshwater resources that may represent a resource to urban coastal centers, if accurately characterized and managed. On a global scale, vast quantities of freshwater have been sequestered in the continental shelf and may represent an increasingly valuable resource to humans. This survey will help constrain process-based mathematical models for more precise estimations of the abundance and distribution of freshwater wells on the continental shelf.

The source vessel, the R/V *Endeavor*, will deploy two low-energy Generator-Injector (GI) guns as an energy source (with a total discharge volume of 90 in^3) and a 600-m hydrophone streamer. The energy to the GI guns is compressed air supplied by compressors on board the source vessel. As the GI guns are towed along the survey lines, the streamer will receive the returning acoustic signals.

The planned seismic survey will consist of ~1757 km of survey lines and turns (Fig. 1). All survey effort will occur within 200 km of MV. Most of the survey effort (~1638 km) will take place in water <100 m deep, and ~119 km will occur just past the shelf edge, in water depths >100 m. There may be additional seismic operations associated with equipment testing, start-up, and repeat coverage of any areas where initial data quality is sub-standard.

All planned geophysical data acquisition activities will be conducted with assistance by the scientists who have proposed the study, Dr. B. Dugan of Rice University, Dr. D. Lizarralde of Woods Hole Oceanographic Institution, and Dr. M. Person of New Mexico Institute of Mining and Technology. The vessel will be self-contained, and the crew will live aboard the vessel for the entire cruise.

In addition to the operations of the two GI guns, a Knudsen 3260 echosounder, an EdgeTech sub-bottom profiler (SBP), and a "boomer" system to image sub-bottom seafloor layers will be used at times during the survey.

Vessel Specifications

The *Endeavor* will be used as the source vessel. The *Endeavor* will tow the two GI guns and one 600-m streamer containing hydrophones along predetermined lines (Fig. 1). Given the presence of the streamer and GI guns behind the vessel, the turning rate and maneuverability of the vessel is slightly limited.

The *Endeavor* has a length of 56.4 m, a beam of 10.1 m, and a maximum draft of 5.6 m. The *Endeavor* has been operated by the University of Rhode Island's Graduate School of Oceanography for over thirty years to conduct oceanographic research throughout U.S. and world marine waters. The ship is powered by one GM/EMD diesel engine, producing 3050 hp, which drives the single propeller directly at a maximum of 900 revolutions per minute (rpm). The vessel also has a 320-hp bowthruster, which is not used during seismic acquisition. The optimal operation speed during seismic acquisition will be ~7.4 km/h. When not towing seismic survey gear, the *Endeavor* can cruise at 18.5 km/h. The *Endeavor* has a range of 14,816 km.

The *Endeavor* will also serve as the platform from which vessel-based marine mammal observers will watch for marine mammals and sea turtles before and during GI-gun operations. The characteristics of the *Endeavor* that make it suitable for visual monitoring are described in § XIII.

Other details of the *Endeavor* include the following:

Owner:	National Science Foundation
Operator:	University of Rhode Island
Flag:	United States of America
Date Built:	1976 (Refit in 1993)
Gross Tonnage:	298
Accommodation Capacity:	30 including ~17 scientists

Airgun Description

The R/V *Endeavor* will be used as the source vessel. It will tow two GI guns and a 600-m hydrophone stream along predetermined lines. As the GI guns are towed along the survey lines, the streamer receives the reflected signals and transfers the data to the on-board processing system. The two GI guns will be towed ~25 m behind the *Endeavor* at a depth of ~3 m. Seismic pulses will be emitted at intervals of ~5 s. At a speed of 7.4 km/h, the 5-s spacing corresponds to a shot interval of ~10 m. The operating pressure will be 2000 psi. A single GI gun will be used during turns.

The generator chamber of each GI gun is responsible for generating the sound pulse and has a volume of 45 in^3. The injector chamber (also 45 in^3) injects air into the previously-generated bubble to maintain its shape, but does not introduce appreciably more sound into the water. Both GI guns will be fired simultaneously, for a total discharge volume of 90 in^3. The GI guns are relatively small compared to most other airgun arrays used for seismic surveys.

GI Airgun Specifications

Energy Source:	One or two GI guns of 45 in^3
Source output, 2 guns (downward):	0-pk is 3.4 bar-m (230.7 dB re 1 $\mu Pa \cdot m_p$); pk-pk is 6.2 bar-m (235.9 dB re 1 $\mu Pa \cdot m_{p-p}$)
Source output, 1 gun (downward):	0–pk is 1.8 bar-m (225.3 dB re 1 $\mu Pa \cdot m_p$); pk–pk is 3.4 bar-m (230.7 dB re 1 $\mu Pa \cdot m_{p-p}$)
Towing depth of energy source:	3 m
Air discharge volume:	~45 or 90 in^3
Dominant frequency components:	2–188 Hz
Gun positions used:	One GI gun or two GI guns in line, 2.4 m apart
Gun volumes at each position (in^3):	45, 45

A single GI gun, a single 15 in^3 watergun, or a boomer system (see description below, under "Description of Operations") may be used in shallow waters with sandy seafloors if the two GI guns do not provide accurate seafloor imaging. The watergun is a marine seismic sound source that uses an implosive mechanism to provide an acoustic signal. Waterguns provide a richer source spectra in high frequencies (>200 Hz) than those of GI or airguns. The 15-in^3 watergun potentially provides a cleaner signal for high-resolution studies in shallow water, with a short pulse (<30 ms) providing resolution of ~10 m. The operating pressure will be 2000 psi. Peak pressure of the single watergun and the boomer system is estimated to be ~212 dB (0.4 bar-m). Thus, both sources would have a considerably lower source level than the two GI guns or the single GI gun.

The rms[1] (root mean square) received levels that are used as impact criteria for marine mammals (see below) are not directly comparable to the peak (pk or 0–pk) or peak to peak (pk–pk) values normally used to characterize source levels of airgun arrays. The measurement units used to describe airgun sources, peak or peak-to-peak decibels, are always higher than the rms decibels referred to in biological literature (Greene 1997; McCauley et al. 1998, 2000). For example, a measured received level of 160 dB re 1 μPa_{rms} in the far field would typically correspond to a peak measurement of ~170–172 dB, and to a peak-to-peak measurement of ~176–178 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.

The sound pressure field of two 45-in^3 GI guns has not been modeled, but those for two 45-in^3 Nucleus G guns and one 45-in^3 GI gun have been modeled by Lamont-Doherty Earth Observatory (L-DEO) of Columbia University in relation to distance and direction from the guns (Figs. 2 and 3). The GI gun is essentially two G guns that are joined head to head. The G-gun signal has more energy than the GI-gun signal, but the peak energy levels are equivalent and appropriate for modeling purposes. The L-DEO model does not allow for bottom interactions, and is most directly applicable to deep water. Based on the modeling, estimates of the maximum distances from the GI guns where sound levels of 190, 180, 170, and 160 dB re 1 μPa_{rms} are predicted to be received in deep (>1000-m) water are shown in Table 1. Because the model results are for G guns, which have more energy than GI guns of the same size, those distances are overestimates of the distances for the 45-in^3 GI guns.

Empirical data concerning the 180-, 170-, and 160-dB distances for various airgun configurations, have been acquired based on measurements during an acoustic verification study conducted by L-DEO in the northern Gulf of Mexico (Tolstoy et al. 2004a,b). 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}, the safety criterion applicable to cetaceans (NMFS 2000), 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 and <100 m; the proposed survey will occur in depths ~20–125 m.

- The empirical data indicate that, for ***deep water*** (>1000 m), the L-DEO model tends to overestimate the received sound levels at a given distance (Tolstoy et al. 2004a,b). However, to be precautionary pending acquisition of additional empirical data, it is proposed that safety radii in deep water will be the values predicted by L-DEO's model (Table 1); however, operations will not occur in water depths >1000 m during the present study.
- Empirical measurements of sounds were not conducted for ***intermediate depths*** (100–1000 m). On the expectation that results would be intermediate between those from shallow and deep water, a correction factor of 1.5× is applied to the estimates provided by the model for deep-water situations to obtain estimates for intermediate-depth sites (Table 1).

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

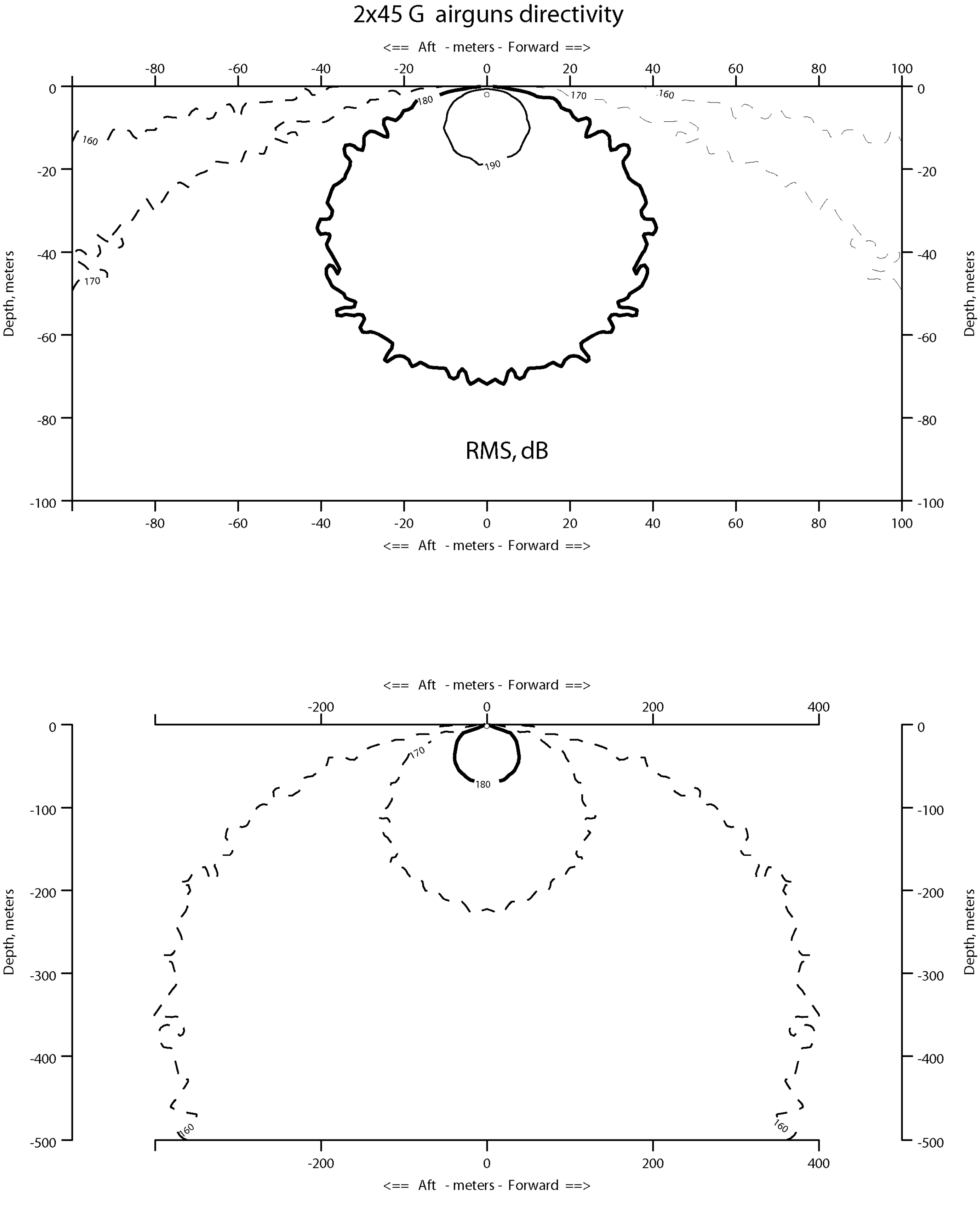
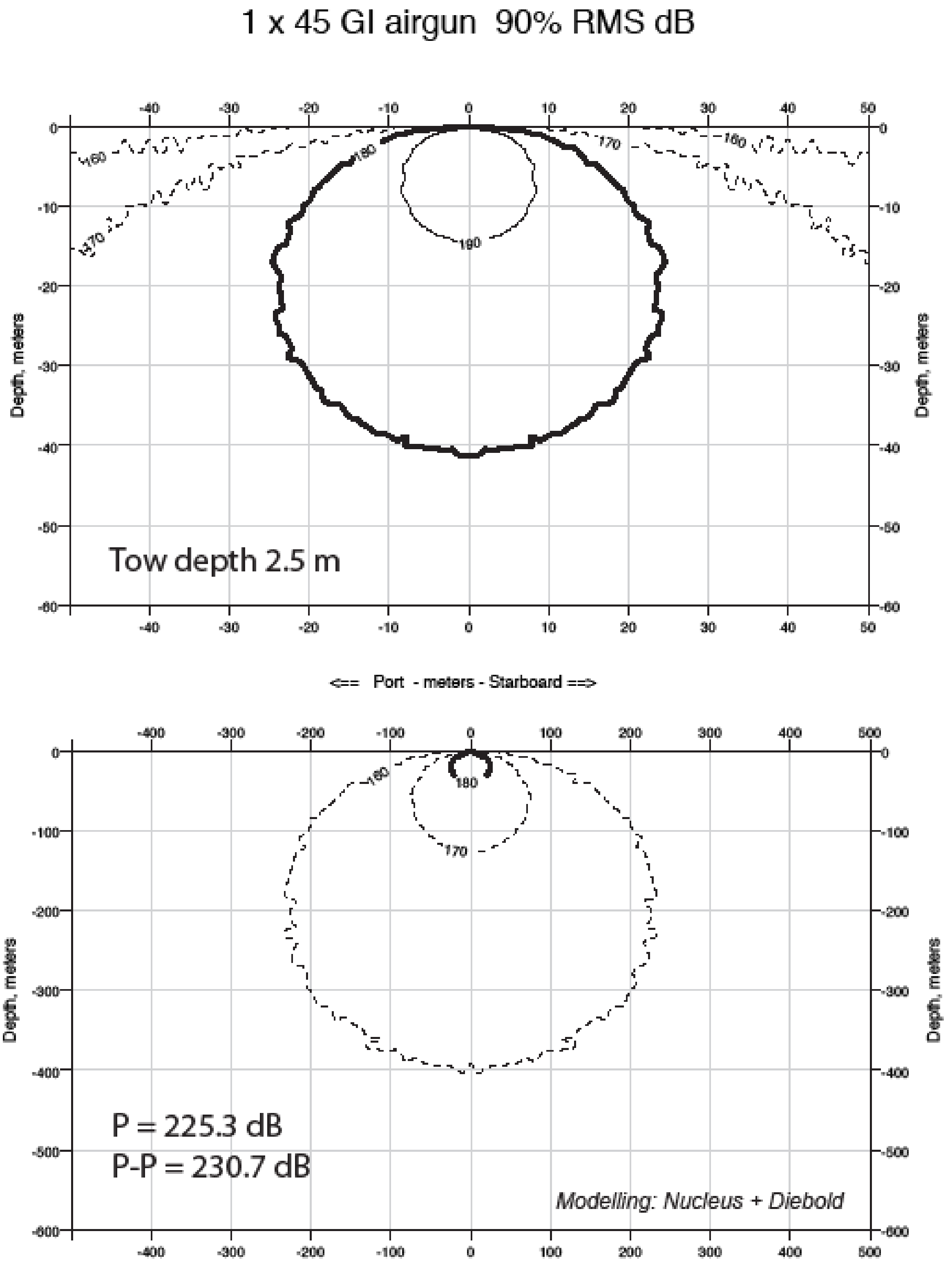


FIGURE 2. Modeled received sound levels from two 45-in^3 G guns, similar to the two 45-in^3 GI guns that will be used during the NWA survey. Model results provided by L-DEO.



1 x 45 GI airgun 90% RMS dB

FIGURE 3. Modeled received sound levels from the 45-in^3 GI gun that will be used on turns during the NWA survey. Model results provided by L-DEO.

TABLE 1. Distances to which sound levels ≥190, 180, 170, and 160 dB re 1 µPa$_{rms}$ might be received from two 45-in^3 G guns, similar to the two 45-in^3 GI guns that will be used during the proposed seismic survey in the NWA, August 2009, and one 45-in^3 GI gun that will be used during turns. Distances are based on model results provided by L-DEO.

		Estimated Distances at Received Levels (m)			
Source	Water depth	190 dB	180 dB	170 dB	160 dB
Two 45-in^3 G guns	100–1000 m	15	60	188	525
	<100 m	147	296	536	1029
One 45-in^3 GI gun	100–1000 m	12	35	105	330
	<100 m	95	150	230	570

- Empirical measurements indicated that in ***shallow water*** (<100 m), the L-DEO model ***underestimates*** actual levels. In L-DEO projects, the exclusion zones (EZs) are typically based on measured values and range from 1.3 to 15× higher than the modeled values depending on the size of the airgun array and the sound level measured (Tolstoy et al. 2004a,b). During the proposed cruise, similar factors are applied to derive appropriate shallow-water radii from the modeled deep-water radii (Table 1).

The GI guns, watergun, or boomer will be shut down immediately when cetaceans or sea turtles are detected within or about to enter the 180-dB re 1 µPa$_{rms}$ radius for the two GI guns, or when pinnipeds are detected within or about to enter the 190-dB re 1 µPa$_{rms}$ radius for the two GI guns. The 180- and 190-dB shut-down criteria are consistent with guidelines listed for cetaceans and pinnipeds, respectively, by the National Marine Fisheries Service (e.g., NMFS 2000).

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

Description of Operations

The survey will involve one vessel, the R/V *Endeavor*. The source vessel will deploy two low-energy GI guns as an energy source (with a discharge volume up to 90 in^3) and a 600-m hydrophone streamer. As the GI guns are towed along the survey lines, the streamer will receive the returning acoustic signals.

The planned seismic survey will consist of ~1757 km of survey lines and turns (Fig. 1). All survey effort will occur within 200 km of MV. Most of the survey effort (~1638 km) will take place in water <100 m deep, and ~119 km will occur just past the shelf edge, in water depths >100 m. There will be some additional seismic operations associated with equipment testing, start-up, and repeat coverage of any areas where initial data quality is sub-standard. The *Endeavor* is scheduled to depart Narragansett, RI, on 12 August and return to port on 25 August 2009.

Along with the GI-gun operations, additional acoustical systems will be operated at times during the cruise. The Knudsen 3260 echosounder, an EdgeTech SBP, and/ or an Applied Acoustics 'boomer' system will be operated from the *Endeavor* during the survey for additional sub-surface imaging. The ocean floor will be mapped with the 3.5–12-kHz Knudsen 3260 dual-frequency echosounder, and either a 0.5–12 kHz EdgeTech SBP or 0.3–3 kHz 'boomer' system will also be operated for sub-bottom seafloor imaging. The echosounder will be operated simultaneously with the GI guns and boomer system, but not with the SBP. The SBP will be used simultaneously with the GI guns in deeper water (>30–40 m), whereas the ‘boomer’ system will be used simultaneously with the GI guns in shallower water (<30–40 m).

Echosounder

The Knudsen 3260 is a deep-water, dual-frequency echosounder with operating frequencies of 3.5 and 12 kHz. The high frequency (12 kHz) can be used to record water depth or to track pingers attached to various instruments deployed over the side. The low frequency (3.5 kHz) is used for sub-bottom profiling. Both frequencies will be used simultaneously during the present study. It will be used with a hull-mounted, downward-facing transducer. A pulse up to 24 ms in length is emitted every several seconds with a nominal beam width of 80º. Maximum output power at 3.5 kHz is 10 kW and at 12 kHz it is 2 kW. The maximum source output (downward) for the 3260 is estimated to be 211 dB re 1 µPa·m at 10 kW.

Sub-bottom Profiler

The SBP is normally operated to provide information about sedimentary features and bottom topography; it will provide a 10-cm resolution of the sub-floor. During operations in deeper waters (>30–40 m), an EdgeTech 3200-XS SBP will be operated from the ship with a SB-512i towfish that will be towed at a depth of 5 m. It will transmit and record a 0.5-12-kHz swept pulse (or chirp), with a nominal beam width of 16–32º. The SBP will produce a 30-ms pulse repeated at 0.5- to 1-s intervals. Depending on seafloor conditions, it could penetrate up to 100 m.

Boomer

The ‘boomer’ system will be an alternative source of sub-floor imaging in shallower waters (<30–40 m). The Applied Acoustics AA200 ‘boomer’ system, run by the National Oceanography Centre, operates at frequencies of ~0.3 to 3 kHz. The system will be surface-towed, and a 60-m hydrophone streamer will receive its pulses. The streamer will be towed at 1 m depth and ~25–30 m behind the *Endeavor*. A 0.1-ms pulse will be transmitted at 1-s intervals. The normal source output (downward) is 212 dB re 1 µPa·m.

II. DATES, DURATION, AND REGION OF ACTIVITY

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

The *Endeavor* is expected to depart Narragansett, RI, on ~12 August 2009 for a ~4-hr transit to the study area southeast of MV (Fig. 1). Seismic operations will commence upon arrival at the study area, with highest priority given to the central NNW-SSE line, followed by the WSW-ENE lines, each of which cross the proposed IODP sites; lowest priority will be given to the survey lines in Nantucket Sound. The 14-day program will consist of ~11 days of seismic operations, and three contingency days in case of inclement weather. The *Endeavor* will return to Narragansett on ~25 August 2009. The exact dates of the activities depend on logistics, weather conditions, and the need to repeat some lines if data quality is substandard.

The proposed survey will encompass the area 39.8–41.5°N, 69.8–70.6°W (Fig. 1). Water depths in the study area range from ~20 to ~125 m, but are typically <100 m. The survey will take place in Nantucket Sound and south of Nantucket and MV. The ship will approach the south shore of MV within 10 km. The seismic survey will be conducted within the EEZ of the U.S.

III. SPECIES AND NUMBERS OF MARINE MAMMALS IN AREA

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

A total of 30 cetacean and four pinniped species are known to or could occur in the study area (Table 2; see Waring et al. 2007). Several species are listed as ***Endangered*** under the ESA: the North Atlantic right, humpback, sei, fin, blue, and sperm whales. The Western North Atlantic Coastal Morphotype Stock of common bottlenose dolphins is listed as ***Depleted*** under the MMPA.

Several federal Marine Protected Areas (MPAs) or sanctuaries have been established near the proposed study area, primarily with the intention of preserving cetacean habitat (Table 3; Hoyt 2005; CetaceanHabitat 2009; see also Fig. 1). Cape Cod Bay is designated as Right Whale Critical Habitat, as is the Great South Channel Northern Right Whale Critical Habitat Area located to the east of Cape Cod. The Gerry E Studds Stellwagen Bank National Marine Sanctuary is located north of the proposed study area in the Gulf of Maine. The proposed survey is not located within any federal MPAs or sanctuaries. However, a sanctuary designated by the state of MA occurs within the study area — the Cape & Islands Ocean Sanctuary. This sanctuary includes nearshore waters of southern Cape Cod, MV, and Nantucket (see Table 3). In addition, there are four National Wildlife Refuges within the study area (Monomoy, Nantucket, Mashpee, and Nomans Island) and a National Estuarine Research Reserve (Waquoit Bay). Except for Nomans Island, these refuges and reserves are located in Nantucket Sound. Three Canadian protected areas also occur in the NWA for cetacean habitat protection, including the Bay of Fundy and Roseway Basin Right Whale Conservation Areas (Fig. 1), as well as the Gully Marine Protected Area off the Scotian Shelf.

There are several areas that are closed to commercial fishing on a seasonal basis to reduce the risk of entanglement or incidental mortality to marine mammals. To protect large whales like right, humpback, and fin whales, NMFS implemented seasonal area management zones for lobster, several groundfish, and other marine invertebrate trap/pot fisheries, prohibiting gear in the Great South Channel Critical Habitat Area from April through June; additional dynamic area management zones could be imposed for 15-day time periods if credible fisheries observers identify concentrations of right whales in areas north of 40ºN (NMFS 1999, 2008). To reduce fishery impacts on harbor porpoises, additional time and area closures in the Gulf of Maine include fall and winter along the mid-coastal area, winter and spring in Massachusetts Bay and southern Cape Cod, winter and spring in offshore areas, and February around Cashes Ledge (NMFS 1998). Fishermen are also required to use pingers, and New Jersey and mid-Atlantic waters could close seasonally for fishermen failing to apply specific gear modifications (NMFS 1998).

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

TABLE 2. The habitat, occurrence, regional population sizes, and conservation status of marine mammals that could occur in or near the proposed study area in the northwest Atlantic Ocean.

Species	**Habitat**	**Occurrence in Study Area**	**Regional Best Abundance Est. (CV)[1]**	**ESA[2]**	**IUCN[3]**	**CITES[4]**
Mysticetes North Atlantic right whale (*Eubalaena glacialis*)	Coastal and shelf waters	Common	325 (0)[5]	EN	EN	I
Humpback whale (*Megaptera novaengliae*)	Mainly nearshore waters and banks	Common	11,570[6]	EN	LC	I
Minke whale (*Balaenoptera acutorostrata*)	Coastal waters	Common	~188,000[7]	NL	LC	I
Bryde's whale (*Balaenoptera brydei*)	Primarily offshore, pelagic	Rare	N.A.	NL	DD	I
Sei whale (*Balaenoptera borealis*)	Primarily offshore, pelagic	Uncommon	~10,300[8]	EN	EN	I
Fin whale (*Balaenoptera physalus*)	Continental slope, mostly pelagic	Common	~35,500[9]	EN	EN	I
Blue whale (*Balaenoptera musculus*)	Coastal, shelf, and coastal waters	Uncommon?	Up to 1400[10]	EN	EN	I
Odontocetes Sperm whale (*Physeter macrocephalus*)	Pelagic	Common?	13,190[11]	EN	VU	I
Pygmy sperm whale (*Kogia breviceps*)	Deep waters off the shelf	Uncommon	N.A.	NL	DD	II
Dwarf sperm whale (*Kogia sima*)	Deep waters off the shelf	Uncommon	N.A.	NL	DD	II
Cuvier's beaked whale (*Ziphius cavirostris*)	Pelagic	Uncommon	N.A.	NL	DD	II
Northern bottlenose whale (*Hyperoodon ampullatus*)	Pelagic	Rare	40,000[12]	NL	DD	II
True's beaked whale (*Mesoplodon mirus*)	Pelagic	Rare	N.A.	NL	DD	II
Gervais' beaked whale (*Mesoplodon europaeus*)	Pelagic	Rare	N.A.	NL	DD	II
Sowerby's beaked whale (*Mesoplodon bidens*)	Pelagic	Rare	N.A	NL	DD	II
Blainville's beaked whale (*Mesoplodon densirostris*)	Pelagic	Rare	N.A.	NL	DD	N.A.
Bottlenose dolphin (*Tursiops truncatus*)	Shelf, coastal, and offshore	Common	81,588 (0.17)[13]	NL^	LC	II
Pantropical spotted dolphin (*Stenella attenuata*)	Coastal and pelagic	Rare	N.A.	NL	LC	II
Atlantic spotted dolphin (*Stenella frontalis*)	Mainly coastal waters	Uncommon?	50,978 (0.42)	NL	DD	II
Spinner dolphin (*Stenella longirostris*)	Coastal and pelagic	Rare	N.A.	NL	DD	II
Striped dolphin (*Stenella coeruleoalba*)	Off the continental shelf	Common?	94,462 (0.40)	NL	LC	II
Short-beaked common dolphin (*Delphinus delphis*)	Continental shelf and pelagic	Common	120,743 (0.23)	NL	LC	II
White-beaked dolphin (*Lagenorhynchus albirostris*)	Continental shelf <200 m	Uncommon?	10s to 100s of 1000s[14]	NL	LC	II
Atlantic white-sided dolphin (*Lagenorhynchus acutus*)	Shelf and slope waters	Common	10s to 100s of 1000s[15]	NL	LC	II
Risso's dolphin (*Grampus griseus*)	Waters 400–1000 m	Common	20,479 (0.59)	NL	LC	II
False killer whale (*Pseudorca crassidens*)	Tropical, temperate, pelagic	Extralimital	N.A.	NL	DD	II

Species	Habitat	Occurrence in Study Area	Regional Best Abundance Est. (CV)[1]	ESA[2]	IUCN[3]	CITES[4]
Killer whale (*Orcinus orca*)	Coastal, widely distributed	Rare	N.A.	NL*	DD	II
Long-finned pilot whale (*Globicephala melas*)	Mostly pelagic	Common?	~810,000[16]	NL	DD	II
Short-finned pilot whale (*Globicephala macrorhynchus*)	Mostly pelagic	Common?	~810,000[16]	NL	DD	II
Harbor porpoise (*Phoecena phocoena*)	Coastal	Common?	~500,000[17]	NL	LC	II
Pinnipeds Harbor seal (*Phoca vitulina*)	Coastal	Common	99,340 (0.097)	NL	LC	N.A.
Gray seal (*Halichoerus grypus*)	Coastal	Common	52,500[18]	NL	LC	N.A.
Harp seal (*Pagophilius groenlandicus*)	Coastal	Uncommon	5.5 million[19]	NL	LC	N.A.
Hooded seal (*Cystophora cristata*)	Coastal	Uncommon	592,100[20]	NL	VU	N.A.

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

[1] Abundance estimates are given from Waring et al. (2007), typically for U.S. Western North Atlantic stocks unless otherwise indicated; CV (coefficient of variation) is a measure of a number's uncertainty on a proportional basis. For species whose distribution is primarily offshore or not known, we do not consider estimates for the U.S. EEZ in Waring et al. (2007) to be valid estimates for the NWA and the regional population is given as N.A. unless it is available from another source.

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

[3] Codes for IUCN classifications from the 2008 IUCN *Red List of Threatened Species* (IUCN 2008): CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient.

[4] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2008): Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled.

[5] Estimate updated in NMFS 2008 Draft stock assessment report, available at http://www.nmfs.noaa.gov/pr/pdfs/sars/ao2008_draft_summary.pdf.

[6] Estimate for the western North Atlantic (IWC 2007a).

[7] Estimate for the North Atlantic (IWC 2007; Waring et al. 2007).

[8] Estimate for the Northeast Atlantic (Cattanach et al. 1993).

[9] Estimate for the North Atlantic (IWC 2007a; Waring et al. 2007).

[10] Estimate for the North Atlantic (NMFS 1998).

[11] Estimate for North Atlantic (Whitehead 2002).

[12] Estimate for Northeast Atlantic (NAMMCO 1995: 77).

[13] Estimate for the Western North Atlantic and Offshore stock, and may include coastal forms. 43,951 animals estimated for all management units of the Coastal morphotype (Waring et al. 2007).

[14] Tens to low hundreds of thousands (Reeves et al. 1999a).

[15] High tens to low hundreds of thousands (Reeves et al. 1999b).

[16] Estimate may include both long- and short-finned pilot whales.

[17] Estimate for the North Atlantic (Jefferson et al. 2008).

[18] Estimate for the northwest Atlantic Ocean in the Gulf of St. Lawrence and along the Nova Scotia eastern shore (Hammill 2005).

[19] Estimate for the northwest Atlantic Ocean (DFO 2007).

[20] Estimate for the northwest Atlantic Ocean (ICES 2006).

* Killer whales in the eastern Pacific Ocean, near Washington state, are listed as endangered under the U.S. ESA but not in the Atlantic Ocean.

^ The Western North Atlantic Coastal Morphotype stock, ranging from NJ to FL, is listed as depleted under the U.S. Marine Mammal Protection Act.

TABLE 3. Proposed and existing protected marine areas located near the proposed study area in the NWA (adapted from Hoyt 2005 and CetaceanHabitat 2009).

Protected Area	Location/Size	Cetacean Species	Notes
Cape Cod Bay/Cape Cod/Cape & Islands Ocean Sanctuary	1596 km^2; of coastline along Cape Cod, including nearshore of Martha's Vineyard and Nantucket Island	North Atlantic right whales, humpback whales, Atlantic white-sided dolphins, others	Established in 1971; managed by MA Office of Coastal Zone Management; limits marine discharges, dumping, non-renewable resource development, and other activities that disturb benthic habitat, other than fishing.
Cape Cod Bay Northern Right Whale Critical Habitat Area	1666 km^2; north and east Cape Cod Bay in the Gulf of Maine	North Atlantic right whales, humpback whales, Atlantic white-sided dolphins, others	Established in 1994 as Critical Habitat for right whales; managed by NMFS
Great South Channel Northern Right Whale Critical Habitat Area	8371 km^2; east of Cape Cod on Great South Channel	North Atlantic right whales, humpback whales, Atlantic white-sided dolphins, others	Established in 1994 as Critical Habitat for right whales; managed by NMFS
Gerry E Studds Stellwagen Bank National Marine Sanctuary	2181 km^2; east of MA on Stellwagen Bank in the Gulf of Maine	Humpback, fin, minke, North Atlantic right, and pilot whales, white-sided dolphins, harbor porpoise, others	Designated in 1992 as part of the National Marine Sanctuary Program
Jeffrey's Ledge (*proposed*)	Proposed extension to existing Stellwagen Bank National Marine Sanctuary	Humpback, fin, minke, North Atlantic right, and pilot whales, white-sided dolphins, harbor porpoise, others	Proposed to cover additional whale habitat or form new national marine sanctuary
Bay of Fundy Right Whale Conservation Area	Grand Manan Basin in the Bay of Fundy, New Brunswick, Canada	North Atlantic right, fin, and humpback whales, white-sided dolphins, harbor porpoise, others	Nursery and mating areas for North Atlantic right whales; in 2003, right whales were given right of way to shipping traffic by the Canadian government.
Roseway Basin Right Whale Conservation Area	Between Browns and Baccaro Banks off southwest Nova Scotia, Canada	North Atlantic right, sperm, fin, and humpback whales, white-sided dolphins, harbor porpoise, others	Nursery and mating areas for North Atlantic right whales; in 2003, right whales were given right of way to shipping traffic by the Canadian government.
The Gully Marine Protected Area	2364 km^2; submarine canyon on Scotian Shelf, 40 km southeast of Sable Island in the open North Atlantic	Northern bottlenose whales, occasionally minke, blue, fin, humpback, and pilot whales, dolphins, harbor porpoise	Critical habitat for a population of bottlenose whales; Designated as MPA in 2004 by Canada's Oceans Act.

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

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

Sections III and IV are integrated here to minimize repetition.

The marine mammals that occur in the proposed study area belong to three taxonomic groups: odontocetes (toothed whales, such as sperm and beaked whales or dolphins), mysticetes (baleen whales), and pinnipeds (seals and sea lions). Twenty-three odontocetes and seven mysticetes may occur in the study area, and several are common in the study area (see below). Of the four species of pinnipeds that could potentially occur along the U.S. northeast coast, only the harbor and gray seals regularly inhabit the region, but not during the summer when the survey is planned to take place.

Mysticetes

North Atlantic right whale (*Eubalaena glacialis*)

The North Atlantic right whale population is one of the world's most critically endangered large whale populations (Clapham et al. 1999; IWC 2001). It is listed as ***Endangered*** under the U.S. ESA (Waring et al. 2007) and on the 2008 IUCN Red List of Threatened Species (IUCN 2008), and is listed in CITES Appendix I (UNEP-WCMC 2008). Historically, right whale populations were severely depleted by commercial whaling. More recently, the lack of recovery in the population has been attributed to direct and indirect impacts from human activities, especially ship collisions and fishing gear entanglements (IWC 2001).

The western North Atlantic right whale minimum population size is estimated at 325 based on individual photo-identification in 2003. No estimate of abundance with an associated coefficient of variation has been calculated for this population (Waring et al. 2007). The trend in population growth rate for the North Atlantic right whale was under some debate, with evidence of modest population growth rate for the period 1986–1992 (Knowlton et al. 1994) but declining survival probability and increased mortality in the late 1990s (Caswell et al. 1999; Fujiwara and Caswell 2001; Clapham 2002; Kraus et al. 2005). There is recent evidence of significant increase in the minimum number of animals known to be alive and a slight mean population growth of 1.8% for the period 1990–2003 (Waring et al. 2007).

The general distribution of North Atlantic right whales encompasses continental shelf waters off the eastern U.S. and Canada, from Florida to Nova Scotia (Winn et al. 1986). However, the range of the population extends from as far north as southeast of Greenland, Iceland, and Norway to as far south as the Gulf of Mexico, including off Texas, where a cow/calf pair was recently sighted (Moore and Clarke 1963; Winn et al. 1986; Knowlton et al. 1992; IWC 2001; NEAQ 2006).

There are five well-known habitats in the Northwest Atlantic used annually by right whales (Winn et al. 1986; NMFS 2005a). These include the winter calving grounds in coastal waters of the southeastern U.S. (Florida/Georgia); spring feeding grounds in the Great South Channel (east of Cape Cod); late winter/spring feeding grounds and nursery grounds in Massachusetts Bay and Cape Cod Bay; summer/fall feeding and nursery grounds in the Bay of Fundy; and summer/fall feeding grounds on the Nova Scotian Shelf.

The first three habitats were designated as critical by the National Marine Fisheries Service (NMFS 1994). The migration route between the Cape Cod summer feeding grounds and the Georgia/ Florida winter calving grounds, known as the mid-Atlantic corridor, has not been considered to include "high use" areas, yet the whales clearly move through these waters regularly in all seasons (Reeves and Mitchell

1986; Winn et al. 1986; Kenney et al. 2001; Reeves 2001; Knowlton et al. 2002). In addition, Jeffreys Ledge, off the coast of northern Massachusetts, New Hampshire, and Maine, could be an important fall feeding area for right whales and an important nursery area during summer, especially in July and August (Weinrich et al. 2000).

There is a general seasonal north-south migration of the North Atlantic population, but right whales might be seen anywhere off the Atlantic U.S. throughout the year (Gaskin 1982). The population generally migrates as two separate components. Pregnant females and some juveniles migrate from the northern feeding grounds to the calving grounds off the southeastern U.S. in late fall–winter. Mothers and calves return northward to the feeding grounds in late winter to early spring. The majority of the right whale population is unaccounted for on the southeastern U.S. winter calving ground, and not all reproductively-active females return to the area each year (Kraus et al. 1986; Winn et al. 1986; Kenney et al. 2001). Some whales, including mothers and calves, remain on the feeding grounds through the fall and winter. However, the majority of the right whale population leaves the feeding grounds for unknown wintering habitats and returns when the cow-calf pairs return. Other wintering areas have been suggested, based upon sparse data or historical whaling logbooks; these include the Gulf of St. Lawrence, Newfoundland and Labrador, the coast of New York and New Jersey, Bermuda, and Mexico (Payne and McVay 1971; Aguilar 1986; Mead 1986; Lien et al. 1989; Knowlton et al. 1992).

North Atlantic right whales are found commonly on the northern feeding grounds off the northeastern United States during early spring and summer. Highest abundance in Cape Cod bay is in February and April (Winn et al. 1986; Hamilton and Mayo 1990) and from April to June in the Great South Channel east of Cape Cod (Winn et al. 1986; Kenney et al. 1995). Throughout the remainder of summer and into fall (June through November), North Atlantic right whales are most commonly seen farther north on feeding grounds in Canadian waters, with peak abundance during August, September, and early October (Gaskin 1987, 1991).

Pregnant females and some juveniles migrate to the calving grounds through the coastal waters off North Carolina, Georgia, and northern Florida during late autumn and winter, generally arriving between November and March (Winn et al. 1986; Kraus et al. 1986; Kenney 2001). Right whales on their winter calving grounds are most often found near the coast in ~10-m water depths (Kraus et al. 1988). The distribution of calving right whales off Florida and Georgia is highly correlated to water temperatures of 13–15ºC and water depths of 15–20 m (Garrison 2005; Keller et al. 2006). In winter, many right whales are found in the currently-defined boundary of the critical habitat, but high densities of whales have been found to the north of the designated critical habitat in response to inter-annual variability in the water temperature (Keller et al. 2006).

The seasonal occurrence of right whales in mid-Atlantic waters is mostly between November and April, with peaks in December, March, and April, when whales transit through the area on their migrations to and from breeding grounds or feeding grounds (Knowlton 1997). An adult female fitted with a transmitter in July 2000 on the northern feeding grounds off New Brunswick migrated along the mid-Atlantic corridor at a steady pace of about 3.5 km/hr, arriving in December in the Southeast Critical Habitat Area (ONR 2000). This represents the longest tracking of a right whale (130 days).

Knowlton et al. (2002) provided an extensive and detailed analysis of survey data, satellite tag data, whale strandings, and opportunistic sightings along State waters of the mid-Atlantic migratory corridor[2],

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[2] Multi-year datasets for the analysis were provided by the New England Aquarium (NEAQ), North Atlantic Right Whale Consortium (NARWC), Oregon State University, Coastwise Consulting Inc, Georgia Department of Natural Resources, University of North Carolina Wilmington (UNCW), Continental Shelf Associates, Cetacean and Turtle Assessment Program (CETAP), NOAA, and University of Rhode Island.

from the border of Georgia/South Carolina to south of New England, including waters in the proposed seismic survey area off MV. The majority of sightings (94%) along the migration corridor were within 56 km of shore, and more than half (64%) were within 18.5 km of shore (Knowlton et al. 2002). Water depth preference was for shallow waters; 80% of all sightings were in depths <27 m, and 93% were in depths <45 m (Knowlton et al. 2002). Most sightings farther than 56 km from shore occurred at the northern end of the corridor, off New York and south of New England.

Right whale sightings in very deep, offshore waters of the western North Atlantic are rare. There is limited evidence suggesting that there could be a regular offshore component of their distribution including:

- the absence of the majority of the population (except for mother/calf pairs and some adult females and juveniles) from most coastal habitats in winter (Winn et al. 1986; Kraus et al. 1986; Kenney et al. 2001);
- genetic and sighting data that indicate that some females consistently take their calves to other, undiscovered summer grounds (Schaeff et al. 1993);
- occasional offshore sightings off the mid-Atlantic states and southeastern U.S. (EWS 1997–2007; Knowlton et al. 2002; Niemeyer 2007, 2008);
- one right whale satellite-tagged whale in the Bay of Fundy in September 1990 that moved offshore for seven days, spending time at the edge of a warm core ring (Mate et al. 1997); and
- an entangled pregnant female off Jacksonville, FL, that was satellite-tracked in January 1996 to nearly the middle of the Atlantic Ocean, where it remained for a period of months (WhaleNet 1998).

All age classes and sexes can be found in all habitats, although there is strong segregation by sex on the southeast winter calving ground, where most sightings are of females with calves and some juveniles (Kraus 1993; Hamilton et al. 2007).

Right whales are generally not gregarious, usually occurring singly or in small transitory groups (Reeves et al. 2002). Along the mid-Atlantic corridor, they are usually found traveling alone (Kraus et al. 1993), whereas in prime feeding habitat, aggregations of up to 150 can be sighted (Reeves et al. 2002). Right whale courtship groups of 2–35 can be found on summer and fall feeding grounds, and on occasion, large groups of adult males can be found in the southeast (Kraus and Hatch 2001; Reeves et al. 2002).

Right whales are slow swimmers. Whales satellite-tagged in the Bay of Fundy during August and September traveled at speeds between 0.8 km/h and 4.6 km/h (Mate et al. 1997). Based on photographic re-identifications, whales traveling along the mid-Atlantic migratory corridor migrated at a mean swim rate of 3.2 km/h (Firestone et al. 2008).

Right whale feeding can occur at the surface (skim-feeding) or throughout the water column; foraging in high-use areas is frequently down to the bottom (Watkins and Schevill 1979; Goodyear 1993; Winn et al. 1986; Mate et al. 1997; Baumgartner et al. 2003b). Feeding dives are characterized by rapid descent to depths of 80–175 m for 5–14 min, and then rapid ascent back to the surface (Goodyear 1993; Baumgartner and Mate 2003). Mother/calf pairs have shorter dive dives and longer surface intervals than single whales, suggesting that they could be more at risk of ship collisions (Kraus et al. 1993; Baumgartner and Mate 2003).

Right whales must locate and exploit very dense patches of prey (zooplankton) in order to feed efficiently (Mayo and Marx 1990). Temporal and spatial formations of zooplankton concentrations have been correlated with shifts in the distribution of right whales on feeding grounds (Brown and Winn 1989). Shifts in copepod abundance are thought to have a tremendous significance to the North Atlantic right whale population, as calving rates have been linked to the abundance of prey; the calving rate remained stable when the abundance of the copepod *Calanus* was high, but it fell when the abundance of *Calanus* declined in the late 1990s (Greene et al. 2003).

Shelf waters off MV in Survey Area.—A review of the mid-Atlantic whale sighting and tracking data archive for the mid Atlantic from 1974 to 2002 found a high density of North Atlantic right whale sightings in the proposed seismic survey area in March and April, few right whale sightings in January, February, June, July, September, October, and December, and no sighting records for May, August, and November (Beaudin Ring 2002). The North Atlantic Right Whale Consortium database contains only 3 sightings during August (all in 2004) for a block (39.5–41.5ºN, 69.5–71ºW) that contains the proposed survey area (Right Whale Consortium 2009); all were just east of Nantucket Shoals. Palka (2006) reviewed North Atlantic right whale density in the U.S. Navy Northeast Operating Area (NE OPERA) based on summer abundance surveys conducted during 1998–2004. One of the lowest whale densities (including right whales) was found in the Georges Bank West stratum, which includes most of the proposed seismic survey area. However, survey effort for this stratum was also the lowest; only two surveys were conducted, one aerial survey from 19 July to 16 August 2002 and another from 12 June to 12 July 2004. No right whales were sighted.

North Atlantic right whales likely travel through the proposed seismic survey area in the month of August only occasionally. In 2001, a tagged entangled right whale traveled south from Georges Bank to New York and back; on 28 August, it was reported 67 km southeast of MV, and two days later, it was reported farther north, in the Great South Channel (Whalenet 2008).

Federal and Other Action.—In 2002, NMFS received a petition to revise and expand the designation of critical habitat for this species. The revision was declined and the critical habitat designated in 1994 remains in place (NMFS 2005b). The designation of critical habitat doesn't restrict activities within the area or mandate any specific management action. However, actions authorized, funded, or carried out by Federal agencies that may have an impact on critical habitat must be consulted upon in accordance with Section 7 of the ESA, regardless of the presence of right whales at the time of impacts. Impacts on these areas that could affect primary constituent elements such as prey availability and the quality of nursery areas must be considered when analyzing whether habitat may be adversely modified.

In an effort to reduce ship collisions with North Atlantic right whales, the Right Whale Sighting Advisory System (EWS; early warning system) was instigated to alert area ship traffic to the presence of right whales in the critical calving habitat in the southeastern U.S. The jointly funded aerial survey program, initiated in 1993, is designed to obtain accurate, current information on the locations of whales and continuously updated sighting information is immediately relayed to mariners in the area. This system was extended to the feeding areas off New England in 1996 (NMFS NEFSC 2008).

In 1999, a Mandatory Ship Reporting System was implemented by the U.S. Coast Guard (USCG 1999; 2001). This reporting system requires specified vessels (larger than 300 gross registered tons) to report their location while in the right whale nursery and feeding areas (Ward-Geiger et al. 2005). Mandatory ship reporting takes place from 15 November to 15 April in the southeastern U.S., in coastal waters within ~46 km of shore along a 167-km stretch of coast in Florida and Georgia. In the northeastern U.S., the reporting system is year-round and the geographical boundaries include the waters of Cape Cod Bay, Massachusetts Bay, and the Great South Channel.

In November 2006, NOAA established recommended shipping routes in key right whale aggregation areas at the entrances to three ports in Georgia and Florida from November through April, and in Cape Cod Bay from January to May (NOAA 2006). In July 2007, the Boston Traffic Separation Scheme

(TSS) was realigned by a 12° shift in the northern leg, and the two traffic lanes were narrowed by 0.8 km each in an effort to reduce ship strike risk to right whales (NOAA 2007).

On 9 December 2008 NMFS established regulations to implement a uniform mandatory vessel speed restriction of 18.5 km or less for all vessels 20 m or longer in specific locations (Seasonal Management Areas or SMAs) along the U.S. east coast during times when whales are likely present (NOAA 2008). The speed restrictions extend out to ~37 km around the major ports along the mid-Atlantic corridor. The restriction applies during 15 November–15 April in the southeast calving grounds, 1 January–15 May in Cape Cod Bay, 1 March–30 April off Race Point at the northern end of Cape Cod, 1 April–31 July in the Great South Channel, and 1 November–30 April near entrances to several ports along the mid-Atlantic corridor. The closest SMA to the proposed survey area, the Block Island Sound SMA, is located to the west of the northern part of the survey area.

NOAA may also establish Dynamically Managed Areas (DMAs), which would be established temporarily in direct response to actual whale sightings. Mariners are encouraged to avoid these areas or reduce speeds to 18.5 km or less while transiting through these areas. The size of a DMA would be determined by the number of whales sighted. Once an area has been designated, the rule stays in effect for 15 days and may be extended for a further 15 days if whales remain in the area (NOAA 2008).

Humpback whale (*Megaptera novaengliae*)

The humpback whale is cosmopolitan in distribution; it migrates between coastal waters in high latitudes, where it forages during summer months, and the tropics, where it breeds in winter months (Jefferson et al. 2008). The humpback whale is listed as ***Endangered*** under the ESA and ***Least Concern*** on the 2008 IUCN Red List of Threatened Species (IUCN 2008). Historical commercial whaling of humpback whales drastically decreased their numbers worldwide, but protection since 1964 has not brought numbers back to more than 10% of pre-exploitation levels. In the NWA, humpbacks feed during spring, summer, and fall in areas ranging from Cape Cod to Newfoundland. A Gulf of Maine stock is recognized off the northeastern U.S. coast as a genetically isolated feeding stock in the North Atlantic (Palsboll et al. 2001). The best abundance estimate for the entire North Atlantic is 11,570, and 847 whales are estimated to comprise the Gulf of Maine stock (Waring et al. 2007).

Single animals or groups of 2–3 are commonly observed, but much larger groups can occur on foraging and breeding grounds (Clapham 2000). Humpbacks appear to use deep, offshore migratory corridors between coastal and nearshore foraging and breeding grounds. During winter, whales from most of the Atlantic feeding areas are found in the West Indies for mating and calving, and apparently genetic mixing among subpopulations occurs (Clapham et al. 1993; Stevick et al. 1998). Some whales do not migrate to the West Indies every winter, and lower densities of humpbacks can be found in mid- and high-latitudes during this time (Clapham et al. 1993).

Movements of humpbacks within the Gulf of Maine have been strongly associated with the relative abundance of herring and sandlance (Stevick et al. 2006). Humpbacks favor shallow banks and shoals or areas with high seafloor relief (Hamazaki 2002), and associate with thermal fronts (Doniol-Valcroze et al. 2007). The highest numbers of humpback whales in New England waters occurs from mid-April to mid-November, and they can be found near Stellwagen Bank, Jeffreys Ledge, the Great South Channel, the edges and shoals of Georges Bank, Cashes Ledge, and northeast into Nova Scotia and Newfoundland waters (DoN 2005; Waring et al. 2007). Greatest concentrations of humpback whales in spring occur in the western and southern edges of the Gulf of Maine. During summer, their greatest concentrations are found throughout the Gulf of Maine, east of Cape Cod, and near the coast from Long Island to northern Virginia. Similar distribution patterns are seen in the fall, although sightings south of Cape Cod Bay are less frequent than those near the Gulf of Maine. From December to March, there are few occurrences of humpback whales over the continental shelf of the Gulf of Maine, and in Cape Cod and Massachusetts Bay (Clapham et al. 1993; DoN 2005). Low numbers of humpbacks are thought to remain during the winter over the continental shelf from the Gulf of Maine to Georges Bank (DoN 2005).

Minke whale (*Balaenoptera acutorostrata*)

The minke whale has a cosmopolitan distribution that spans polar, temperate, and tropical regions (Jefferson et al. 2008). Four populations are recognized in the North Atlantic, including the Canadian East Coast stock that ranges from the eastern U.S. coast to the eastern half of Davis Strait (Waring et al. 2007). The best abundance estimate for the Canadian East Coast stock of minke whales is 3312. The populations of the Northeastern and Central Atlantic and West Greenland stocks are estimated to be 174,000 and 10,800, respectively (IWC 2007a), for a total of ~188,000 animals in the North Atlantic.

The minke whale is a small baleen whale and tends to be solitary or in groups of 2–3, but can occur in much larger aggregations around prey resources (Jefferson et al. 2008). Its small size, inconspicuous blows, and brief surfacings make the minke whale difficult to detect at sea, but it is also known to approach vessels at times (Stewart and Leatherwood 1985). Minke whales feed primarily on small schooling fish in the western North Atlantic, generally occupy waters over the continental shelf, and are known to make short-duration dives (Stewart and Leatherwood 1985).

Minke whales are common off the U.S. east coast over continental slope and shelf waters. They also appear to associate with thermal fronts (Doniol-Valcroze et al. 2007). Some seasonal movements are apparent in many regions, and movement patterns likely mirror the abundance and distribution of their primary prey species (Macleod et al. 2004a). Seasonal movements in the NWA are apparent, with animals moving south and offshore from New England waters during the winter; the highest numbers sighted are during spring and summer, with fewer records during fall (DoN 2005; Waring et al. 2007).

Bryde's whale (*Balaenoptera brydei*)

Bryde's whale has a circumpolar distribution, typically between 40ºN and 40ºS (Jefferson et al. 2008). The distribution of Bryde's whale is not well known, but in the NWA, it most frequently occurs in or near the Gulf of Mexico. Bryde's whale is not included in the 2007 stock assessment for the North Atlantic (Waring et al. 2007).

Bryde's whales can be observed in offshore and coastal areas, but tend to be associated with areas of unusually high productivity (Jefferson et al. 2008). Other than a single stranding in Chesapeake Bay, there are no records of Bryde's whales north of NC, and any animals in the NWA would be considered strays (Mead 1977). Thus, sightings of Bryde's whales in the proposed study area are not expected.

Sei whale (*Balaenoptera borealis*)

The distribution of the sei whale is not well known, but it is found in all oceans and appears to prefer mid-latitude temperate waters (Jefferson et al. 2008). The species is listed as ***Endangered*** under the ESA and on the 2008 IUCN Red List of Threatened Species (IUCN 2008), and is listed in CITES Appendix I (UNEP-WCMC 2008). The species is poorly known because of confusion with Bryde's whales and unpredictable distribution patterns, such that it may be common in an area for several years and then seemingly disappear (Schilling et al. 1992; Jefferson et al. 2008). Two stocks are recognized in the North Atlantic, the Labrador Sea Stock and the Nova Scotia Stock; the latter has a distribution that includes continental shelf waters from the northeastern U.S. to areas south of Newfoundland (Waring et al. 2007). The best abundance estimate for the Nova Scotia stock is 207 (Waring et al. 2007). Cattanach et al. (1993) estimated a total of ~10,300 sei whales for the Northeast Atlantic.

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

The southern portion of the Nova Scotia stock's range includes the Gulf of Maine and Georges Bank during spring and summer (Waring et al. 2007). Peak sightings occur in spring and are concentrated along the eastern edge of Georges Bank into the Northeast Channel and the southwestern edge of Georges Bank (DoN 2005; Waring et al. 2007). Mitchell and Chapman (1977) suggested that this stock moves from spring feeding grounds on or near Georges Bank to the Scotian Shelf in June and July, eastward to Newfoundland and the Grand Banks in late summer, back to the Scotian Shelf in fall, and offshore and south in winter. Aerial surveys detected several sei whales near the continental shelf edge region south of Nantucket in the spring of 2001, and rare sei whales sightings occur from Cape Cod south to Florida in winter (Mitchell and Chapman 1977; Waring et al. 2007). During summer and fall, most sei whales sightings were in feeding grounds in the Bay of Fundy and on the Scotian Shelf; sightings south of Cape Cod were rare (Table B-6a in DoN 2005). Thus, sightings of sei whales in the proposed study area are not expected.

Fin whale (*Balaenoptera physalus*)

The fin whale is widely distributed in all the world's oceans (Gambell 1985b), but typically occurs in temperate and polar regions from 20° to 70° north and south of the equator (Perry et al. 1999). It is listed as ***Endangered*** under the U.S. ESA and on the 2008 IUCN Red List of Threatened Species (IUCN 2008), and is listed in CITES Appendix I (UNEP-WCMC 2008). The current best available population estimates are 2269 for the western North Atlantic (Waring et al. 2007) and 30,000 and 3200 for the Central/Northeastern and West Greenland, respectively (IWC 2007a), for a total of ~35,500 in the North Atlantic.

Fin whales eat euphausids and small fish (Borobia et al. 1995) and tend to concentrate in areas near thermal fronts or shallow areas with high topographic variation that help to mix and stratify the water column (Woodley and Gaskin 1996; Doniol-Valcroze et al. 2007). They can be found as individuals or groups of 2–7, but can form much larger feeding aggregations, sometimes with humpback and minke whales (Jefferson et al. 2008). Foraging fin whales reach mean dive depths and times of 98 m and 6.3 min, respectively, while recorded mean dive depths and times for non-foraging fin whales in the Pacific are 59 m and 4.2 min, respectively (Croll et al. 2001).

It is debatable whether all fin whales in the North Atlantic undergo annual migrations between warm water breeding grounds and cool water foraging areas, and current year-round monitoring of fin whale calls provide no evidence for such large-scale movements (Watkins et al. 2000). Fin whales are present in U.S. shelf waters during the winter, and are sighted more frequently than any other large whale at this time (DoN 2005). However, it is possible that fin whales undergo migrations into Canadian waters, open-ocean areas, and potentially subtropical or tropical regions (Waring et al. 2007). Clark (1995) reported a southward migration of whales in the fall from Newfoundland south past Bermuda, and into the West Indies.

Fin whales occur year-round in New England continental shelf waters (Waring et al. 2007). Winter sightings are most concentrated around Georges Bank and in Cape Cod Bay. During summer, most fin whale sightings are north of 40ºN, with concentrations in the Gulf of Maine, Great South Channel, and Georges Basin, and smaller numbers on the shelf south of there (Figure B-8a in DoN 2005). During fall, almost all fin whales move out of U.S. waters to feeding grounds in the Bay of Fundy and on the Scotian Shelf or remain at Stellwagen Bank and Murray Basin (Figure B-8a in DoN 2005), or begin a southward migration (Clark 1995).

Blue whale (*Balaenoptera musculus*)

The blue whale has a cosmopolitan distribution, and tends to be pelagic, only coming nearshore to feed and possibly to breed (Jefferson et al. 2008). It is listed as ***Endangered*** under the U.S. ESA and on the 2008 IUCN Red List of Threatened Species (IUCN 2008), and is listed in CITES Appendix I (UNEP-WCMC 2008). All blue whale populations have been exploited commercially, and many have been severely depleted as a result. The worldwide population has been estimated at 15,000, with 10,000 in the Southern Hemisphere (Gambell 1976), 3500 in the North Pacific, and up to 1400 in the North Atlantic (NMFS 1998).

In the western North Atlantic, the distribution of the blue whale extends as far north as Davis Strait and Baffin Bay (Sears 2002). Little is known about the movements and wintering grounds of the stocks (Mizroch et al. 1984). Two strandings of blue whales have been reported from the Gulf of Mexico (Baughman 1946; Lowery 1974 *in* Sears and Calambokidis 2002). The acoustic detection of blue whale, using the U.S. Navy's Sound Surveillance System (SOSUS) program, has tracked blue whales throughout most of the North Atlantic, including deep waters east of the U.S. Atlantic Exclusive Economic Zone (EEZ) and subtropical waters north of the West Indies (Clark 1995).

Wenzel et al. (1988) reported the occurrence of three blue whales in the Gulf of Maine in 1986 and 1987, which were the only reports of blue whales in shelf waters from Cape Hatteras to Nova Scotia, where sighting coverage was intensive since 1979, and suggested that it is unlikely that blue whales occur regularly in the shelf waters off the U.S. east coast. Waring et al. (2007) suggested that "the blue whale is best considered as an occasional visitor in U.S. Atlantic Exclusive Economic Zone (EEZ) waters". Sightings of blue whales in the proposed study are not expected.

Odontocetes

Sperm Whale (*Physeter macrocephalus*)

The sperm whale is the largest of the toothed whales, with an extensive worldwide distribution (Jefferson et al. 2008). This species is listed as ***Endangered*** under the ESA, but on a worldwide basis it is abundant and not biologically endangered. It is listed as ***Vulnerable*** on the 2008 IUCN Red List of Threatened Species (IUCN 2008) and is listed in CITES Appendix I (UNEP-WCMC 2008). Rice (1989) estimated the North Atlantic population at ~190,000, whereas Whitehead (2002) estimated the population of the Iceland-Faeroes area, the area to the northeast of it, and the U.S east coast at 13,190.

Sperm whales range as far north and south as the edges of the polar pack ice, although they are most abundant in tropical and temperate waters where temperatures are >15ºC (Jefferson et al. 2008). Sperm whale distribution and relative abundance can vary in response to prey availability, most notably mesopelagic and benthic squid (Jaquet and Gendron 2002). Sperm whales undertake some of the deepest-known dives for the longest durations among cetaceans. They can dive as deep as ~2 km and possibly deeper on rare occasions, for periods of over 1 h; however, most of their foraging occurs at depths of ~300–800 m during dives ranging 30–45 min (Whitehead 2003). Distribution of sperm whales can also be linked to social structure. Sperm whales occur singly (older males) or in groups, with a mean group size of 20–30 (Whitehead 2003). Groups of adult females and juveniles generally occur in warm waters, whereas males are commonly alone or in same-sex aggregations of 10–30 males, often occurring in higher latitudes outside of the breeding season (Letteval et al. 2002; Whitehead 2003).

In the NWA, sperm whales generally occur in deep water along the continental shelf break from Virginia to Georges Bank and along the northern edge of the Gulf Stream (Waring et al. 2001). Shelf edge, oceanic waters, seamounts, and canyon shelf edges are also predicted habitats of sperm whales in the NWA (Waring et al. 2001). Off the eastern U.S. coast, they are also known to concentrate in regions with well-developed temperature gradients, such as along the edges of the Gulf Stream and warm core rings, which may aggregate their primary prey, squid (Jaquet 1996). Sperm whales appear to have a well-defined seasonal cycle in the NWA. In winter, most historical records are in waters east and northeast of Cape Hatteras, with few animals north of 40ºN; in spring, they shift the center of their distribution northward to areas east of Delaware and Virginia, but they are widespread throughout the central area of the MAB and southern tip of Georges Bank. During summer, they expand their spring distribution to include areas east and north of Georges Bank, the Northeast Channel, and the continental shelf south of New England (inshore of 100 m deep). By fall, sperm whales are most common south of New England on the continental shelf but also along the shelf edge in the MAB (Watkins et al. 2007). Based on mapping of sperm whale records in the NWA, it appears that sperm whales generally do not occur north of 40ºN in fall and winter and, for all seasons, sperm whales tend to occur in deep water and over or beyond the continental slope (DoN 2005). Because of the sperm whale's preference for deep, offshore waters, sightings of sperm whales in the proposed study area are not expected.

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

Pygmy and dwarf sperm whales are distributed widely throughout tropical and temperate seas, but their precise distributions are not well known as most information on these species comes from strandings (Jefferson et al. 2008). They are difficult to sight at sea, perhaps because of their avoidance reactions to ships and behavior changes in relation to survey aircraft (Würsig et al. 1998). Additionally, the two species are difficult to distinguish from one another when sighted (Jefferson et al. 2008). During sighting surveys and, hence, in population and density estimates, the two species are most often categorized together as *Kogia* spp. (Waring et al. 2007). Abundance estimates for these largely offshore species in the NWA are not available.

Both species inhabit deep waters along the continental shelf and slope, where they feed mainly on various species of squid, crustaceans, and fish (McAlpine et al. 1997; Reeves et al. 1999c; McAlpine 2002). Several studies have suggested that pygmy sperm whales live mostly beyond the continental shelf edge, whereas dwarf sperm whales tend to occur closer to shore, often over the continental shelf (Rice 1998; Wang et al. 2002; MacLeod et al. 2004b). Barros et al. (1998), on the other hand, suggested that dwarf sperm whales might be more pelagic and dive deeper than pygmy sperm whales. Another suggestion is that the pygmy sperm whale is more temperate, and the dwarf sperm whale more tropical, based at least partially on live sightings at sea from a large database from the ETP (Wade and Gerrodette 1993).

Although both species have often been sighted alone, pygmy and dwarf sperm whales occur in groups of up to 6 and 10, respectively (Caldwell and Caldwell 1989). In the Gulf of California, median dive time for dwarf or unidentified sperm whales was 8.6 min and median surface time was 1.2 min, and dives of up to 25 min and surface times up to 3 min were common (J. Barlow, pers. comm. *in* Willis and Baird 1998).

In the NWA, both species are thought to occur as far north as the Canadian east coast, with the pygmy sperm whale ranging as far as southern Labrador; both species prefer offshore waters (Jefferson et al. 2008. Between 1999 and 2003, 125 pygmy and 37 dwarf sperm whales strandings were recorded from Nova Scotia to Puerto Rico (Waring et al. 2007), mostly off the southeastern U.S. coast. Previous stranding records during 1990–1998 also indicate that pygmy and dwarf sperm whale strandings occur more commonly along the coast from North Carolina to Florida (194 and 43 strandings, respectively) than along the coast of the northeastern states (21 and 3 strandings, respectively; Barros et al. 1998). Sightings of dwarf or pygmy sperm whales in the proposed study area are not expected.

Cuvier's Beaked Whale (*Ziphius cavirostris*)

Cuvier's beaked whale is probably the most widespread of the beaked whales, although it is not found in polar waters (Jefferson et al. 2008). It is occasionally observed at sea and is mostly known from strandings. Its inconspicuous blows, deep-diving behavior, and tendency to avoid vessels all help to explain the infrequent sightings (Barlow and Gisiner 2006). Cuvier's beaked whale is not listed under the ESA, but the Western North Atlantic Stock is considered a strategic stock because of uncertainty regarding stock size and evidence of human-induced mortality and serious injury associated with acoustic activities (Waring et al. 2007). Abundance estimates for this largely offshore species in the NWA are not available.

Cuvier's beaked whale is an offshore, deep-diving species that feeds almost exclusively on large-bodied squid (MacLeod et al. 2003). Deep dives last a median duration of 28.6 min followed by surfacings lasting a median duration of 126 s (MacLeod and D'Amico 2006). Adult males of this species usually travel alone, but these whales can be seen in groups of up to 15, with a mean group size of 2.3 (MacLeod and D'Amico 2006).

In the NWA, Cuvier's beaked whales have stranded and been sighted as far north as the Nova Scotian shelf and occur most commonly from Massachusetts to Florida (MacLeod et al. 2006). Most sightings in the NWA occur in late spring or summer, particularly along the continental shelf edge in the mid-Atlantic region (Waring et al. 2001, 2007). Mapping of combined beaked whale sightings in the NWA suggests that beaked whales are rare in winter and fall, uncommon in spring, and abundant in summer in waters north of Virginia, off the shelf break and over the continental slope and areas of high relief (DoN 2005). Sightings of Cuvier's beaked whales in the proposed study area are not expected. .

Northern bottlenose whale (*Hyperoodon ampullatus*)

Northern bottlenose whales are considered extremely uncommon within waters of the U.S. Atlantic EEZ, but have two primary areas of known concentration in Canadian waters: "The Gully" just north of Sable Island, Nova Scotia, and Davis Strait off northern Labrador (Reeves et al. 1993; Waring et al. 2007). They range from the NWA off New England to subarctic waters, with only two sightings made in 1993 and 1996 along the southern edge of Georges Bank (MacLeod and D'Amico 2006; Waring et al. 2007). Abundance estimates for this largely offshore species in the NWA are not available, although there are ~40,000 bottlenose whales estimated in the Northeast Atlantic (NAMMCO 1995:77).

Northern bottlenose whales are deep divers, and animals tagged off Nova Scotia dove every ~80 min to over 800 m, with a maximum dive depth of 1453 m (Hooker and Baird 1999). They forage primarily on large-bodied squid (MacLeod et al. 2003) and travel in groups of 1–22 (average 3.6) that may consist of individuals of different age and sex classes (MacLeod and D'Amico 2006).

Sightings of northern bottlenose whales in the proposed study area are not expected.

Mesoplodon spp.

Four species of beaked whales from the genus *Mesoplodon* occur in the NWA, known almost entirely from stranding records: True's beaked whale (*M. mirus*), Gervais' beaked whale (*M. europaeus*), Sowerby's beaked whale (*M. bidens*), and Blainville's beaked whale (*M. densirostris*). The cryptic behavior, small group sizes, and short surface durations of these species make them difficult to observe and identify at sea, and stock structure for each of these species is currently unknown (MacLeod 2000; Waring et al. 2007; Jefferson et al. 2008). *Mesoplodon* spp. are not listed under the ESA, but they are considered as a cumulative strategic stock because of uncertainty regarding stock size and evidence of human induced mortality and serious injury associated with acoustic activities (Waring et al. 2007). The best abundance estimate for grouped beaked whales (*Ziphius* and *Mesoplodon* spp.) off the U.S. east coast is 3513 animals, including 2839 animals from the northern U.S. Atlantic (Waring et al. 2007). Abundance estimates for these largely offshore species in the NWA are not available.

The different mesoplodont species are difficult to distinguish in the field, and are most often categorized as *Mesoplodon* spp. during sighting surveys, and therefore in density and population estimates. Almost everything that is known regarding most of the species has come from stranded animals (Pitman 2002). They are all thought to be deep-water animals (e.g., Davis et al. 1998) that tend to inhabit shelf-edge habitat associated with underwater canyons, and are only rarely seen over the continental shelf (Waring et al. 2001). Typical group sizes are 1–6 (Pitman 2002). Based on limited information, *Mesoplodon* spp. appear to feed on mesopelagic (200–1000 m) squid and fish (Mead 1989b).

True's Beaked Whale (Mesoplodon mirus).—In the North Atlantic, True's beaked whale occurs from Nova Scotia and Ireland south to Florida, the Bahamas, and the Canary Islands (Rice 1998). Carwardine (1995) suggested that this species could be associated with the Gulf Stream. Group size is up to three (Jefferson et al. 2008).

Gervais' Beaked Whale (M. europaeus).—Gervais' beaked whale is mainly oceanic, and occurs in tropical and warmer temperate waters of the Atlantic Ocean from Ireland to southeast Brazil (MacLeod et al. 2006; Jefferson et al. 2008). Strandings are thought to be associated with calving, which could take place in shallow water; pregnant females or those with calves have stranded in May, June, and August in the southeastern U.S. and Gulf of Mexico, indicating a spring–summer calving period (Würsig et al. 2000).

Gervais' beaked whale is much more common in the western Atlantic (40 strandings on the U.S east coast) than in the eastern Atlantic (2 records), and off the U.S. east coast, it occurs from Cape Cod Bay, Massachusetts (Moore et al. 2004) to Florida, with a few records in the Gulf of Mexico (Mead 1989b).

Sowerby's Beaked Whale (M. bidens).—Sowerby's beaked whale occurs in cold temperate waters of the North Atlantic (Mead 1989b) from the Labrador Sea to the Norwegian Sea, and south to New England, the Azores, and Madeira; a stranding on the west coast of Florida is thought to be a stray (MacLeod et al. 2006). Off the coast of Nova Scotia, Sowerby's beaked whales observed during 1997 and 1998 in water depths 550–1500 m were in groups of 3–10, and dives were 12–28 min in duration (Hooker and Baird 1999).

Blainville's Beaked Whale (M. densirostris).—Blainville's beaked whale is the *Mesoplodon* species with the widest distribution throughout the world in tropical and warm temperate waters (Mead 1989b). Occasional occurrences in cooler, higher-latitude waters are presumably related to warm-water incursions such as the Gulf Stream (Reeves et al. 2002).

Detailed studies in the Bahamas indicated that Blainville's beaked whales prefer moderate-depth waters of 200–1000 m (Jefferson et al. 2008). The most commonly observed group size for this species is 1–2, with a maximum of 9 off Hawaii (Baird et al. 2004; Jefferson et al. 2008). MacLeod and D'Amico (2006) reported a mean group size of 3.5 (n = 31), and Ritter and Brederlau (1999) reported a mean group size of 3.4. Two Blainville's beaked whales tagged off Hawaii made long (>50 min), deep (>800 m; maximum 1408 m) dives at ~2-h intervals, often alternating with several shorter dives to 100–200 m or <50 m, or numerous "inter-ventilation" dives to 2–4 m (Baird et al. 2006).

In the western North Atlantic, Blainville's beaked whale is found from Nova Scotia to Florida, the Bahamas, and the Gulf of Mexico (Würsig et al. 2000). Mead (1989b) suggested that the Nova Scotia records represented strays from Gulf Stream waters.

Sightings of *Mesoplodon* spp. in the proposed study area are not expected.

Bottlenose dolphin (*Tursiops truncatus*)

The bottlenose dolphin is distributed almost worldwide in temperate and tropical waters. In the Northwest Atlantic, it occurs from Nova Scotia to Florida, the Gulf of Mexico and the Caribbean, and south to Brazil (Würsig et al. 2000). There are two morphologically and genetically distinct bottlenose dolphin morphotypes: a shallow-water form mainly found in coastal waters, and a deep-water form mainly found in oceanic waters (Duffield et al. 1983; Mead and Potter 1995; Hoelzel et al. 1998; Walker et al. 1999). As well as inhabiting different areas, these forms differ in their diving abilities (Klatsky 2004) and prey types (Mead and Potter 1995). Although not listed as threatened or endangered under the U.S. ESA, the western North Atlantic coastal migratory bottlenose dolphin stock is listed as ***depleted*** under the MMPA (NMFS 1993) and the seven currently recognized management units are considered strategic stocks (Waring et al. 2007). The best estimate for the western North Atlantic offshore stock is 81,588, and the sum of the estimates for the coastal management units is 43,951 (Waring et al. 2007)

Bottlenose dolphins occur in groups of 2–15, but can be observed offshore in groups of hundreds (Shane et al. 1986; Jefferson et al. 2008). They have a fluid and dynamic social organization, and group sizes are associated with habitat complexity and water depth; shallow-water areas tend to have smaller group sizes than open or pelagic regions (Shane et al. 1986; Connor et al. 2000). Although often seen in coastal areas, bottlenose dolphins can dive to depths up to 535 m for periods up to 12 min (Schreer and Kovacs 1997).

There are regional and seasonal differences in the distribution of the offshore and coastal forms of bottlenose dolphins off the U.S. east coast. Evidence of year-round or seasonal residents and migratory groups exist for the coastal form of bottlenose dolphins, with the so-called "northern migratory management unit" occurring north of Cape Hatteras to New Jersey, but only during summer and in waters <25 m deep (Waring et al. 2007). For all other management units and during other seasons, it is unlikely that coastal forms of bottlenose dolphins would occur near the proposed study area. The offshore form appears to be most abundant along the shelf break and is differentiated from the coastal form by occurring in waters typically >40 m deep (Waring et al. 2007). Bottlenose dolphin records in the NWA suggest that they generally can occur year-round from the continental shelf to deeper waters over the abyssal plain, from the Scotian Shelf to North Carolina (DoN 2005).

Pantropical Spotted Dolphin (*Stenella attenuata*)

As its name indicates, the pantropical spotted dolphin can be found throughout tropical oceans of the world (Waring et al. 2007). In the western North Atlantic, it generally occurs from North Carolina to the West Indies and down to the equator (Würsig et al. 2000), although there have been a few sightings at the southern edge of Georges Bank (Waring et al. 2007). There are two forms of pantropical spotted dolphin, coastal and offshore forms, although the coastal form occurs mainly in the eastern tropical Pacific (Jefferson et al. 2008). The best estimate for the population off the U.S. east coast is 4439 (Waring et al. 2007). Abundance estimates for this largely offshore species in the Northwest Atlantic are not available.

Pantropical spotted dolphins are usually pelagic, although they occur close to shore where water near the coast is deep (Jefferson et al. 2008). They extremely gregarious, forming schools usually numbering <100 for the coastal form and often in the thousands for the offshore form (Jefferson et al. 2008).

These large aggregations contain smaller groups that can consist of only adult females with their young, only juveniles, or only adult males (Perrin and Hohn 1994). Baird et al. (2001) found that the coastal form of this species in Hawaii dove deeper at night (mean of 57 m, maximum 213 m) than during the day (mean of 13 m, maximum 122 m).

Sightings of pantropical spotted dolphins in the proposed study area are not expected.

Atlantic spotted dolphin (*Stenella frontalis*)

The Atlantic spotted dolphin is distributed in tropical and warm temperate waters of the western North Atlantic (Leatherwood et al. 1976). In the western Atlantic, its distribution extends from southern New England, south to the Gulf of Mexico, the Caribbean Sea, Venezuela, and Brazil (Leatherwood et al. 1976; Perrin et al. 1994a; Rice 1998). There are two forms of Atlantic spotted dolphin, a large, heavily spotted coastal form that is usually found on the shelf, and a smaller and less spotted offshore form (Waring et al. 2007). The best estimate of abundance for the population off the U.S. east coast is 50,978 (Waring et al. 2007).

The Atlantic spotted dolphin can be seen in groups of up to 50 or more, but coastal groups usually consist of 5–15 (Jefferson et al. 2008). Davis et al. (1996) found that most dives of Atlantic spotted dolphins in the Gulf of Mexico were shallow and of short duration, regardless of the time of day. Spotted dolphins usually dove to depths of 4 to <30 m, and the deepest dives recorded were to 40–60 m. Most of the dives were less than 2 min in duration (Davis et al. 1996).

During summer, Atlantic spotted dolphins are sighted in shelf waters south of Chesapeake Bay, and near the continental shelf edge, on the slope, and offshore north of there (Waring et al. 2007). During fall, very few Atlantic spotted dolphins occur north of New Jersey (Fig. B-15a in DoN 2005).

Spinner dolphin (*Stenella longirostris*)

The spinner dolphin is pantropical in distribution, with a range nearly identical to that of the pantropical spotted dolphin, including oceanic tropical and sub-tropical waters between 40ºN and 40ºS (Jefferson et al. 2008). There is no estimate for numbers of spinner dolphins off the U.S. east coast because it has been seen only rarely in surveys.

Spinner dolphins are extremely gregarious, and usually form large schools when in the open sea and small ones in coastal waters (Perrin and Gilpatrick 1994). Spinner dolphins can be seen in groups of 30 to hundreds or even thousands (Würsig et al. 2000). They often travel in mixed-groups with pantropical spotted dolphins and other species (Perrin 2002).

The distribution of spinner dolphins in the Atlantic is poorly known, but they are thought to occur in deep waters along most of the U.S. coast; sightings off the northeast U.S. coast have occurred exclusively in offshore waters >2000 m (Waring et al. 2007). Thus, sightings of spinner dolphins in the proposed study area are not expected.

Striped dolphin (*Stenella attenuata*)

The striped dolphin has a cosmopolitan distribution in tropical to warm temperate waters (Perrin et al. 1994b). In the western North Atlantic, this species occurs from Nova Scotia to the Gulf of Mexico and south to Brazil (Würsig et al. 2000). The best abundance estimate for the striped dolphin off the U.S. east coast is 94,462 (Waring et al. 2007).

Striped dolphins are primarily pelagic, apparently preferring waters offshore from the continental shelf and typically over the continental slope in waters associated with upwelling or convergence zones (Au and Perryman 1985). Striped dolphin group sizes are typically several dozen to 500, though groups of thousands sometimes form (Jefferson et al. 2008). School composition varies and consists of adults, juveniles, or both adults and juveniles (Perrin et al. 1994b). Their breeding season has two peaks, one in the summer and one in the winter (Boyd et al. 1999). Striped dolphins are believed to be capable of diving to depths of 200–700 m based on stomach content analyses (Archer and Perrin 1999).

Off the northeastern U.S. coast, striped dolphins occur along the continental shelf edge and over the continental slope from Cape Hatteras to the southern edge of Georges Bank (Waring et al. 2007). In all seasons, striped dolphin sightings have been centered along the 1000-m depth contour, and sightings have been associated with the north edge of the Gulf Stream and warm core rings (Waring et al. 2007).

Short-beaked common dolphin (*Delphis delphis*)

The common dolphin is one of the most widely distributed cetaceans and occurs in temperate, tropical, and subtropical regions (Jefferson et al. 2008). There are two species of common dolphin: the long- and short-beaked common dolphins. However, the long-beaked common dolphin is much less abundant, and the short-beaked common dolphin is most likely the only species that would be encountered in the NWA. The best estimate of abundance for short-beaked common dolphins off the U.S. east coast is 120,743 (Waring et al. 2007).

Groups of short-beaked common dolphins can range from several dozen to over 10,000, and they are typically fast-moving with many aerial behaviors such as jumping and bow-riding (Jefferson et al. 2008). They can occupy a variety of habitats, but in the northeastern U.S., short-beaked common dolphins are most abundant within a broad band of waters 100–2000 m deep, paralleling the continental slope from 35ºN to the northeast edge of Georges Bank (Selzer and Payne 1988). They are also often associated with features of the Gulf Stream (Hamazaki 2002).

Short-beaked common dolphins occur from Cape Hatteras to Georges Bank during mid-January to May, move onto Georges Bank and the Scotian Shelf during mid-summer and fall, and have been observed in large aggregations on Georges Bank in fall (Selzer and Payne 1988; Waring et al. 2007). Mass strandings of common dolphins occurred on Massachusetts beaches from at least 2001 to 2006, including four separate events in 2005 (Waring et al. 2007).

White-beaked dolphin (*Lagenorhynchus albirostris*)

The white-beaked dolphin is widely distributed in cold temperature and subarctic North Atlantic waters (Reeves et al. 1999a), often occurring to the edge of the arctic pack ice (Carwardine 1995). It occurs in immediate offshore waters of the east coast of the North America, from Labrador to Massachusetts (Rice 1998). Off the northeastern U.S. coast, white-beaked dolphins are mainly found in the western Gulf of Maine and around Cape Cod (CETAP 1982 *in* Waring et al. 2007). The best estimate of abundance for white-beaked dolphins off the U.S. east coast is 2003 (Waring et al. 2007). Reeves et al. (1999a) estimated that there were ~high tens to low hundreds of thousands of white-beaked dolphins in the North Atlantic.

White-beaked dolphins are found widely over the continental shelf, especially along the shelf edge (Carwardine 1995). They usually occur in groups of <30, with occasional groups of several hundred or even thousands (Jefferson et al. 2008). While feeding, white-beaked dolphins are sometimes associated with large whales such as fin or humpback whales, but also with smaller cetaceans including pilot and killer whales, as well as bottlenose, white-sided, and common dolphins (Jefferson et al. 1993).

White-beaked dolphins have been observed in shallow, coastal waters near Cape Cod during Cetacean & Turtle Assessment Program (CETAP) surveys (Lien et al. 2001). In the 1970s, white-beaked dolphins were found primarily over the continental shelf of the Gulf of Maine and Georges Bank, but were apparently replaced by Atlantic white-sided dolphins as a result of shifts in prey species (Kenney et al. 1996). Mapping of historical records suggests that white-beaked dolphins occur primarily over the continental shelf north of Georges Bank in summer (DoN 2005).

Sightings of white-beaked dolphins in the proposed study area are not expected.

Atlantic white-sided dolphin (*Lagenorhynchus acutus*)

The Atlantic white-sided dolphin occurs in cold temperate to subpolar waters of the North Atlantic in deep continental shelf and slope waters (Jefferson et al. 2008), and concentrates in areas with high seafloor relief (Reeves et al. 2002). In the western North Atlantic it ranges from Labrador and southern Greenland to ~38ºN (Jefferson et al. 2008). The best abundance estimate for Atlantic white-sided dolphins off the U.S. east coast is 63,368 (Waring et al. 2007). Reeves et al. (1999b) estimated that there were ~tens to low hundreds of thousands white-sided dolphins in the North Atlantic.

Atlantic white-sided dolphins apparently replaced white-beaked dolphins on the continental shelf of the Gulf of Maine and Georges Bank, potentially as a result of increases in sandlance and declines in herring (Kenney et al. 1996). The Atlantic white-sided dolphin is gregarious; group size in New England waters is 2–2500 with a mean of 52.4 (Weinrich et al. 2001).

There are seasonal shifts in Atlantic white-sided dolphin distribution off the northeastern U.S. coast, with low numbers in winter from Georges Basin to Jeffrey's Ledge and very high numbers in spring in the Gulf of Maine. In summer, Atlantic white-sided dolphins are distributed northward from south of Cape Cod with the highest numbers from Cape Cod north to the lower Bay of Fundy, and in fall, the distribution is similar with lower numbers (Fig. B-21a *in* DoN 2005).

Risso's dolphin (*Grampus griseus*)

Risso's dolphin is primarily a tropical and temperate species distributed worldwide between 60ºN and 60ºS, where surface water temperatures are ~10ºC (Kruse et al. 1999). In the western Atlantic Ocean, this species is distributed from Newfoundland to Brazil (Kruse et al. 1999). The best abundance estimate for Risso's dolphin off the U.S. east coast is 20,479, including 15,053 from the northern U.S. Atlantic (Waring et al. 2007).

In the northern Gulf of Mexico, Risso's dolphin usually occurs over steeper sections of the upper continental slope (Baumgartner 1997) in waters 150–2000 m deep (Davis et al. 1998). In Monterey Bay, California, it is most numerous where there is steep bottom topography (Kruse et al. 1999). Risso's dolphin occurs individually or in small to moderate-sized groups of 10–100, although groups of up to 4000 have been reported (Jefferson et al. 2008). Dives have been recorded to a maximum depth of 600 m (DiGiovanni et al. 2005) with dive times up to 30 min (Jefferson et al. 2008).

Off the northeast U.S. coast during spring, summer, and autumn, Risso's dolphins are distributed along the continental shelf edge and occur from Cape Hatteras to Georges Bank, but they range around the MAB and into oceanic waters during the winter (Waring et al. 2007). Mapping of Risso's dolphin sightings off the U.S. east coast suggests that they could occur year-round from the Scotian Shelf to the coast of the southeastern U.S. in waters extending from the continental shelf to the continental rise (DoN 2005). The greatest occurrences of Risso's dolphins occur off New Jersey, near the continental slope, in fall (DoN 2005).

False killer whale (*Pseudorca crassidens*)

The false killer whale is found worldwide in tropical and temperate waters generally between 50ºN and 50ºS (Odell and McClune 1999). It is widely distributed, but not abundant anywhere (Carwardine 1995). In the western Atlantic, it occurs from Maryland to Argentina (Rice 1998). The false killer whale is not included in the 2007 NMFS U.S. Atlantic Stock Assessment. Very few false killer whales were sighted off the U.S. northeast coast in the numerous surveys mapped by DON (2005).

False killer whales generally inhabit deep, offshore waters, but sometimes are found over the continental shelf and occasionally move into very shallow water (Jefferson et al. 2008). False killer whales are gregarious and form strong social bonds, as is evident from their propensity to strand en masse (Baird 2002). They travel in groups of 20–100 (Baird 2002), although groups of several hundred are sometimes observed (Odell and McClune 1999). Recently-stranded groups ranged from 28 to over 1000 animals (Baird 2002).

Sightings of false killer whales in the proposed study area are not expected.

Killer whale (*Orcinus orca*)

The killer whale is cosmopolitan and globally fairly abundant; it has been observed in all oceans of the world (Ford 2002). It is very common in temperate waters, and also frequents tropical waters (Heyning and Dahlheim 1988). High densities of the species occur in high latitudes, especially in areas where prey is abundant. Killer whale movements generally appear to follow the distribution of their diverse prey, which includes marine mammals, fish, squid, and turtles. The greatest abundance is thought to occur within 800 km of major continents (Mitchell 1975). There is no population estimate for the killer whale off the U.S. east coast (Waring et al. 2007).

Killer whales appear to prefer coastal areas, but are also known to occur in deep water (Dahlheim and Heyning 1999). They are large and conspicuous, often traveling in close-knit matrilineal groups of a few to tens of individuals (Dahlheim and Heyning 1999). They have been reported to dive as deep as 264 m off British Columbia (Baird et al. 2005).

In the western North Atlantic, killer whales occur from the polar ice pack to Florida and the Gulf of Mexico (Würsig et al. 2000). Based on historical sightings and whaling records, killer whales apparently were most often found along the shelf break and offshore in the NWA (Katona et al. 1988). They are considered uncommon or rare in waters of the U.S. Atlantic EEZ; they only represented 0.1 % of all cetacean sightings (12 of 11,156 sightings) in surveys during 1978–1981 (CETAP 1982 *in* Waring et al. 2007). They are more common off New England in summer than in any other month, occurring nearshore and off the shelf break (Fig. B-24 *in* DoN 2005).

Long- and short-finned pilot whales (*Globicephala melas* and *G. macrorhynchus*)

There are two species of pilot whale, both of which could occur in the survey area. The long-finned pilot whale (*G. melas*) is distributed antitropically, whereas the short-finned pilot whale (*G. macrorhynchus*) is found in tropical and warm temperate waters (Olson and Reilly 2002). Their distributions apparently overlap. Water temperature appears to be the primary factor determining their distributions (Fullard et al. 2000). The two species are difficult to distinguish at sea, but their distributions are thought to have little overlap (Olson and Reilly 2002); off the mid-Atlantic U.S. coast is one of the locations where they do (Bernard and Reilly 1999). Because of the difficulty in distinguishing the two species, the best abundance estimate for both species off the U.S. east coast is 31,139 (Waring et al. 2007).

Pilot whales occur on the continental shelf break, in slope waters, and in areas of high topographic relief and have seasonal inshore/offshore movements coinciding with the abundance of their preferred prey, squid (Jefferson et al. 2008). Pilot whales are highly social, appear to live in stable female-based groups, and group sizes typically are 20–100, with some groups containing >1000 (Jefferson et al. 2008). Heide-Jørgensen et al. (2002) found that pilot whales outfitted with time-depth recorders dove to depths of up to 828 m, although most of their time was spent above depths of 7 m. Pilot whales are known to mass strand frequently (Olson and Reilly 2002). Pilot whales are often involved in relatively frequent mass strandings, and 2–168 pilot whales have stranded annually, either individually or in groups, along the eastern U.S. coast since at least 1980 (Waring et al. 2007).

In the NWA, pilot whales often occupy areas of high relief or submerged banks and associate with the Gulf Stream edge or thermal fronts along the continental shelf edge (Waring et al. 1992 *in* Waring et al. 2007). The ranges of the two species overlap in the shelf/shelf-edge and slope waters of the northeastern U.S. between New Jersey and Cape Hatteras, with long-finned pilot whales occurring to the north. During winter and early spring, long-finned pilot whales are distributed along the continental shelf edge off the northeast U.S. coast and in Cape Cod Bay, and in summer and fall also occur on Georges Bank, in the Gulf of Maine, and north into Canadian waters (Fig. B-25a in DoN 2005).

Harbor porpoise (*Phoecena phoecena*)

The harbor porpoise inhabits cool temperate to subarctic waters of the Northern Hemisphere (Jefferson et al. 2008). There could be four populations in the western North Atlantic: Gulf of Maine/Bay of Fundy, Gulf of St. Lawrence, Newfoundland, and Greenland (Gaskin 1984, 1992). Individuals found off the eastern U.S. coast likely would be almost exclusively from the Gulf of Maine/Bay of Fundy stock. The harbor porpoise is not listed as endangered or threatened under the ESA, but the Gulf of Maine/Bay of Fundy stock is considered a strategic stock because average annual human-related mortality and serious injury exceeds potential biological removal (Waring et al. 2007). The best estimate of abundance for the Gulf of Maine/Bay of Fundy Stock is 89,054 (Waring et al. 2007). Jefferson et al. (2008) estimated a total of ~500,000 harbor porpoises in the North Atlantic.

Harbor porpoises tend to remain in relatively cool waters, seldom being found in waters warmer than 17ºC, presumably because these temperatures are preferred by their primary prey, Atlantic herring (Read 1999). They prefer areas with coastal fronts or topographically generated upwellings, and generally occur on the continental shelf, but also have an offshore component to their distribution (Westgate et al. 1998; Read 1999). They make short dives that are generally less than 5 min, spend 3–7% of their time at the surface versus 33–60% in the upper 2 m of the water column, and average dive depths range from 14–41 m (Westgate et al. 1995).

In the NWA, harbor porpoises concentrate in the northern Gulf of Maine and southern Bay of Fundy from July to September, with a few sightings ranging as far south as the northern edge of Georges Bank (Waring et al. 2007). From October-December and April-June, harbor porpoises are dispersed and range from New Jersey to Maine, although there are lower densities at the northern and southern extremes (Waring et al. 2007). Most animals would be found over the continental shelf, but some are also encountered over deep waters (Westgate et al. 1998). From January to March, they concentrate farther south, from New Jersey to North Carolina, with lower densities occurring from New York to New Brunswick (Waring et al. 2007). Because of their more northerly distribution in summer and early fall, sightings of harbor porpoises in the proposed study area are not expected.

Pinnipeds

Harbor seal (*Phoca vitulina*)

Harbor seals are among the most widespread of pinnipeds, but they are primarily restricted to coastal regions (Jefferson et al. 2008). In the NWA, harbor seals are distributed from the eastern Canadian Arctic to southern New England and New York, with occasional occurrences in the Carolinas (Waring et al. 2007). Summing the estimates for several regions, the best abundance estimate for harbor seals off the U.S east coast is 99,340 (Waring et al. 2007).

Harbor seals occur in coastal waters and are rarely seen more than 20 km from shore; they often use bays, estuaries, and inlets, and sometimes follow anadromous prey upstream in coastal rivers (Baird 2001). They periodically haul out of the water; in New England, they typically haul out on rocky outcroppings and intertidal ledges (Schneider and Payne 1983; Payne and Selzer 1989). Most harbor seals haul out on land daily, although they can spend several days at sea feeding (Jefferson et al. 2008). Harbor seals can form large aggregations at haulout sites, sometimes co-existing with gray seals (Baird 2001). At sea, they are usually alone, but small groups occur and larger groups occur when prey is abundant (Jefferson et al. 2008). Over 50% of dives by harbor seals tagged in the Gulf of St. Lawrence were to depths <4 m, and the rest of the dives could be categorized into five types based on descriptive characteristics like dive depth, ascent and descent rates, and bottom time; the deepest dives average ~20 m (Lesage et al. 1999).

Harbor seals may occur year-round in the Gulf of Maine and New England waters (DoN 2005; Waring et al. 2007). From late September through late May, they occur predominantly south of Maine, with 75% of counted seals in New England waters hauling out on Cape Cod and Nantucket Island (Schneider and Payne 1983; Payne and Selzer 1989). In summer, almost all harbor seals are found north of ~43º, in coastal waters of central and northern Maine and the Bay of Fundy (Fig. B-27a in DoN 2005).

Because of the more northerly distribution of harbor seals during summer, and their preference for coastal areas, few if any harbor seals are expected to be encountered during the proposed study.

Gray seal (*Halichoerus grypus*)

The gray seal is found in cold temperate to sub-arctic waters of the North Atlantic, and has three major populations, in eastern Canada, northwestern Europe, and the Baltic Sea (Jefferson et al. 2008). The western North Atlantic stock, considered as the same population as the eastern Canadian population, ranges from New England to Labrador (Lesage and Hammill 2001; Waring et al. 2007). Hammill (2005) estimated a total population of 52,500 gray seals for the NWA, including the Gulf of St. Lawrence and the Nova Scotia eastern shore.

The gray seal is primarily a coastal species, and foraging appears to be restricted to continental shelf regions (Lesage and Hammill 2001). Foraging gray seals tagged on Sable Island, Nova Scotia, nearly always remained within the 100-m isobath and mostly over offshore banks (Austin et al. 2006). There are two main breeding sites in the NWA where gray seals aggregate from December to February: Sable Island and in the southern Gulf of St. Lawrence. Gray seals disperse widely after breeding but return for a spring molt (Lesage and Hammill 2001).

After harbor seals, gray seals are the most commonly sighted seal in the northeastern U.S. (Waring et al. 2007). They range south along the east coast of the U.S., and strandings have occurred as far south as NC. Small numbers of gray seals were observed pupping on several isolated islands along the Maine coast and in Nantucket Sound in the mid-1980s (Katona et al. 1993). A year-round breeding population of ~400 animals on outer Cape Cod and Muskeget Island was documented in the late 1990s (Barlas 1999 *in* DoN 2005), and as many as 30 adult gray seals were reported at a haulout in New York waters (Hoover et al. 1999 *in* DoN 2005). Similar to harbor seals, grey seals are most common in the waters of Maine in winter and spring, and sighting records indicate that they occur only off northern Maine and in Canadian waters during summer and fall (Fig. 28a in DoN 2005). Thus, few if any gray seals are expected to occur in the proposed study at the time of the survey.

Harp seal (*Pagophilius groenlandicus*)

The harp seal has a widespread distribution in the Arctic and in cold waters of the North Atlantic (Jefferson et al. 2008). It is the most abundant seal in the North Atlantic, with most seals aggregating off the east coast of Newfoundland and Labrador to pup and breed; the remainder congregates in the Gulf of St. Lawrence (Lavigne and Kovacs 1988). DFO (2005) estimated a total of 5.9 million harp seals in these two areas; this is not considered a strategic stock by NMFS (Waring et al. 2007). This population estimate was updated to a total of 5.5 million in 2007 (DFO 2007).

Jefferson et al. (2008) indicate that vagrant harp seals reach as far south as New York. Sightings of harp seals off the U.S. east coast, from Maine to New Jersey, are rare but have been increasing in recent years, particularly from January to May (Harris et al. 2002; Harris and Gupta 2006; Waring et al. 2007). In fall, DoN (2005) predicted that harp seals may occasionally occur along the coast from southern Maine to Long Island. However, sightings of harp seals in the proposed study area are not expected.

Hooded seal (*Cystophora crisata*)

The hooded seal inhabits the Arctic and high latitudes of the North Atlantic, with four primary pupping areas, in the Gulf of St. Lawrence, northeast of Newfoundland, Davis Strait, and Greenland (Jefferson et al. 2008). Pupping and breeding occurs on pack ice in March (Waring et al. 2007). A total of 592,100 hooded seals are estimated in the western North Atlantic (ICES 2006).

Hooded seals appear to prefer deeper water and occur farther offshore than harp seals (Lavigne and Kovacs 1988). Although they tend to occur at high latitudes of the North Atlantic, hooded seals are highly migratory and known to wander widely, with animals beached on the U.S. east coast from New England to Florida and Puerto Rico (Waring et al. 2007; Jefferson et al. 2008). Occurrences of hooded seals tend to be from January-May in New England waters and summer or fall off the southeast U.S. coast (McAlpine et al. 1999; Harris et al. 2002; Waring et al. 2007). Sightings of hooded seals in the proposed study area are not expected.

V. TYPE OF INCIDENTAL TAKE AUTHORIZATION REQUESTED

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

Rice requests an IHA pursuant to Section 101 (a) (5) (D) of the Marine Mammal Protection Act (MMPA) for incidental take by harassment during its planned seismic survey in the NWA during August 2009.

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

VI. NUMBERS OF MARINE MAMMALS THAT MAY BE TAKEN

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

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

VII. ANTICIPATED IMPACT ON SPECIES OR STOCKS

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

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

- First we summarize the potential impacts on marine mammals of airgun operations, as called for in § VII. A more comprehensive review of the relevant background information appears in Appendix A of the Environmental Assessment (EA).
- Then we discuss the potential impacts of operations by the echosounders.
- Finally, we estimate the numbers of marine mammals that might be affected by the proposed activity in the NWA during August 2009. This section includes a description of the rationale for the estimates of the potential numbers of harassment "takes" during the planned survey, as called for in § VI.

(a) Summary of Potential Effects of Airgun Sounds

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

Tolerance

Numerous studies have shown that pulsed sounds from airguns are often readily detectable in the water at distances of many kilometers. For a brief summary of the characteristics of airgun pulses, see Appendix A. 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 proposed 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. 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 usually seem to be more tolerant of exposure to airgun pulses than are baleen whales. Given the relatively small and low-energy GI gun source planned for use in this project, mammals (and sea turtles) are expected to tolerate being closer to this source than would 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. Because of the intermittent nature and low duty cycle of seismic pulses, animals can emit and receive sounds in relatively quiet intervals between pulses. However, in some situations, multi-path arrivals and reverberation cause airgun sound to arrive for much or all of the interval between pulses (e.g., Simard et al. 2005; Clark and Gagnon 2006), which could mask calls.

Some baleen and toothed whales are known to continue calling in the presence of seismic pulses. 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; Smultea et al. 2004; Holst et al. 2005a,b, 2006). Among odontocetes, there has been one report that sperm whales cease calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994). However, more recent studies found that this species continued calling in the presence of seismic pulses (Madsen et al. 2002; Tyack et al. 2003; Smultea et al. 2004; Holst et al. 2006; Jochens et al. 2006, 2008). Dolphins and porpoises commonly are heard calling while airguns are operating (e.g., Gordon et al. 2004; Smultea et al. 2004; Holst et al. 2005a,b; Potter et al. 2007). The sounds important to small odontocetes are predominantly at much higher frequencies than are the dominant components of airgun sounds, thus limiting the potential for masking. In general, masking effects of seismic pulses are expected to be negligible, given the normally intermittent nature of seismic pulses and the relatively low source level of the GI guns to be used here. Masking effects on marine mammals are discussed further in Appendix A.

Disturbance Reactions

Disturbance includes a variety of effects, including subtle changes in behavior, more conspicuous changes in activities, and displacement. Based on NMFS (2001, p. 9293) and NRC (2005), we assume that simple exposure to sound, or brief reactions that do not disrupt behavioral patterns in a potentially significant manner, do not constitute harassment or "taking". By potentially significant, we mean "in a manner that might have deleterious effects to the well-being of individual marine mammals or their populations".

Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors (Richardson et al. 1995; Wartzok et al. 2004; Southall et al. 2007; Weilgart 2007). If a marine mammal does react briefly to an underwater sound by changing its behavior or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or population. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on individuals and populations could be significant (e.g., Lusseau and Bejder 2007; Weilgart 2007). Given the many uncertainties in predicting the quantity and types of impacts of noise on marine mammals, it is common practice to estimate how many mammals would be present within a particular distance of industrial activities and exposed to a particular level of industrial sound. In most cases, this approach likely overestimates the numbers of marine mammals that would be affected in some biologically-important manner.

The sound criteria used to estimate how many marine mammals might be disturbed to some biologically-important degree by a seismic program are based 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, small toothed whales, and sea otters. Most of those studies have concerned reactions to much larger airgun sources than 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, baleen whales exposed to strong noise pulses from airguns often react by deviating from their normal migration route and/or interrupting their feeding and moving away. In the cases of migrating gray and bowhead whales, the observed changes in behavior appeared to be of little or no biological consequence to the animals. They simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors.

Studies of gray, bowhead, and humpback whales have 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 to 14.5 km 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 studies summarized in Appendix A have shown that some species of baleen whales, notably bowhead and humpback whales, at times show strong avoidance at received levels lower than 160–170 dB re 1 μPa_{rms}. Reaction distances would be considerably smaller during the present project, in which the 160-dB radius is predicted to be $\leq$1 km (Table 1), as compared with several kilometers when a large array of airguns is operating.

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

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

Among wintering humpback whales off Angola (n = 52 useable groups), there were no significant differences in encounter rates (sightings/hr) when a 24-airgun array (3147 in^3 or 5085 in^3) was operating vs. silent (Weir 2008a). There was also no significant difference in the mean CPA of the humpback sightings when airguns were on vs. off (3050 m vs. 2700 m, respectively).

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

Results from *bowhead whales* show that responsiveness of baleen whales to seismic surveys can be quite variable depending on the activity (migrating vs. feeding) of the whales. Bowhead whales migrating west across the Alaskan Beaufort Sea in autumn, in particular, are unusually responsive, with substantial avoidance occurring out to distances of 20–30 km from a medium-sized airgun source, where received sound levels were on the order of 130 dB re 1 μPa_{rms} [Miller et al. 1999; Richardson et al. 1999; see Appendix A of EA]. However, more recent research on bowhead whales (Miller et al. 2005) corroborates earlier evidence that, during the summer feeding season, bowheads are not as sensitive to seismic sources. In summer, bowheads typically begin to show avoidance reactions at a received level of about 160–170 dB re 1 μPa_{rms} (Richardson et al. 1986; Ljungblad et al. 1988; Miller et al. 1999).

Reactions of migrating and feeding (but not wintering) *gray whales* to seismic surveys have been studied. Malme et al. (1986, 1988) studied the responses of feeding Eastern Pacific gray whales to pulses from a single 100 in^3 airgun off St. Lawrence Island in the northern Bering Sea. They estimated, based on small sample sizes, that 50% of feeding gray whales ceased feeding at an average received pressure level of 173 dB re 1 μPa on an (approximate) rms basis, and that 10% of feeding whales interrupted feeding at received levels of 163 dB. Those findings were generally consistent with the results of experiments conducted on larger numbers of gray whales that were migrating along the California coast, and with observations of Western Pacific gray whales feeding off Sakhalin Island, Russia (Johnson et al. 2007).

Various species of *Balaenoptera* (blue, sei, fin, and minke whales) have occasionally been reported in areas ensonified by airgun pulses. Sightings by observers on seismic vessels off the United Kingdom from 1997 to 2000 suggest that, at times of good sightability, numbers of rorquals seen are similar when airguns are shooting and not shooting (Stone 2003; Stone and Tasker 2006). Although individual species did not show any significant displacement in relation to seismic activity, all baleen whales combined were found to remain significantly further from the airguns during shooting compared with periods without shooting (Stone 2003; Stone and Tasker 2006). In a study off Nova Scotia, Moulton and Miller (2005) found little or no difference in sighting rates and initial sighting distances of balaenopterid whales when airguns were operating vs. silent. However, there were indications that these whales were more likely to be moving away when seen during airgun operations.

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). The Western Pacific gray whale population did not seem affected by a seismic survey in its feeding ground during a prior year (Johnson et al. 2007). 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 proposed GI guns are highly unlikely to result in prolonged effects.

Toothed Whales.—Little systematic information is available about reactions of toothed whales to sound pulses. Few studies similar to the more extensive baleen whale/seismic pulse work summarized above and (in more detail) in Appendix A of the EA have been reported for toothed whales. However, a systematic study on sperm whales has been done (Jochens and Biggs 2003; Tyack et al. 2003; Jochens et al. 2006; Miller et al. 2006). There is also an increasing amount of information about responses of various odontocetes to seismic surveys based on monitoring studies (e.g., Stone 2003; Smultea et al. 2004; Moulton and Miller 2005; Bain and Williams 2006; Holst et al. 2006; Stone and Tasker 2006; Potter et al. 2007; Hauser et al. 2008; Holst and Smultea 2008; Weir 2008a).

Seismic operators and marine mammal observers on seismic vessels regularly see dolphins and other small toothed whales near operating airgun arrays, but in general there is a tendency for most delphinids to show some avoidance of operating seismic vessels (e.g., Goold 1996a,b,c; Calambokidis and Osmek 1998; Stone 2003; Moulton and Miller 2005; Holst et al. 2006; Stone and Tasker 2006; Weir 2008a). Some dolphins seem to be attracted to the seismic vessel and floats, and some ride the bow wave of the seismic vessel even when large arrays of airguns are firing (e.g., Moulton and Miller 2005). Nonetheless, small toothed whales more often tend to head away, or to maintain a somewhat greater distance from the vessel, when a large array of airguns is operating than when it is silent (e.g., Stone and Tasker 2006; Weir 2008a). In most cases the avoidance radii for delphinids appear to be small, on the order of 1 km or less, and some individuals show no apparent avoidance.

Weir (2008b) noted that a group of short-finned pilot whales initially showed an avoidance response to ramp up of a large airgun array, but that this response was limited in time and space. Although the ramp-up procedure is a widely-used mitigation measure, it remains uncertain whether it is effective or not at alerting marine mammals and causing them to move away from seismic operations (Weir 2008b).

The beluga is a species that (at least at times) shows long-distance avoidance of seismic vessels. Aerial surveys conducted in the southeastern Beaufort Sea during summer found that sighting rates of beluga whales were significantly lower at distances 10–20 km compared with 20–30 km from an operating airgun array, and observers on seismic boats in that area rarely see belugas (Miller et al. 2005; Harris et al. 2007).

Captive bottlenose dolphins and beluga whales exhibited changes in behavior when exposed to strong pulsed sounds similar in duration to those typically used in seismic surveys (Finneran et al. 2000, 2002, 2005; Finneran and Schlundt 2004). However, the animals tolerated high received levels of sound (>200 dB re 1 $\mu\text{Pa}\cdot\text{m}_{\text{p–p}}$) before exhibiting aversive behaviors. For pooled data at 3, 10, and 20 kHz, sound exposure levels during sessions with 25, 50, and 75% altered behavior were 180, 190, and 199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$, respectively (Finneran and Schlundt 2004).

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

Most studies of sperm whales exposed to airgun sounds indicate that this species shows considerable tolerance of airgun pulses (e.g., Stone 2003; Moulton et al. 2005, 2006a; Jochens et al. 2006, 2008; Stone and Tasker 2006; Weir 2008a). In most cases, the whales do not show strong avoidance and continue to call (see Appendix A of EA for review). However, controlled exposure experiments in the Gulf of Mexico indicate that foraging behavior was altered upon exposure to airgun sound (Jochens et al. 2006, 2008). In the SWSS study, D-tags (Johnson and Tyack 2003) were used to record the movement and acoustic exposure of eight foraging sperm whales before, during, and after controlled sound exposures of airgun arrays in the Gulf of Mexico (Jochens et al. 2008). Whales were exposed to maximum received sound levels between 111 and 147 dB re 1 μPa_{rms} (131–164 dB re 1 μPa_{pk-pk}) at ranges of ~1.4–12.6 km from the sound source. Although the tagged whales showed no horizontal avoidance, some whales changed foraging behavior during full-array exposure (Jochens et al. 2008).

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

Odontocete reactions to large arrays of airguns are variable and, at least for delphinids and some porpoises (e.g., Dall's), seem to be confined to a smaller radius than has been observed for mysticetes (Appendix A). A ≥170 dB disturbance criterion (rather than ≥160 dB) is considered appropriate for delphinids (and pinnipeds), which tend to be less responsive than most other cetaceans. Thus, behavioral reactions of most odontocetes to the small GI gun source to be used here are expected to be very localized.

Pinnipeds.—In the event that any pinnipeds are encountered, they are not likely to show a strong avoidance reaction to the airgun array. Visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds, and only slight (if any) changes in behavior—see Appendix A. In the Beaufort Sea, some ringed seals avoided an area of 100 m to (at most) a few hundred meters around seismic vessels, but many seals remained within 100–200 m of the trackline as the operating airgun array passed by (e.g., Harris et al. 2001; Moulton and Lawson 2002; Miller et al. 2005a). Ringed seal sightings averaged somewhat farther away from the seismic vessel when the airguns were operating than when they were not, but the difference was small (Moulton and Lawson 2002). Similarly, in Puget Sound, sighting distances for harbor seals and California sea lions tended to be larger when airguns were operating (Calambokidis and Osmek 1998). Previous telemetry work suggests that avoidance and other behavioral reactions may be stronger than evident to date from visual studies (Thompson et al. 1998). Nonetheless, reactions are expected to be confined to relatively small distances and durations, with no long-term effects on pinniped individuals or populations. As for delphinids, a ≥170 dB disturbance criterion is considered appropriate for pinnipeds, which tend to be less responsive than many cetaceans.

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

Hearing Impairment and Other Physical Effects

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

- the 180-dB criterion for cetaceans is probably quite precautionary, i.e. lower than necessary to avoid temporary threshold shift (TTS), let alone permanent auditory injury, at least for delphinids and similar species;
- TTS is not injury and does not constitute "Level A harassment" in U.S. MMPA terminology.
- the minimum sound level necessary to cause permanent threshold shift (PTS) is higher, by a variable and generally unknown amount, than the level that induces barely-detectable TTS; 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. The actual PTS threshold is likely to be well above the level causing onset of TTS (Southall et al. 2007).

Recommendations for new science-based noise exposure criteria for marine mammals, frequency-weighting procedures, and related matters were published recently (Southall et al. 2007). Those recommendations have not, as of early 2009, been formally adopted by NMFS for use in regulatory processes and during mitigation programs associated with seismic surveys. However, some aspects of the recommendations have been taken into account in certain Environmental Impact Statements (EISs) and small-take authorizations. NMFS has indicated that it may issue new noise exposure criteria for marine mammals that account for the now-available scientific data on TTS, the expected offset between the TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors. Preliminary information about possible changes in the regulatory and mitigation requirements, and about the possible structure of new criteria, was given by Wieting (2004) and NMFS (2005).

Because of the small airgun source in this project (two GI guns totaling up to 90 in^3), along with the planned monitoring and mitigation measures, there is little likelihood that any marine mammals or sea turtles 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 GI guns (and other sound sources), and to avoid exposing them to sound pulses that might, at least in theory, cause hearing impairment (see § XI, Mitigation Measures). In addition, many cetaceans 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) prevent 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, 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 §XI and XIII). The following subsections discuss in somewhat more detail the possibilities of TTS, PTS, and non-auditory physical effects.

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

For toothed whales exposed to single short pulses, the TTS threshold appears to be, to a first approximation, a function of the energy content of the pulse (Finneran et al. 2002, 2005). Given the available data, the received energy level of a single seismic pulse (with no frequency weighting) might need to be ~186 dB re 1 $\mu Pa^2 \cdot s$ (i.e., 186 dB SEL or ~221–226 dB re 1 $\mu Pa \cdot m_{p-p}$) in order to produce brief, mild TTS[3]. Exposure to several strong seismic pulses that each have received levels near 175–180 dB SEL 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. The distances from the *Endeavor*'s GI guns at which the received energy level (per pulse, flat-weighted) would be expected to be ≥175–180 dB SEL are the distances shown in the 190 dB re 1 μPa_{rms} column in Table 1 (given that the rms level is ~10–15 dB higher than the SEL value for the same pulse). Seismic pulses with received energy levels ≥175–180 dB SEL (190 dB re 1 μPa_{rms}) are expected to be restricted to radii no more than 150 m around the two GI guns (Table 1). The specific radius depends on the depth of the water. For an odontocete closer to the surface, the maximum radius with ≥175–180 dB SEL or ≥190 dB re 1 μPa_{rms} would be smaller.

The above TTS information for odontocetes is derived from studies on the bottlenose dolphin and beluga. There is no published TTS information for other types of cetaceans. However, preliminary evidence from a harbor porpoise exposed to airgun sound suggests that its TTS threshold may have been lower (Lucke et al. 2007).

For baleen whales, there are no data, direct or indirect, on levels or properties of sound that are required to induce TTS. The frequencies to which baleen whales are most sensitive are lower than those to which odontocetes are most sensitive, and natural background noise levels at those low frequencies tend to be higher. As a result, auditory thresholds of baleen whales within their frequency band of best hearing are believed to be higher (less sensitive) than are those of odontocetes at their best frequencies (Clark and Ellison 2004). From this, it is suspected that received levels causing TTS onset may also be higher in baleen whales (Southall et al. 2007). In any event, no cases of TTS are expected given three considerations: (1) small size of the airgun source (two 45 in^2 GI guns);(2) the strong likelihood that baleen whales would avoid the approaching airguns (or vessel) before being exposed to levels high enough for TTS to occur; and (3) the mitigation measures that are planned.

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

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

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

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

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

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 could occur at a received sound level at least several decibels above that inducing mild TTS if the animal were exposed to strong sound pulses with rapid rise time—see Appendix A. Based on data from terrestrial mammals, a precautionary assumption is that the PTS threshold for impulse sounds (such as airgun pulses as received close to the source) is at least 6 dB higher than the TTS threshold on a peak-pressure basis, and probably >6 dB (Southall et al. 2007). On an SEL basis, Southall et al. (2007:441-4) estimated that received levels would need to exceed the TTS threshold by at least 15 dB for there to be risk of PTS. Thus, for cetaceans they estimate that the PTS threshold might be an M-weighted SEL (for the sequence of received pulses) of ~198 dB re 1 µPa^2·s (15 dB higher than the TTS threshold for an impulse). Additional assumptions had to be made to derive a corresponding estimate for pinnipeds, as the only available data on TTS-thresholds in pinnipeds pertain to non-impulse sound. Southall et al. (2007) estimate that the PTS threshold could be a cumulative M$_{pw}$-weighted SEL of ~186 dB re 1 µPa^2·s in the harbor seal exposed to impulse sound. The PTS threshold for the California sea lion and northern elephant seal would probably be higher, given the higher TTS thresholds in those species.

Southall et al. (2007) also noted that, regardless of the SEL, there is concern about the possibility of PTS if a cetacean or pinniped received one or more pulses with peak pressure exceeding 230 or 218 dB re 1 µPa, respectively. A peak pressure of 230 dB re 1 µPa (3.2 bar·m) would only be found within a few meters of the largest (600-in^3) airguns in most airgun arrays (Caldwell and Dragoset 2000). A peak pressure of 218 dB re 1 µPa could be received somewhat farther away; to estimate that specific distance, one would need to apply a model that accurately calculates peak pressures in the near-field around an array of airguns.

In the present project employing two GI guns, marine mammals are unlikely to be exposed to received levels of seismic pulses strong enough to cause TTS, as they would need to be quite close to the

GI guns for that to occur. Given the higher level of sound necessary to cause PTS, it is even less likely that PTS could occur. A mammal would not be exposed to more than one strong pulse unless it swam immediately alongside the GI guns for a period longer than the inter-pulse interval. Baleen whales generally avoid the immediate area around operating seismic vessels, as do some other marine mammals and sea turtles. The planned monitoring and mitigation measures, including visual monitoring and shut downs of the GI guns when mammals are seen within the safety or exclusion zone, will minimize the already-low 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, and other types of organ or tissue damage (Cox et al. 2006; Southall et al. 2007). Studies examining such effects are very limited. However, resonance (Gentry 2002) and direct noise-induced bubble formation (Crum et al. 2005) are not expected in the case of an impulsive source like an airgun array. If seismic surveys disrupt diving patterns of deep-diving species, this might perhaps result in bubble formation and a form of “the bends”, as speculated to occur in beaked whales exposed to sonar. However, there is no specific evidence of this upon exposure to airgun pulses.

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

Strandings and Mortality

Marine mammals close to underwater detonations of high explosives can be killed or severely injured, and the auditory organs are especially susceptible to injury (Ketten et al. 1993; Ketten 1995). However, explosives are no longer used for marine seismic research or commercial seismic surveys, and have been replaced entirely by airguns or related non-explosive pulse generators. Airgun pulses are less energetic and have slower rise times, and there is no specific evidence that they can cause serious injury, death, or stranding even in the case of large airgun arrays. However, the association of mass strandings of beaked whales with naval exercises and, in one case, an L-DEO seismic survey (Malakoff 2002; Cox et al. 2006), has raised the possibility that beaked whales exposed to strong “pulsed” sounds may be especially susceptible to injury and/or behavioral reactions that can lead to stranding (e.g., Hildebrand 2005; Southall et al. 2007). Appendix A provides additional details.

Specific sound-related processes that lead to strandings and mortality are not well documented, but may include (1) swimming in avoidance of a sound into shallow water; (2) a change in behavior (such as a change in diving behavior) that might contribute to tissue damage, gas bubble formation, hypoxia, cardiac arrhythmia, hypertensive hemorrhage or other forms of trauma; (3) a physiological change such as a vestibular response leading to a behavioral change or stress-induced hemorrhagic diathesis, leading in turn to tissue damage; and (4) tissue damage directly from sound exposure, such as through acoustically mediated bubble formation and growth or acoustic resonance of tissues. As noted in the preceding subsection, some of these mechanisms are unlikely to apply in the case of impulse sounds. However, there are increasing indications that gas-bubble disease (analogous to “the bends”), induced in supersaturated tissue by a behavioral response to acoustic exposure, could be a pathologic mechanism for the strandings and mortality of some deep-diving cetaceans exposed to sonar. The evidence for this remains circumstantial and associated with exposure to naval mid-frequency sonar, not seismic surveys (Cox et al. 2006; Southall et al. 2007).

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

There is no conclusive evidence of cetacean strandings or deaths at sea as a result of exposure to seismic surveys, but a few cases of strandings in the general area where a seismic survey was ongoing have led to speculation concerning a possible link between seismic surveys and strandings. Suggestions that there was a link between seismic surveys and strandings of humpback whales in Brazil (Engel et al. 2004) were not well founded (IAGC 2004; IWC 2007b). In Sept. 2002, there was a stranding of two Cuvier's beaked whales in the Gulf of California, Mexico, when the L-DEO vessel R/V *Maurice Ewing* was operating a 20-airgun, 8490-in^3 airgun array in the general area. The link between the stranding and the seismic surveys was inconclusive and not based on any physical evidence (Hogarth 2002; Yoder 2002). Nonetheless, the Gulf of California incident plus the beaked whale strandings near naval exercises involving use of mid-frequency sonar suggests a need for caution in conducting seismic surveys in areas occupied by beaked whales until more is known about effects of seismic surveys on those species (Hildebrand 2005).

No injuries of beaked whales are anticipated during the proposed study because of (1) the high likelihood that any beaked whales nearby would avoid the approaching vessel before being exposed to high sound levels, (2) the proposed monitoring and mitigation measures, including avoiding submarine canyons, where deep-diving species may congregate, and (3) differences between the planned airgun sound and the sonar sounds involved in the naval exercises associated with strandings.

(b) Possible Effects of Echosounder Signals

The Knudsen echosounder will be operated from the source vessel during most of the proposed study. Information about the equipment was provided in § I. Sounds from the echosounder are short pulses, occurring for up to 24 ms once every few seconds. Most of the energy in the sound pulses is at 3.5 and 12 kHz, and the beam is directed downward. The source level of the echosounder is expected to be relatively low compared to the GI guns. Kremser et al. (2005) noted that the probability of a cetacean swimming through the area of exposure when an echosounder emits a pulse is small, and if the animal was in the area, it would have to pass the transducer at close range in order to be subjected to sound levels that could cause TTS.

Masking

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

Behavioral Responses

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

During a previous low-energy seismic survey from the R/V *Thomas G. Thompson,* several echosounders were in operation most of the time, and a fathometer was also used during part of the survey. Many cetaceans and small numbers of fur seals were seen by the observers aboard the ship, but no specific information about echosounder effects (if any) on mammals were obtained (Ireland et al. 2005). These responses (if any) could not be distinguished from responses to the GI guns (when operating) and to the ship itself.

Captive bottlenose dolphins and a white whale exhibited changes in behavior when exposed to 1 s pulsed sounds at frequencies of ~30 kHz and to shorter broadband pulsed signals. Behavioral changes typically involved what appeared to be deliberate attempts to avoid the sound exposure (Schlundt et al. 2000; Finneran et al. 2002; Finneran and Schlundt 2004). The relevance of those data to free-ranging odontocetes is uncertain, and in any case, the test sounds were quite different in either duration or bandwidth as compared with those from an echosounder.

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

During the proposed 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. In the case of baleen whales, the echosounder will operate at too high a frequency to have any effect. As noted earlier, NMFS (2001) has concluded that momentary behavioral reactions “do not rise to the level of taking”. Thus, brief exposure of cetaceans or pinnipeds to small numbers of signals from the echosounder would not result in a “take” by harassment, even if a brief reaction did occur.

Hearing Impairment and Other Physical Effects

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

Given the maximum source level of 211 dB re 1 μPa·m rms (see § I), the received energy level from a single pulse of duration 24 ms would be ~195 dB re 1 $\mu Pa^2 \cdot s$ at 1 m, i.e., 211 dB + 10 log (0.024 s). As the TTS threshold for a cetacean receiving a single non-impulse sound is 195 dB re 1 $\mu Pa^2 \cdot s$ and the anticipated PTS threshold is 215 dB re 1 $\mu Pa^2 \cdot s$ (Southall et al. 2007), it is very unlikely that an animal would ever come close enough to the transducer to incur TTS (which would be fully recoverable), let alone PTS. As noted by Burkhardt et al. (2007, 2008), cetaceans are very unlikely to incur PTS from operation of scientific echosounders on a ship that is underway.

For the harbor seal, the TTS threshold for non-impulse sounds is ~183 dB re 1 $\mu Pa^2 \cdot s$, as compared with ~195 dB re 1 $\mu Pa^2 \cdot s$ in odontocetes (Kastak et al. 2005; Southall et al. 2007). TTS onset occurs at higher received energy levels in the California sea lion and northern elephant seal than in the harbor seal. The received level for a harbor seal within the echosounder beam 10 m below the ship would be ~191 dB re 1 μPa_{rms}, assuming 40 dB of spreading loss over 100 m (circular spreading). Given the narrow beam, only one pulse is likely to be received by a given animal as the ship passes overhead. At 10 m, the received energy level from a single pulse of duration 24 ms would be ~175 dB re 1 $\mu Pa^2 \cdot s$, i.e., 191 dB + 10 log (0.024 s). Thus, a harbor seal would have to come very close to the transducer in order to receive a single echosounder pulse with a received energy level of ≥183 dB re 1 $\mu Pa^2 \cdot s$. Given the intermittent nature of the signals and the narrow echosounder beam, only a small fraction of the pinnipeds below (and close to) the ship would receive a pulse as the ship passed overhead. Thus, it seems unlikely that a pinniped would incur TTS, let along PTS, if exposed to a single pulse by the echosounder.

(c) Possible Effects of the Sub-bottom Profiler Signals

An SBP will be operated from the source vessel at times during the planned study. Details about this equipment were provided in § I. Sounds from the SBP are relatively short pulses, occurring for 30 ms once every 0.5 to 1 s. The SBP will transmit a 0.5-12 kHz swept pulse (or chirp). The source level of the SBP is expected to be similar to or less than that of the Knudsen echosounder. Kremser et al. (2005) noted that the probability of a cetacean swimming through the area of exposure when a SBP emits a pulse is small—if the animal was in the area, it would have to pass the transducer at close range and in order to be subjected to sound levels that could cause TTS.

Masking

Marine mammal communications will not be masked appreciably by the SBP signals given the brief period when an individual mammal is likely to be within its beam.

Behavioral Responses

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

Hearing Impairment and Other Physical Effects

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

(d) Possible Effects of the Boomer

The boomer will be operated from the source vessel at times during the planned study. Details about this equipment were provided in § I. Sounds from the boomer are very short pulses, occurring for 0.1 ms once every second. The boomer will transmit a 0.3 to 3 kHz pulse. The source level of the boomer is similar to that of the Knudsen echosounder—212 dB re 1 µPa·m. If the animal was in the area, it would have to pass the transducer at close range and in order to be subjected to sound levels that could cause TTS.

Masking

Marine mammal communications will not be masked appreciably by the boomer signals given the directionality and brief period when an individual mammal is likely to be within its beam.

Behavioral Responses

Marine mammal behavioral reactions to other pulsed sound sources are discussed above, and responses to the boomer are likely to be similar to those for other pulsed sources if received at the same levels. Behavioral responses are not expected unless marine mammals are very close to the source.

Hearing Impairment and Other Physical Effects

It is unlikely that the boomer 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 boomer will be operated simultaneously with the higher-power GI guns. Many marine mammals will move away in response to the approaching GI guns 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 boomer. In the case of mammals that do not avoid the approaching vessel and its various sound sources, mitigation measures that would be applied to minimize effects of other sources [see § XI] would further reduce or eliminate any minor effects of the Boomer.

(e) Numbers of Marine Mammals that Might be "Taken by Harassment"

All anticipated takes would be "takes by harassment" involving temporary changes in behavior. The mitigation measures to be applied will minimize the possibility of injurious takes. (However, as noted earlier and in Appendix A, 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 NWA. The estimates are based on data concerning (1) cetacean densities (numbers per unit area) obtained during aerial surveys off New England during 2002 and 2004 by NMFS/Northeast Fisheries Science Center (NEFSC), and (2) estimates of the size of the area where effects could potentially occur. Few, if any, pinnipeds are expected to be encountered during the proposed survey in the summer (see § IV).

The following estimates are based on a consideration of the number of marine mammals that could be disturbed appreciably by operations with the two GI guns to be used during ~1757 line-km of surveys (including turns) off the New England coast. The anticipated radii of influence of the other sound sources (i.e., a sub-bottom profiler, boomer system, and echosounder) are less than those for the GI guns. It is assumed that, during simultaneous operations of the GI guns and other sound sources, any marine mammals close enough to be affected by the other sound sources would already be affected by the GI guns. However, whether or not the GI guns are operating simultaneously with the other sound sources, marine mammals are expected to exhibit no more than short-term and inconsequential responses to the other sound sources given their characteristics (e.g., narrow downward-directed beam in the echosounder) and other considerations described in § I and above. Such reactions are not considered to constitute "taking" (NMFS 2001). Therefore, no additional allowance is included for animals that could be affected by the other sound sources.

Basis for Estimating "Take by Harassment"

Extensive systematic aircraft- and ship-based surveys have been conducted for marine mammals offshore from New England (e.g., see Palka 2006). Those that were conducted in the proposed seismic survey area[4] were used for density estimates. Oceanographic conditions influence the distribution and numbers of marine mammals present in the study area, resulting in year-to-year variation in the distribution and abundance of many marine mammal species. Thus, for some species the densities derived from these surveys may not be representative of the densities that will be encountered during the proposed seismic survey. To provide some allowance for these 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[5] estimates of densities calculated from the appropriate densities reported by Palka (2006).

Table 4 gives the average and maximum densities for each species of cetacean reported in the proposed survey area off New England, corrected for effort, based on the densities as described above. 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 trackline [$f(0)$]. Availability bias refers to the fact that there is less-than-100% probability of sighting an animal that is present along the survey trackline, and it is measured by $g(0)$.

It should be noted that the following estimates of "takes by harassment" assume that the surveys will be undertaken and completed. As is typical for offshore ship surveys, inclement weather and equipment malfunctions are likely to cause delays and may limit the number of useful line-kilometers of seismic operations that can be undertaken. Furthermore, any marine mammal sightings within or near the designated 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- or 170-dB sounds are precautionary, and probably overestimate the actual numbers of marine mammals that might be

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[4] The abundance data in Palka (2006) are given by survey and location, according to U.S. Navy Operating Areas; the areas where the proposed seismic survey is planned (mostly Georges West, extending slightly into Georges Central and Shelf Central) were covered only by aerial surveys in 2002 and 2004.

[5] Average density is the mean of the calculated densities for all strata (year-area combinations), weighted by survey effort in each stratum and the proportional # seismic survey km in each area, whereas maximum density is the highest calculated density in any stratum.

Table 4. Densities of marine mammals sighted during NMFS aerial surveys in the proposed survey area off MV during summer 2002 and 2004 (Palka 2006) with their approximate coefficients of variation (CV). Densities are corrected for *f*(0) and *g*(0). Species listed as "Endangered" under the ESA are in italics.

	Average Density ($\#/1000\ km^2$)		**Maximum Density ($\#/1000\ km^2$)**	
Species	**Density**	**CV** [a]	**Density**	**CV** [a]
Mysticetes				
Humpback whale	*0.56*	*0.60*	*19.68*	*0.65*
Minke whale	0.05	0.94	7.35	0.94
Fin whale	*3.86*	*0.68*	*26.09*	*0.76*
Odontocetes				
Sperm whale	*0.38*	*0.94*	*26.88*	*0.94*
Unidentified beaked whale	<0.01	N.A. [b]	0.82	N.A. [b]
Bottlenose dolphin	14.02	0.76	163.02	N.A. [b]
Striped dolphin	0.11	N.A. [b]	73.61	N.A. [b]
Common dolphin [c]	128.88	0.41	1108.71	0.05
Risso's dolphin	0.48	N.A. [b]	322.67	N.A. [b]
Pilot whale	6.44	0.52	382.52	0.52

[a] CV (Coefficient of Variation) is a measure of a number's variability. The larger the CV, the higher the variability. It is estimated by 0.94 - $0.162\log_e n$ from Koski et al. (1998), but likely underestimates true variability.

[b] Not available. Sightings for one stratum (Shelf Center) not given.

[c] Not identified to species level.

involved. These estimates assume that there will be no weather, equipment, or mitigation delays, which is highly unlikely.

There is some uncertainty about how representative these data are and the assumptions used in the calculations below. However, the approach used here is believed to be the best available approach. As noted above, to provide some allowance for these uncertainties "maximum estimates" as well as "best estimates" of the numbers potentially affected have been derived. The estimated numbers of potential individuals exposed are presented below based on the 160-dB re 1 μPa_{rms} criterion for all cetaceans, and also based on the 170-dB criterion for delphinids only. It is assumed that a marine mammal exposed to airgun sounds this strong might change its behavior sufficiently to be considered "taken by harassment" (see § I and Table 1 for a discussion of the origin of these potential disturbance isopleths).

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

Number of Cetaceans that could be Exposed to ≥160 dB

The number of different individuals that may be exposed to GI-gun sounds with received levels ≥160 dB re 1 μPa_{rms} on one or more occasions can be estimated by considering the total marine area that would be within the 160-dB radius around the operating GI guns on at least one occasion. The proposed seismic lines do not run parallel to each other in close proximity, which minimizes the number of times an individual mammal may be exposed during the survey; in this case, an individual could be exposed 1.13 times on average. Table 5 shows the best and maximum estimates of the number of marine mammals that could potentially be affected during the seismic survey.

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

TABLE 5. Estimates of the possible numbers of marine mammals exposed to sound levels >160 and >170 dB during Rice's proposed seismic surveys off MV in August 2009. The proposed sound source is two 45-in^3 GI guns. Received levels of airgun sounds are expressed in dB re 1 µPa (rms, averaged over pulse duration). Not all marine mammals will change their behavior when exposed to these sound levels, but some may alter their behavior when levels are lower (see text). Delphinids are unlikely to react to levels below 170 dB. Species in italics are listed under the U.S. ESA as endangered. The column of numbers in boldface shows the numbers of "takes" for which authorization is requested.

	Number of Individuals Exposed to Sound Levels >160 dB (>170 dB, Delphinids)					
	Best Estimate[1]					
Species	**Number**		**% of Regional Pop'n[2]**	**Maximum Estimate[1]**		**Requested Take Authorization**
Balaenopteridae						
North Atlantic right whale[3]	*1*		0.31	*1*		***1***
Humpback whale	*2*		0.02	*57*		***2***
Minke whale	0		<0.01	21		**0**
Fin whale	*11*		0.03	*75*		***11***
Physeteridae						
Sperm whale	*2*		0.02	*77*		***2***
Ziphiidae						
Unidentified beaked whale	0		NA	2		**0**
Delphinidae						
Bottlenose dolphin	39	(21)	0.05	4700	(255)	**39**
Atlantic spotted dolphin[3]	0		0	0		**0**
Striped dolphin	0	(0)	<0.01	212	(115)	**0**
Common dolphin	349	(190)	0.17	3189	(1734)	**349**
Atlantic white-sided dolphin[3]	0		0	0	0	**0**
Risso's dolphin	2	(1)	0.01	929	(505)	**2**
Pilot whale	10	(6)	<0.01	1101	(599)	**10**
Phocidae						
Harbor seal[4]	10		0.01			**10**
Gray seal[4]	5		<0.01			**5**

[1] Best and maximum density estimates are primarily from Table 4 (see text).

[2] Regional population size estimates are from Table 2; NA means not available.

[3] Species not sighted in the surveys used for density estimates, but that could occur in low densities in the proposed survey area.

[4] Species for which summer densities in the study area are unavailable, but could occur there in low numbers.

- the expected species density, either "mean" (i.e., best estimate) or "maximum", times
- the anticipated area to be ensonified to that level during GI-gun operations.

The area expected to be ensonified was determined by entering the planned survey lines into a MapInfo Geographic Information System (GIS), using the GIS to identify the relevant areas by "drawing" the applicable 160-dB or 170-dB buffer (see Table 1) around each seismic line (2-gun buffer) and turn (1-gun buffer) and then calculating the total area within the buffers. Areas where overlap occurred (because of intersecting lines) were included only once to determine the minimum area expected to be ensonified.

Applying the approach described above, ~2877 km^2 would be within the 160-dB isopleth on one or more occasions during the survey. This approach does not allow for turnover in the mammal populations in the study area during the course of the studies. That might underestimate actual numbers of individuals exposed, although the conservative distances used to calculate the area may offset this. In addition, the approach assumes that no cetaceans will move away or toward the trackline as the *Endeavor* approaches in response to increasing sound levels prior to the time the levels reach 160 dB. Another way of interpreting the estimates that follow is that they represent the number of individuals that are expected (in the absence of a seismic program) to occur in the waters that will be exposed to ≥160 dB re 1 μPa_{rms}.

The 'best estimate' of the number of individual cetaceans that might be exposed to seismic sounds with received levels ≥160 dB re 1 μPa_{rms} during the surveys is 416 (Table 5). That total includes 16 ***endangered*** whales (1 North Atlantic right, 2 humpback, 11 fin, and 2 sperm whales) and no beaked whales. The common dolphin and bottlenose dolphin are estimated to be the most common species exposed; the best estimates for those species are 372 and 40, respectively. Estimates for the other dolphin species that could be exposed are lower (Table 5). In addition, it is estimated that 15 pinnipeds may be exposed during the proposed study.

The 'Maximum Estimate' column in Table 5 shows an estimated total of 6134 cetaceans exposed to seismic sounds ≥160 dB during the surveys. Those estimates are based on the highest calculated density in any survey stratum; in this case, the stratum with the highest density invariably was one of the areas where very little of the proposed seismic survey will take place, i.e., Georges Central or Shelf Central. In other words, densities observed in the 2002 and 2004 aerial surveys were lowest in the Georges West operation area, where most of the proposed seismic surveys will take place. Therefore, the numbers for which "***take authorization"*** is requested, given in the far right column of Table 5, are the best estimates. For three ***endangered*** species, the best estimates were set at the species' mean group size. The North Atlantic right whale, which was not sighted during the aerial surveys, could occur in the survey area, and is usually seen individually (feeding aggregations are not expected to occur in the study area). The humpback and sperm whales, each of whose calculated best estimate was 1, have a mean group size of 2.

Number of Delphinids that could be Exposed to ≥170 dB

The 160-dB criterion, on which the preceding estimates are based, was derived from studies of baleen whales. Odontocete hearing at low frequencies is relatively insensitive, and delphinids generally appear to be more tolerant of strong low-frequency sounds than are most baleen whales. As summarized in Appendix A, delphinids commonly occur within distances where received levels would be expected to exceed 160 dB re 1 μPa_{rms}. There is no generally accepted alternative "take" criterion for delphinids exposed to airgun sounds. However, our estimates assume that only those delphinids exposed to ≥170 dB re 1 μPa_{rms}, on average, would be affected sufficiently to be considered "taken by harassment". ("On average" means that some individuals might react significantly upon exposure to levels somewhat <170 dB, but others would not do so even upon exposure to levels somewhat >170 dB.) The area ensonified by levels ≥170 dB was determined (as described above for levels ≥160 dB) and was multiplied by the marine mammal density in order to obtain best and maximum estimates.

The best and maximum estimates of the numbers of exposures to ≥170 dB for all delphinids during the surveys are 217 and 3209, respectively (Table 5). The best estimates of the numbers of individuals that might be exposed to ≥170 dB for the three most abundant delphinid species are 190 common dolphins, 21 bottlenose dolphins, and 6 pilot whales. These values are based on the predicted 170-dB radii around the GI guns to be used during the study and are considered to be more realistic estimates of the number of individual delphinids that may be affected.

Conclusions

The proposed survey off MV will involve towing two GI-guns that introduce pulsed sounds into the ocean, along with simultaneous operation of at least one of a sub-bottom profiler, an echosounder, or a boomer system. A towed hydrophone streamer will be deployed to receive and record the returning signals. Routine vessel operations, other than the proposed GI-gun operations, are conventionally assumed not to affect marine mammals sufficiently to constitute "taking". No "taking" of marine mammals is expected in association with operations of the echosounders given the considerations discussed in § VII, i.e., sounds are beamed downward, the beam is narrow, and the pulses are extremely short.

Cetaceans

Strong avoidance reactions by several species of mysticetes to seismic vessels have been observed at ranges up to 6–8 km and occasionally as far as 20–30 km from the source vessel when much larger airgun arrays have been used. However, reactions at the longer distances appear to be atypical of most species and situations and to the larger arrays. Furthermore, if they are encountered, the numbers of mysticetes estimated to occur within the 160-dB isopleth in the survey area are expected to be very low. In addition, the estimated numbers presented in Table 5 are considered overestimates of actual numbers because the estimated 160-and 170-dB radii used here are probably overestimates of the actual 160-and 170-dB radii at the deep-water locations in this study (Tolstoy et al. 2004a,b).

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

Taking into account the mitigation measures that are planned (see § XI), effects on cetaceans are generally expected to be limited to avoidance of the area around the seismic operation and short-term changes in behavior, falling within the MMPA definition of "Level B harassment". Furthermore, the estimated numbers of animals potentially exposed to sound levels sufficient to cause appreciable disturbance are very low percentages of the regional population sizes. The best estimate of the number of individual cetaceans (57 for all species combined) that would be exposed to sounds ≥160 dB re 1 μPa_{rms} during the proposed survey represent, on a species-by-species basis, no more than 0.19% of the regional populations (Table 5). Dolphins are the cetaceans with the highest estimated numbers exposed, but the population sizes of species likely to occur there are also large, and the numbers within the ≥160-dB zones are small relative to the population sizes (Table 5). Also, these delphinids are not expected to be disturbed appreciably at received levels below 170 dB re 1 μPa_{rms}. The numbers of delphinids estimated to be exposed to sounds >170 dB during the proposed survey represent ≤0.10% of the population size of any of the species.

Varying estimates of the numbers of marine mammals that might be exposed to GI-gun sounds during the proposed seismic survey off New England have been presented, depending on the specific exposure criterion (≥160 or ≥170 dB) and density criterion used (best or maximum). The requested "take authorization" for each species is based on the estimated average numbers of individuals exposed to ≥160 dB re 1 μPa_{rms}. That figure likely overestimates the actual number of animals that will be exposed to the seismic sounds; the reasons for that are outlined above. The relatively short-term exposures are unlikely to result in any long-term negative consequences for the individuals or their populations.

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

Pinnipeds

An estimated 10 harbor seals and five gray seals may be exposed to airgun sounds during the proposed study. This estimate represents 0.01% or less of the regional populations.

VIII. ANTICIPATED IMPACT ON SUBSISTENCE

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

There is no legal subsistence hunting for marine mammals off the coast of New England, so the proposed activities will not have any impact on the availability of the species or stocks for subsistence users.

IX. ANTICIPATED IMPACT ON HABITAT

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

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

(a) Effects on Fish

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

The specific received sound levels at which permanent adverse effects to fish potentially could occur are little studied and largely unknown. Furthermore, the available information on the impacts of seismic surveys on marine fish is from studies of individuals or portions of a population; there have been no studies at the population scale. Thus, available information provides limited insight on possible real-world effects at the ocean or population scale. This makes drawing conclusions about impacts on fish problematic because ultimately, the most important aspect of potential impacts relates to how exposure to seismic survey sound affects marine fish populations and their viability, including their availability to fisheries.

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

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

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

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

Some studies have reported, some equivocally, that mortality of fish, fish eggs, or larvae can occur close to seismic sources (Kostyuchenko 1973; Dalen and Knutsen 1986; Booman et al. 1996; Dalen et al. 1996). Some of the reports claimed seismic effects from treatments quite different from actual seismic survey sounds or even reasonable surrogates. Saetre and Ona (1996) applied a 'worst-case scenario' mathematical model to investigate the effects of seismic energy on fish eggs and larvae. They concluded that mortality rates caused by exposure to seismic surveys are so low, as compared to natural mortality rates, that the impact of seismic surveying on recruitment to a fish stock must be regarded as insignificant.

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

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

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

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

(b) Effects on Invertebrates

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

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

The following sections provide a synopsis of available information on the effects of exposure to seismic survey sound on species of decapod crustaceans and cephalopods, the two taxonomic groups of invertebrates on which most such studies have been conducted. The available information is from studies with variable degrees of scientific soundness and from anecdotal information. A more detailed review of the literature on the effects of seismic survey sound on invertebrates is provided in Appendix D.

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

Some studies have suggested that seismic survey sound has a limited pathological impact on early developmental stages of crustaceans (Pearson et al. 1994; Christian et al. 2003; DFO 2004). However, the impacts appear to be either temporary or insignificant compared to what occurs under natural conditions. Controlled field experiments on adult crustaceans (Christian et al. 2003, 2004; DFO 2004) and adult cephalopods (McCauley et al. 2000a,b) exposed to seismic survey sound have not resulted in any significant pathological impacts on the animals. It has been suggested that exposure to commercial seismic survey activities has injured giant squid (Guerra et al. 2004), but there is no evidence to support such claims.

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

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

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

X. ANTICIPATED IMPACT OF LOSS OR MODIFICATION OF HABITAT ON MARINE MAMMALS

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

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

During the proposed survey, marine mammals will be distributed according to their habitat preferences, in shelf, slope, and pelagic waters. Concentrations of marine mammals and/or marine mammal prey species are not expected to occur in the proposed study area at the time of the survey, and that area does not appear to constitute an area of localized or critical feeding, breeding, or migration for any marine mammal species.

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

XI. MITIGATION MEASURES

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

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

The following subsections provide more detailed information about the mitigation measures that are an integral part of the planned activities. The procedures described here are based on protocols used during previous seismic research cruises and on recommended best practices in Richardson et al. (1995), Pierson et al. (1998), and Weir et al. (2006).

Received sound levels have been estimated by L-DEO in relation to distance from two 45-in^3 Nucleus GI guns; information for two 45-in^3 GI guns was not available. The radii around two 45-in^3 Nucleus G guns where received levels would be 180 and 190 dB re 1 µPa (rms) are small, especially in the intermediate waters of the survey area (60 and 15 m, respectively, see Table 1 in § I). The 180- and 190-dB levels are shut-down criteria applicable to cetaceans and pinnipeds, respectively, as specified by NMFS (2000). Those radii will also be used as shut-down criteria for the other sound sources (single GI gun, watergun, and boomer), all of which have lower source levels than the two GI guns.

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

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

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

Proposed Exclusion Zones

Empirical data concerning 180, 170, and 160 dB re 1 μPa_{rms} distances were acquired for various airgun configurations during the acoustic calibration study of the R/V *Maurice Ewing*'s 20-airgun 8600 in^3 array in 2003 (Tolstoy et al. 2004a,b). The results showed that distances around the airgun array where the received level was 160 dB re 1 μPa_{rms} varied with water depth. Similar depth-related variation is likely for the 180- and the 190-dB re 1 μPa_{rms} levels.

Received sound levels have been modeled by L-DEO for a number of airgun configurations, including two GI guns, in relation to distance and direction from the airguns. Based on the modeling and various correction factors determined from the work by Tolstoy et al. (2004a,b), the distances from the source where sound levels are predicted to be 190, 180, 170, and 160 dB re 1 μPa_{rms} were determined (see Table 1 in § I). Because the model was based on two larger GI guns, the values in Table 1 overestimate the distances for the actual GI guns to be used. The 180 and 190 dB re 1 μPa_{rms} distances are the safety criteria as specified by NMFS (2000) and are applicable to cetaceans and pinnipeds, respectively; these levels are used to establish the EZs. If the marine mammal visual observer (MMVO) detects marine mammal(s) or turtle(s) within or about to enter the appropriate EZ, the GI guns will be shut down immediately (see § XI).

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

Mitigation During Operations

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

Shut-down Procedures

If a marine mammal or turtle is within or about to enter the EZ for the GI guns, the GI guns will be shut down immediately. Following a shut down, GI gun activity will not resume until the marine mammal or turtle is outside the EZ for the two GI guns. The animal will be considered to have cleared the EZ if it

1. is visually observed to have left the EZ;
2. has not been seen within the EZ for 10 min in the case of small odontocetes and pinnipeds;
3. has not been seen within the EZ for 15 min in the case of mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, and beaked whales; or
4. the vessel has moved outside the EZ for turtles (up to 5 min) depending on sighting distance, depth, and vessel speed [based on the lengths of time it would take the vessel to leave the turtle behind and outside of the exclusion zone].

The 10- and 15-min periods specified in (2) and (3), above, are shorter than would be used in a large-source project given the small 180- and 190-dB_{rms} radii for the two GI guns.

Power-downs During Turns

A power-down involves decreasing the number of GI guns in use from two to one. During turns between successive survey lines, a single GI gun will be operated. The continued operation of one gun is intended to alert marine mammals to the presence of the survey vessel in the area.

Ramp-up Procedures

A ramp-up procedure will be followed when the GI guns begin operating after a specified period without GI gun operations. It is proposed that, for the present cruise, this period would be ~1–2 min. This period is based on the 180-dB radii for the GI guns (see Table 1) in relation to the planned speed of the *Endeavor* while shooting (see above).

Ramp up will begin with a single GI gun (45 in^3). The second GI gun (45 in^3) will be added after 5 min. During ramp up, the MMOs will monitor the exclusion zone, and if marine mammals or turtles are sighted, a shut down will be implemented as though both GI guns were operational.

If the complete exclusion zone has not been visible for at least 30 min prior to the start of operations in either daylight or nighttime, ramp up will not commence. If one GI gun has operated, ramp up to full power will be permissible at night or in poor visibility, on the assumption that marine mammals and turtles will be alerted to the approaching seismic vessel by the sounds from the single GI gun and could move away if they choose. A ramp up from a shut down may occur at night, but only in intermediate-water depths, where the safety radius is small enough to be visible. Ramp up of the GI guns will not be initiated if a sea turtle or marine mammal is sighted within or near the applicable exclusion zones during the day or close to the vessel at night.

Special Procedures for Situations or Species of Concern

Several species of particular concern could occur in the study area. Special mitigation procedures will be used for those species, as follows:

- The GI guns will be shut down if a North Atlantic right whale is sighted at any distance from the vessel because of its rarity and conservation status
- Concentrations of humpback, fin, sperm, blue, and sei whales will be avoided.

XII. PLAN OF COOPERATION

> Where the proposed activity would take place in or near a traditional Arctic subsistence hunting area and/or may affect the availability of a species or stock of marine mammal for Arctic subsistence uses, the applicant must submit either a plan of cooperation or information that identifies what measures have been taken and/or will be taken to minimize any adverse effects on the availability of marine mammals for subsistence uses. A plan must include the following:
>
> (i) A statement that the applicant has notified and provided the affected subsistence community with a draft plan of cooperation;
>
> (ii) A schedule for meeting with the affected subsistence communities to discuss proposed activities and to resolve potential conflicts regarding any aspects of either the operation or the plan of cooperation;
>
> (iii) A description of what measures the applicant has taken and/or will take to ensure that proposed activities will not interfere with subsistence whaling or sealing; and
>
> (iv) What plans the applicant has to continue to meet with the affected communities, both prior to and while conducting activity, to resolve conflicts and to notify the communities of any changes in the operation.

Not applicable. The proposed activity will take place off the coast of New England in the NWA, and no activities will take place in or near a traditional Arctic subsistence hunting area.

XIII. MONITORING AND REPORTING PLAN

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

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

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

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

Vessel-based Visual Monitoring

MMVOs will be based aboard the seismic source vessel and will watch for marine mammals and turtles near the vessel during daytime GI-gun operations and during start-ups at night. MMVOs will also watch for marine mammals and turtles near the seismic vessel for at least 30 minutes prior to the start of GI gun operations after an extended shut down. When feasible, MMVOs will also observe during daytime periods when the seismic system is not operating for comparison of sighting rates and behavior with vs. without GI gun operations. Based on MMVO observations, the GI rguns will be shut down when marine mammals are observed within or about to enter a designated EZ. The EZ is a region in which a possibility exists of adverse effects on animal hearing or other physical effects.

MMVOs will be appointed by the academic institution conducting the research cruise, with NMFS Office of Protected Resources concurrence. A total of three MMVOs are planned to be aboard. At least one MMVO will monitor the EZ during daytime GI-gun operations and any night-time startups. MMVOs will normally work in daytime shifts of 4 hour duration or less. The vessel crew will also be instructed to assist in detecting marine mammals and turtles.

The *Endeavor* will serve as the platform from which MMVOs will watch for mammals and sea turtles before and during GI-gun operations. Two locations are likely as observation stations onboard the *Endeavor*; observations may take place from the flying bridge ~11 m above sea level (asl) or the bridge (8.2 m asl).

Standard equipment for marine mammal observers will be 7 x 50 reticule binoculars and optical range finders. At night, night-vision devices (NVDs) will be available. Vessel lights and/or NVDs[6] are useful in sighting some marine mammals *at the surface* within a short distance from the ship (within the

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[6] See Smultea and Holst (2003), Holst (2004), Smultea et al. (2004), and MacLean and Koski (2005) for evaluations of the effectiveness of NVDs for nighttime marine mammal observations.

EZ for the two GI guns). 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 GI gun shut down.

MMVO Data and Documentation

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

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

1. Species, group size, age/size/sex categories (if determinable), behavior when first sighted and after initial sighting, heading (if consistent), bearing and distance from seismic vessel, sighting cue, apparent reaction to the GI guns or vessel (e.g., none, avoidance, approach, paralleling, etc.), and behavioral pace.
2. Time, location, heading, speed, activity of the vessel, sea state, visibility, and sun glare.

The data listed under (2) will also be recorded at the start and end of each observation watch, and during a watch whenever there is a change in one or more of the variables.

All observations, as well as information regarding GI gun shut down, will be recorded in a standardized format. Data accuracy will be verified by the MMVOs at sea, and preliminary reports will be prepared during the field program and summaries forwarded to the operating institution's shore facility and to NSF weekly or more frequently. MMVO observations will provide the following information:

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

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

XIV. COORDINATING RESEARCH TO REDUCE AND EVALUATE INCIDENTAL TAKE

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

Rice will coordinate the planned marine mammal monitoring program associated with the seismic survey in the NWA (as summarized in § XI and XIII) with other parties that may have interest in the area and/or be conducting marine mammal studies in the same region during the proposed seismic survey.

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