Draft Environmental Assessment of a Low-Energy Marine Geophysical Survey by the US Geological Survey in the Northwestern Gulf of Mexico, April–May 2013

Prepared for

United States Geological Survey
384 Woods Hole Road
Woods Hole, MA 02543

by

LGL Ltd., environmental research associates
22 Fisher St., POB 280
King City, Ont. L7B 1A6

23 October 2012

LGL Report P1263-1

TABLE OF CONTENTS

ABSTRACT

The U.S. Geological Survey (USGS) plans to conduct a low-energy seismic survey onboard the oceanographic research vessel R/V *Pelican*, owned by the Louisiana Universities Marine Consortium, or aboard a similar vessel in the northwestern Gulf of Mexico during 17 April–4 May 2013. The survey will take place in the U.S. Exclusive Economic Zone (EEZ) in water depths 1500–2000 m. The seismic study will be conducted from the R/V *Pelican* (or similar vessel) with a towed pair of GI airguns, each with a discharge volume of 105 in^3. There will be ~8 days of airgun operations during this survey.

The purpose of the seismic survey is to develop technology and to collect data to assist in the characterization of marine gas hydrates in order to better understand their impact on seafloor stability, their role in climate change, and their potential as an energy source.

The USGS is requesting an Incidental Harassment Authorization (IHA) from the U.S. National Marine Fisheries Service (NMFS) to authorize the incidental, i.e., not intentional, harassment of small numbers of marine mammals should this occur during the seismic survey. The information in this Environmental Assessment (EA) supports the IHA application process and provides information on marine species that are not addressed by the IHA application, including seabirds and sea turtles that are listed under the U.S. Endangered Species Act (ESA) including candidate species, fish, and Essential Fish Habitat (EFH). The EA addresses the requirements of the National Environmental Policy Act (NEPA). Alternatives addressed in this EA consist of a corresponding program at a different time, along with issuance of an associated IHA; and the no action alternative, with no IHA and no seismic survey.

Numerous species of marine mammals inhabit the GOM. Several of these species are listed as endangered under the U.S. Endangered Species Act (ESA): the sperm, North Atlantic right, humpback, sei, fin, and blue whales, and the West Indian manatee. Other ESA-listed species that could occur in the area are the endangered leatherback, hawksbill, green, and Kemp’s ridley turtles, and the threatened loggerhead turtle.

Potential impacts of the seismic survey on the environment would be primarily a result of the operation of the GI airguns. Impacts would be associated with increased underwater noise, which may result in avoidance behavior by marine mammals, sea turtles, seabirds, and fish, and other forms of disturbance. An integral part of the planned survey is a monitoring and mitigation program designed to minimize impacts of the proposed activities on marine animals present during the proposed research, and to document as much as possible the nature and extent of any effects. Injurious impacts to marine mammals, sea turtles, and seabirds have not been proven to occur near airgun arrays. The planned monitoring and mitigation measures would reduce the possibility of injurious effects.

Protection measures designed to mitigate the potential environmental impacts to marine mammals and turtles will include the following: ramp ups; typically two, but a minimum of one dedicated observer maintaining a visual watch during all daytime airgun operations; two observers 30 min before and during ramp ups during the day and at night; no start ups during poor visibility or at night unless at least one airgun has been operating or only where the safety radius is small enough to be visible; and shut downs when marine mammals or sea turtles are detected in or about to enter designated exclusion zones. USGS and its contractors are committed to applying these measures in order to minimize effects on marine mammals and sea turtles and other environmental impacts.

With the planned monitoring and mitigation measures, unavoidable impacts to each species of marine mammal and turtle that could be encountered are expected to be limited to short-term, localized changes in behavior and distribution near the seismic vessel. At most, effects on marine mammals may be interpreted as falling within the U.S. Marine Mammal Protection Act (MMPA) definition of “Level B

Harassment" for those species managed by NMFS. No long-term or significant effects are expected on individual marine mammals, sea turtles, seabirds, the populations to which they belong, or their habitats.

LIST OF ACRONYMS

~	approximately
BOEM	Bureau of Ocean Energy Management
BOEMRE	Bureau of Ocean Energy Management, Regulation, and Enforcement
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CITES	Convention on International Trade in Endangered Species
dB	decibel
DoN	Department of the Navy
EA	Environmental Assessment
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
ESA	(U.S.) Endangered Species Act
EEZ	Exclusive Economic Zone
EZ	Exclusion Zone
GI	Generator-Injector
GIS	Geographic Information System
GOM	Gulf of Mexico
h	hour
hp	horsepower
Hz	Hertz
IHA	Incidental Harassment Authorization (under MMPA)
in	inch
IUCN	International Union for the Conservation of Nature
JIP	Joint Industry Project
kHz	kiloHertz
kJ	kiloJoule
km	kilometer
kt	knot
kW	kiloWatt
L-DEO	Lamont-Doherty Earth Observatory
LWD	logging while drilling
m	meter
mgC	milligrams of carbon
min	minute
MMPA	(U.S.) Marine Mammal Protection Act
MPA	Marine Protected Area
ms	millisecond
n.mi.	nautical mile
NEPA	(U.S.) National Environmental Policy Act
NMFS	(U.S.) National Marine Fisheries Service
NODE	(U.S.) Navy OPAREA Density Estimates
NRC	(U.S.) National Research Council
NSF	National Science Foundation

OBS	Ocean Bottom Seismometer
OBSIP	OBS Instrument Pool
OCS	Outer Continental Shelf
OEIS	Overseas Environmental Impact Statement
p or pk	peak
PEIS	Programmatic Environmental Impact Statement
PI	Principal Investigator
PTS	Permanent Threshold Shift
PSO	Protected Species Observer
RL	Received level
rms	root-mean-square
s	second
TTS	Temporary Threshold Shift
UNEP	United Nations Environment Programme
U.S.	United States of America
USC	United States Code
USGS	U. S. Geological Survey
USFWS	U.S. Fish and Wildlife Service
USN	U.S. Navy
μPa	microPascal
vs.	versus
W	west
WCMC	World Conservation Monitoring Centre
WHOI	Woods Hole Oceanographic Institution

I. PURPOSE AND NEED

The U.S. Geological Survey (USGS) intends to conduct a low-energy seismic survey onboard the R/V *Pelican* (owned and operated by LUMCON) or a similar vessel in the northwestern Gulf of Mexico (GOM) during a 15-day cruise in April–May 2013. The seismic survey will take place in water depths ranging from ~1500 m to 2000 m, within the U.S. Exclusive Economic Zone (EEZ).

The goal of the proposed research, to be carried about by the USGS Gas Hydrates Project, is to develop technology and to collect data to assist in the characterization of marine gas hydrates in order to better understand their potential as an energy resource, their impact on seafloor stability, and their role in climate change. These sites have been extensively studied, including detailed logging while drilling (LWD), and are known to hold thick sequences of sand containing high saturations of gas hydrate. The purpose of this new seismic acquisition is to expand outward from the boreholes the detailed characterization that has been accomplished there, and to develop and calibrate improved geophysical techniques for gas hydrate characterization.

Numerous species of marine mammals inhabit the GOM. Several of these species are listed as endangered under the U.S. Endangered Species Act (ESA): the sperm, North Atlantic right, humpback, sei, fin, and blue whales, and the West Indian manatee. Other ESA-listed species that could occur in the area are the endangered leatherback, hawksbill, green, and Kemp's ridley turtles, and the threatened loggerhead turtle.

The purpose of this Environmental Assessment (EA) is to provide the information needed to assess the potential environmental impacts associated with the use of the GI airguns during the proposed survey. The EA was prepared under the National Environmental Policy Act (NEPA). The EA addresses potential impacts of the proposed seismic survey on marine mammals, as well as other species of concern in the survey area, notably sea turtles. The EA also provides useful information in support of an application for an Incidental Harassment Authorization (IHA) from the National Marine Fisheries Service (NMFS). The requested IHA would, if issued, allow the non-intentional, non-injurious "take by harassment" of small numbers of marine mammals during the proposed seismic survey by USGS during April–May 2013.

To be eligible for an IHA, the proposed "taking" (with mitigation measures in place) must not cause serious physical injury or death of marine mammals, must have negligible impacts on the species and stocks, must "take" no more than small numbers of those species or stocks, and must not have an un-mitigable adverse impact on the availability of the species or stocks for legitimate subsistence uses.

Protection measures designed to mitigate the potential environmental impacts are also described in this EA as an integral part of the planned activities. With these mitigation measures in place, any impacts on marine mammals and sea turtles are expected to be limited to short-term, localized changes in behavior of small numbers of animals. No long-term or significant effects are expected on individual mammals, turtles, or populations.

II. ALTERNATIVES INCLUDING PROPOSED ACTION

Three alternatives are evaluated: (1) the proposed seismic survey and issuance of an associated IHA, (2) a corresponding seismic survey at an alternative time, along with issuance of an associated IHA, and (3) no action alternative.

Proposed Action

The project objectives and context, activities, and mitigation measures for USGS' planned seismic survey are described in the following subsections.

(1) Project Objectives and Context

The Principal Investigators (PIs) plan to conduct a seismic survey at two sites that have been studied as part of the Gulf of Mexico Gas Hydrates Joint Industry Project (JIP), the GC955 and WR313 study sites, in the northwest GOM (Fig. 1). The goal of the proposed research is to develop technology and to collect data to assist in the characterization of marine gas hydrates in order to better understand their potential as an energy resource, their impact on seafloor stability, and their role in climate change. These sites have been extensively studied, including detailed LWD, and are known to hold thick sequences of sand containing high saturations of gas hydrate. The purpose of this new seismic acquisition is to expand outward from the boreholes the detailed characterization that has been accomplished there, and to develop and calibrate improved geophysical techniques for gas hydrate characterization.

(2) Proposed Activities

(a) Location of the Activities

The survey will encompass the area ~26.5ºN–27°N, ~90.5–92°W in the northwest GOM (Fig. 1). Water depths in the survey area range from ~1500 m to ~2000 m. The seismic survey will be conducted within the U.S. EEZ, with airgun operations scheduled to occur for ~8 days of a 15-day cruise in April–May 2013. Some minor deviation from these dates is possible, depending on logistics and weather.

(b) Description of the Activities

The survey will involve one source vessel, the R/V *Pelican* or similar ship. The source vessel will deploy a pair of low-energy Generator-Injector (GI) airguns as an energy source (each with a discharge volume of 105 in^3), one 450-m long, 72-channel hydrophone streamer, and 25 ocean bottom seismometers (OBSs). The energy to the airguns is compressed air supplied by compressors on board the source vessel. As the airguns are towed along the survey lines, the hydrophone streamer will receive the returning acoustic signals and transfer the data to the on-board processing system. The OBSs record the returning acoustic signals internally for later analysis. A subset of the survey lines will be repeated using either a single 35-in^3 GI gun or a 6-kJ sparker. Regardless of which energy source is used, calculations in § IV assume that the two 105-in^3 GI guns will be used.

At each of the two study sites, 25 OBSs will be deployed and a total of ~700 km of survey lines will be collected in a grid pattern (Fig. 1). Water depths are 1500–2000 m at each site. All planned geophysical data acquisition activities will be conducted by technicians provided by USGS with on-board assistance by the scientists who have proposed the study. The Principal Investigators are Dr. Seth Haines, USGS (Energy Program), Denver, CO, and Mr. Patrick Hart, USGS (Coastal and Marine Geology), Santa Cruz, CA. The vessel will be self-contained, and the crew will live aboard the vessel for the entire cruise

(c) Schedule

The survey is scheduled during 16 April–5 May 2013. Total survey time would be ~96 h at each of the two sites. The remainder of the cruise consists of transit plus OBS deployment and retrieval. The exact dates of the activities depend on logistics and weather conditions.

.

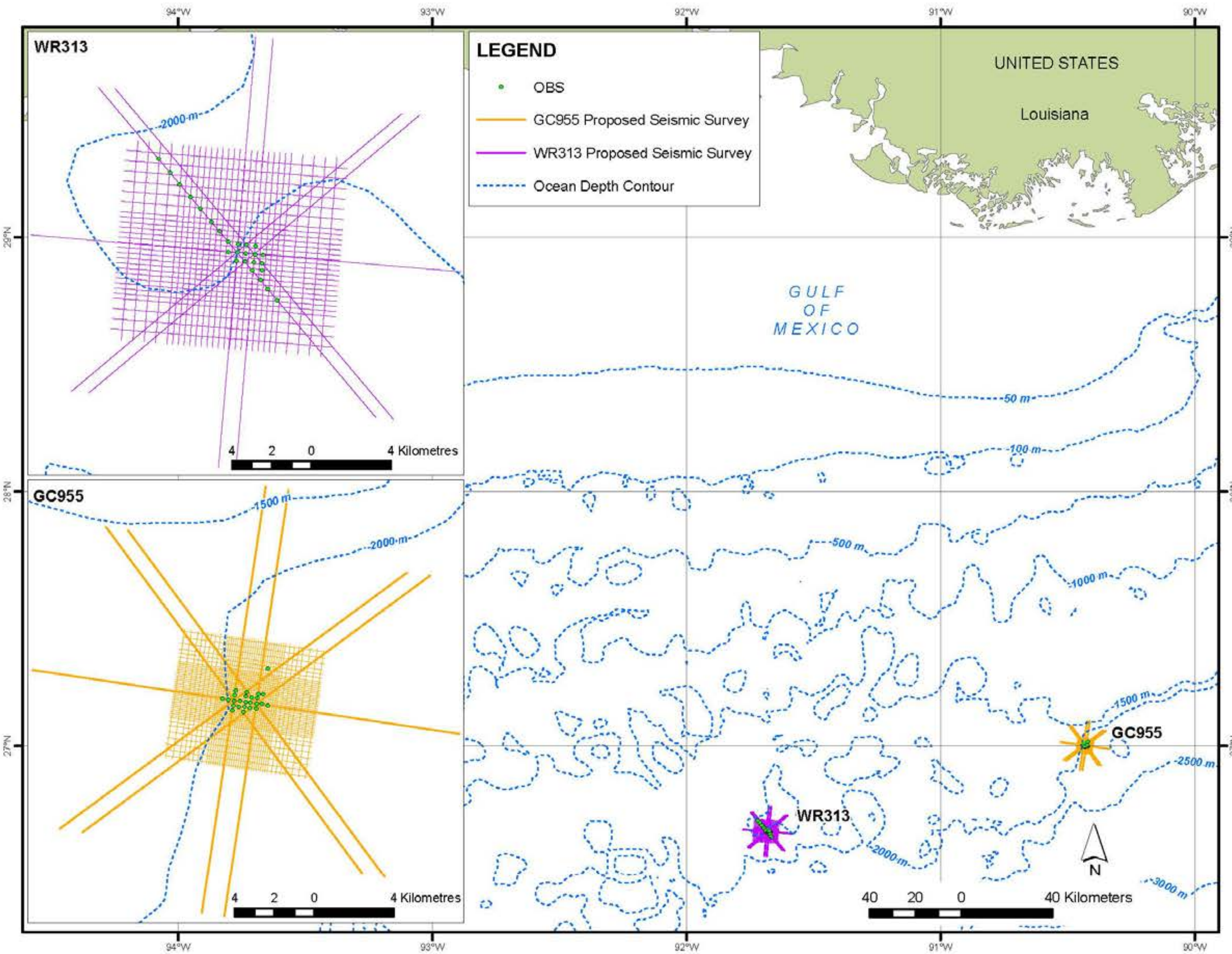

Figure 1. Location of the proposed seismic surveys and OBSs at the GC955 and WR313 study sites, northwest Gulf of Mexico.

(d) Source Vessel Specifications

The *R/V Pelican* or a similar vessel will be used for this survey. **The specifications given here and the descriptions in the rest of the document are keyed to the *R/V Pelican* although a vessel with similar characteristics may be substituted.** The R/V *Pelican* has a length of 35.5 m, a beam of 8 m, and a full load draft of 2.9 m. It is equipped with two Caterpillar Model 3412 1648-in^3 diesel engines and a 80-hp Schottel bow thruster. Electrical power is provided by two Caterpillar 3306, 99-kW diesel generators. An operation speed of ~8.1 km/h (4.5 kt) will be used during seismic acquisition. When not towing seismic survey gear, the R/V *Pelican* cruises at 17 km/h (9.2 kt). It has a normal operating range of ~5600 km.

The R/V *Pelican* will also serve as the platform from which vessel-based protected species observers (PSOs) will watch for marine mammals and sea turtles before and during airgun operations. The characteristics of the vessel that make it suitable for visual monitoring are described in § XI.

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

Owner:	Louisiana Universities Marine Consortium
Operator:	Louisiana Universities Marine Consortium
Flag:	United States of America
Launch Date:	1985, refit in 2003
Gross Tonnage:	261 T
Accommodation Capacity:	22 including 15 scientists

(e) Airgun Description

The R/V *Pelican* (or similar vessel) will tow a pair of 105-in^3 Sercel GI airguns as the primary energy source and a streamer containing hydrophones along predetermined lines. A subset of the survey lines will be repeated using either a single 35-in^3 GI gun or a 6-kJ sparker. Seismic pulses for the GI guns will be emitted at intervals of ~ 6–10 s. At speeds of ~ 8.1 km/h, the shot intervals correspond to spacing of ~14–23 m. Intervals for the sparker will be ~3 s or 7 m.

The generator chamber of each GI airgun in the primary source, the one responsible for introducing the sound pulse into the ocean, is 105 in^3. The injector chamber injects air into the previously-generated bubble to maintain its shape, and does not introduce more sound into the water. The two GI airguns will be towed 8 m apart side by side, 21 m behind the R/V *Pelican*, at a depth of 3 m. The total effective volume will be 210 in^3.

The single 35-in^3 GI gun is the same type of dual chamber gun as the 105-in^3 GI gun described above, with the generator and injector chambers each being 35 in^3. The manufacturer's literature indicates that a 35-in^3 GI gun has an rms source level of ~208 dB re 1 μPa · m, a duration of about 10 ms, and dominant frequency components <500 Hz. Field measurements by USGS personnel indicate that the GI gun outputs low sound amplitudes at frequencies >500 Hz. The 35-in^3 GI gun will be towed ~15 m behind the ship at ~2 m depth.

The 6-kJoule Delta Sparker source is manufactured by Applied Acoustics Engineering Ltd. The sparker generates a steam bubble by discharging electrical energy through a point electrode surrounded by seawater. The rapid expansion of the steam bubble generates a positive pressure impulse lasting 0.3–5.0 ms and frequencies concentrated between 200 and 1000 Hz. The manufacturer's literature indicates that this sparker system operated at 6 kJoules has a pk-pk source level of ~226 dB re 1 μPa · m. The sparker array will be towed at a nominal depth of 2 m and a distance of 10–20 m behind the ship.

As the GI airguns are towed along the survey line, the towed hydrophone array receives the reflected signals and transfers the data to the on-board processing system. The OBSs record the returning acoustic signals internally for later analysis. Given the relatively short streamer length behind the vessel, the turning rate of the vessel while the gear is deployed is much higher than the limit of five degrees per minute for a seismic vessel towing a streamer of more typical length (>>l km). Thus, the maneuverability of the vessel is not limited much during operations.

<u>GI Airgun Specifications</u>

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

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

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

(f) OBS Description and Deployment

For the study, 25 OBSs will be deployed by the R/V *Pelican* (or similar vessel) at each of the two study sites in sequence (Fig. 1). Once the seismic surveys have been completed at the first site, the OBSs will be retrieved, then redeployed at the second site. Once the seismic surveys have been completed at the second site, the OBSs will be retrieved.

OBSs operated by the U.S. National OBS Instrument Pool (OBSIP) will be used during the cruise. This type of OBS has a height of ~1 m and a maximum diameter of 50 cm. The anchor is an iron plate weighing ~40 kg with dimensions ~30×30×8 cm.

Once an OBS is ready to be retrieved, an acoustic release transponder interrogates the instrument at a frequency of 9–11 kHz, and a response is received at a frequency of 9–13 kHz. The burn-wire release assembly is then activated, and the instrument is released from the anchor to float to the surface.

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

(3) Monitoring and Mitigation Measures

Marine mammals and sea turtles are known to occur in the proposed survey area. However, the number of individual animals expected to be approached closely during the proposed activities will be relatively small in relation to regional population sizes. With the proposed monitoring and mitigation provisions, potential effects on most if not all individuals are expected to be limited to minor behavioral disturbance. Those potential effects are expected to have negligible impacts both on individual marine mammals and on the associated species and stocks.

To minimize the likelihood that potential impacts could occur to the species and stocks, airgun operations will be conducted in accordance with all applicable U.S. federal regulations and IHA requirements. The proposed seismic activities will take place in the U.S. EEZ.

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

(a) Visual Monitoring

Vessel-based Protected Species Observer (PSO) observations will take place during daytime airgun operations and nighttime start ups of the airguns. Airgun operations will be suspended when marine mammals or turtles are observed within, or about to enter, designated exclusion zones [see subsection (e) below] where there is concern about potential effects on hearing or other physical effects. PSOs will also watch for marine mammals and turtles around the seismic vessel for at least 30 minutes prior to the start of seismic operations after an extended shutdown. When feasible, PSOs will also make observations during daytime periods when the seismic system is not operating for comparison of animal abundance and behavior.

Two professional PSOs will be appointed by USGS, with NMFS Office of Protected Resources concurrence. At least two of the USGS personnel aboard the ship will also be on the approved PSO list and will be available to cover work breaks by the professional PSOs. At least one PSO will monitor the EZ during seismic operations. PSOs will normally work in shifts of 4-hour duration or less. The total hours of daylight, including periods before dawn and just after dusk, will not exceed 14 hours during the cruise, and two professional PSOs supplemented by trained USGS personnel should be able to fully cover PSO needs. The vessel crew will also be instructed to assist in detecting marine mammals and turtles.

The *Pelican* will serve as the platform from which PSOs will watch for mammals and sea turtles before and during GI airgun operations. Two locations are likely as observation stations onboard the *Pelican*. At the aft control station on the upper deck (01 level), the eye level will be ~12 m above sea level and the location will offer a ~210° view aft of the vessel centered on the air gun source location for one observer. At the bridge station, the eye level will be ~13 m above sea level and the location will offer a full 360° view.

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

(b) PSO Data and Documentation

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

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

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

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

All observations, as well as information regarding seismic source shutdown, will be recorded in a standardized format. Data accuracy will be verified by the PSOs at sea, and preliminary reports will be prepared during the field program. Summaries will be forwarded to the designated personnel at the USGS (if possible given communications and network availability) after the seismic work at each of the two sites is complete. PSO observations will provide the following information:

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

(c) Reporting

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.

(d) Proposed Exclusion Zones

Received sound levels have been modeled by Lamont-Doherty Earth Observatory of Columbia University (L-DEO) for a number of airgun configurations, including two 105-in^3 GI Guns, in relation to distance and direction from the airguns (Fig. 2). The model does not allow for bottom interactions, and is most directly applicable to deep water. Based on the modeling, estimates of the maximum distances from the GI airguns where sound levels of 190, 180, and 160 dB re 1 μPa_{rms} are predicted to be received in deep (>1000-m) water are shown in Table 1. Received sound levels have not been modeled for the single 35-in^3 GI gun or the 6-kJ sparker, but maximum distances for those sources would be much lower than

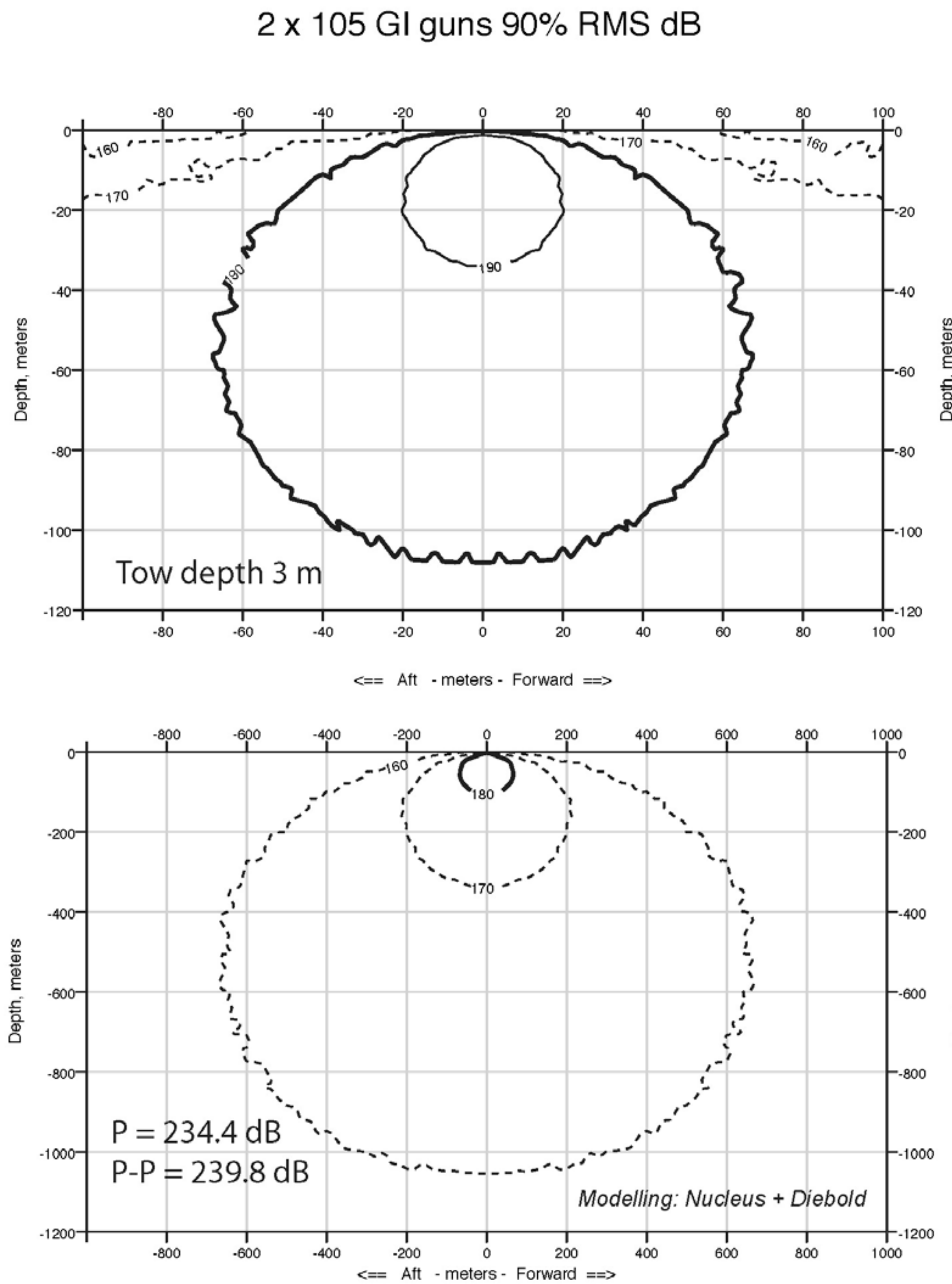

FIGURE 2. Modeled received sound levels from two 105-in^3 GI airguns that will be used during the USGS survey in the northwest GOM during April–May 2013. Model results provided by the Lamont-Doherty Earth Observatory of Columbia University (L-DEO).

TABLE 1. Distances to which sound levels ≥190, 180, and 160 dB re 1 μPa_{rms} could be received from two 105-in^3 GI airguns that will be used during the proposed seismic survey in the northwest GOM during April–May 2013. Distances are based on model results provided by L-DEO.

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

those for the two 105-in^3 GI guns. We will use the results for the two 105-in^3 GI guns for all seismic lines, resulting in conservative (precautionary) results when the smaller sources are used.

Empirical data concerning the 190-, 180-, 170- and 160-dB distances were acquired for various airgun arrays based on measurements during the acoustic verification studies conducted by L DEO in the northern Gulf of Mexico in 2003 (6-, 10-, 12-, and 20-airgun arrays, and 2 GI airguns; Tolstoy et al. 2004) and 2007–2008 (36-airgun array; Tolstoy et al. 2009). Results for the 36-airgun array are not relevant for the 2 GI airguns to be used in the proposed survey. The empirical data for the 6-, 10-, 12-, and 20-airgun arrays indicate that, for deep water (>1000 m), the L-DEO model tends to overestimate the received sound levels at a given distance (Tolstoy et al. 2004). Measurements were not made for the 2 GI airgun array in deep water, however, we propose to use the safety radii predicted by LDEO's model for the proposed GI airgun operations in deep water, although they are likely conservative given the empirical results for the other arrays. Table 1 shows the distances at which three rms sound levels are expected to be received from the GI airguns. The 180- and 190-dB re 1 μPa_{rms} distances are the safety criteria as specified by NMFS (2000) and are applicable to cetaceans and pinnipeds, respectively. The 180-dB distance will also be used as the exclusion zone for sea turtles, as required by NMFS in most other recent seismic projects (e.g., Smultea et al. 2004; Holst et al. 2005; Holst and Beland 2008; Holst and Smultea 2008; Hauser et al. 2008). If marine mammals or sea turtles are detected within or about to enter the appropriate exclusion zone, the airguns will be shut down immediately.

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

(e) Mitigation During Operations

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

Speed or course alteration

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

Shut-down procedures

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

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

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

Ramp-up procedures

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

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

Alternative Action: Another Time

An alternative to issuing the IHA for the period requested and to conducting the project then, is to issue the IHA for another time and to conduct the project at that alternative time. The proposed time for the cruise in April–May 2013 is the most suitable time logistically for the R/V *Pelican* and the participating scientists and provides a good weather window. If the IHA is issued for another period, it could result in significant delay and disruption not only of this cruise, but of additional studies that are planned on the R/V *Pelican* for 2013 and beyond. An evaluation of the effects of this alternative action is given in § IV.

No Action Alternative

An alternative to conducting the proposed activities is the "No Action" alternative, i.e., do not issue an IHA and do not conduct the research operations. If the research is not conducted, the "No Action" alternative would result in no disturbance to marine mammals due to the proposed activities.

The goal of the proposed research is to develop technology and to collect data to assist in the characterization of marine gas hydrates in order to better understand their potential as an energy resource. These sites have been extensively studied, including detailed LWD, and are known to hold thick sequences of sand containing high saturations of gas hydrate. The purpose of this new seismic acquisition is to expand outward from the boreholes the detailed characterization that has been accomplished there, and to develop and calibrate improved geophysical techniques for gas hydrate characterization.

The "No Action" alternative could also, in some circumstances, result in significant delay of other studies that are planned on the R/V *Pelican* for 2013 and beyond, depending on the timing of the decision. Not conducting this cruise (no action) would result in less data and support for the academic institutions involved. Data collection is an essential first step for a much greater effort to analyze and report information for the significant topics indicated. The field effort provides material for years of analyses involving multiple professors, students, and technicians. The lost opportunity to collect valuable scientific information is compounded by lost opportunities for support of research infrastructure, training, and professional career growth.

III. Affected Environment

Oceanography

The GOM is a dynamic water body, being mainly driven by the Loop Current. The Loop Current is a clockwise water-mass movement, which essentially consists of warm water from the Yucatan Current coming from the Caribbean Sea to the south, which then loops northward and then eastward, exiting as the Florida Current. Extensions of the Loop Current are sometimes pinched off, and form anticyclonic (warm-core) eddies, which dissipate into the western part of the Gulf. These eddies are countered by cyclonic (cold-core) eddies. Interaction between these two types of eddies results in waters being mixed, which in turn can increase biologically productivity by bringing nutrient-rich cold waters from below to mix with surface waters. These eddies can also bring nutrient-rich waters from the shelf to mix with waters from the open Gulf (Würsig et al. 2000).

The freshwater inflow from the Mississippi River also has a great impact on the northern Gulf (Davis et al. 2002). The highest discharge occurs from March through May, whereas the lowest flow occurs from August through October. This freshwater inflow affects the distribution of primary and secondary production in the northern Gulf (Davis et al. 2002). The input of nutrients increases phytoplankton production and thus supports increased zooplankton productivity (Lohrenz et al. 1990; Biggs 1992). The offshore waters where the survey areas are located have a relatively low annual mean primary productivity rate of <500 $mgCm^{-2}day^{-1}$ (Sea Around Us Project 2012).

Protected Areas

Marine protected areas (MPAs) in the GOM are described and mapped in § 3.9.1.1.1 of the Final 2012–2017 OCS Oil and Gas Leasing Program Programmatic Environmental Impact Statement (PEIS) (BOEM 2012). The only offshore MPA, the Flower Garden Banks National Marine Sanctuary, occurs ~300 km northwest of the western survey area.

Marine Mammals

Twenty-eight cetacean species and one species of manatee are known to occur in the GOM (Jefferson and Schiro 1997; Würsig et al. 2000; Jefferson et al. 2008; Table 2). Seven of these species are listed as endangered under the ESA (the sperm, North Atlantic right, humpback, sei, fin, and blue whales, and the West Indian manatee). However, of those species, only sperm whales are likely to be encountered

TABLE 2. The habitat, occurrence, estimated abundance, and conservation status of marine mammals that are known to occur in the Gulf of Mexico.

Species	Occurrence in Gulf of Mexico[1]	Abundance in Gulf or North Atlantic[2]	U.S. ESA[3]	IUCN[4]	CITES[5]
Mysticetes Bryde's whale	Uncommon	15[6], *90,000*[7]	NL	DD	I
Odontocetes Sperm whale	Common	1665[6], *13,190*[8]	EN	VU	I
Pygmy sperm whale	Common	453[6,9], *395*[10,9]	NL	DD	II
Dwarf sperm whale					
Cuvier's beaked whale	Rare	65[6], *3513*[10,11]	NL	LC	II
Gervais' beaked whale	Uncommon	57[6], *3513*[10,11]	NL	DD	II
Blainville's beaked whale	Rare		NL	DD	II
Rough-toothed dolphin	Common	1508[6], *2653*[12]	NL	LC	II
Bottlenose dolphin	Common	3708[6], *81,588*[10,13]	NL[§]	LC	II
Pantropical spotted dolphin	Common	34,067[6], *4439*[10]	NL	LC	II
Atlantic spotted dolphin	Common	37,786[12], *50,978*[10]	NL	DD	II
Spinner dolphin	Common	1989[6]	NL	DD	II
Clymene dolphin	Common	6575[6]	NL	DD	II
Striped dolphin	Common	3325[6], *94,462*[10]	NL	LC	II
Fraser's dolphin	Rare	726[14]	NL	LC	II
Risso's dolphin	Common	1589[6], *20,479*[10]	NL	LC	II
Melon-headed whale	Common	2283[6]	NL	LC	II
Pygmy killer whale	Uncommon	323[6]	NL	DD	II
False killer whale	Uncommon	777[6]	NL	DD	II
Killer whale	Uncommon	49[6]	NL	DD	II
Short-finned pilot whale	Common	716[6], *24,674*[10]	NL*	DD	II
Sirenian West Indian manatee	Common (FL), rare elsewhere	3802[15]	EN	EN	I

N.A. - Data not available or species status was not assessed.
[1] Occurrence from Würsig et al. (2000).
[2] Estimate for North Atlantic (and outside of Gulf) populations shown in italics.
[3] Endangered Species Act: EN = Endangered, T = Threatened, NL = Not listed.
[4] IUCN (International Union for Conservation of Nature and Natural Resources) Red List of Threatened Species (IUCN 2011). EN = Endangered; VU = vulnerable; LC = Least Concern; DD = Data Deficient.
[5] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2011). Appendix I=Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled.
[6] Abundance estimate for the oceanic northern U.S. Gulf of Mexico, 2003–2004 (Mullin 2007)
[7] World population estimate (ACS 2005).
[8] *g*(o) corrected total estimate for the Northeast Atlantic, Faeroes-Iceland, and the U.S. east coast (Whitehead 2002).
[9] Estimate for *Kogia* sp.
[10] Abundance estimate for U.S. Western North Atlantic stock (Waring et al. 2010).
[11] This estimate is for *Mesoplodon* and *Ziphius* spp. combined.
[12] Abundance estimate for the northern Gulf of Mexico stock, outer continental shelf and oceanic (Waring et al. 2010).
[13] Abundance estimate is for the Western North Atlantic offshore stock (Waring et al. 2010).
[14] Abundance estimate for the northern Gulf of Mexico oceanic waters from 1996 to 2001 (Mullin and Fulling 2004)

[15] Best available estimate for Florida stock (Waring et al. 2010).

in the survey area. In addition to the 28 species known to occur in the GOM, another three species of cetaceans could potentially occur there: the long-finned pilot whale, the long-beaked common dolphin, and the short-beaked common dolphin. There are no confirmed sightings of these species in the GOM, although they have been seen close to the GOM and could eventually be found there (Würsig et al. 2000). Those species are not considered further here. Also, 7 of the 28 species—the North Atlantic right, humpback, minke, sei, fin, blue, and Sowerby's beaked whales—are considered sufficiently rare that BOEMRE (2011) concluded that no potential effect from seismic surveys is expected. Those species are also not considered further here. Manatees are very unlikely to be encountered in or near the deep offshore waters of Keathley Canyon. No species of pinnipeds are known to occur regularly in the Gulf of Mexico and any pinniped sighted in the study area would be extralimital.

General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities are given in § 3.6.1 and § 3.7.1 of the Final Programmatic Environmental Impact Statement (EIS)/Overseas Environmental Impact Statement (OEIS) (hereafter called NSF/USGS PEIS) for Marine Seismic Research funded by the National Science Foundation or Conducted by the U.S. Geological Survey. The rest of this section deals specifically with their distribution in the GOM.

In general, cetaceans in the GOM appear to be partitioned by habitat preferences likely related to prey distribution (Baumgartner et al. 2001). Most species in the northern Gulf are concentrated along the upper continental slope in or near areas of cyclonic circulation in waters 200–1000 m deep. Species sighted regularly in these waters include Risso's dolphin, the rough-toothed, spinner, striped, pantropical spotted, and Clymene dolphins, short-finned pilot whales, pygmy and dwarf sperm whales, sperm whales, beaked whales of the genus *Mesoplodon*, and unidentified beaked whales (Davis et al. 1998). In contrast, continental shelf waters (<200 m deep) are primarily inhabited by two species: the bottlenose and Atlantic spotted dolphins (Davis et al. 2000, 2002; Mullin and Fulling 2004). Bottlenose dolphins are also found in deeper waters (Baumgartner et al. 2001). There appears to be a resident population of sperm whales within 100 km of the Mississippi River delta (Davis et al. 2002).

The following text contains descriptions of the distribution of marine mammal species in the GOM. The known and likely occurrence of marine mammals in and near the study area is assessed based primarily from results of the "GulfCet" aerial and shipboard surveys (Davis and Fargion 1996), from shipboard surveys during spring and summer (Fulling et al. 2003; Mullin 2007), and from a comprehensive sighting compilation for U.S. Navy operating areas in the Gulf of Mexico (DoN 2007a).

(1) Mysticetes

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

Bryde's whale is considered uncommon in the Gulf of Mexico, although is the only baleen whale that occurs there on a regular basis throughout the year (Würsig et al. 2000). It can be pelagic or coastal (Jefferson et al. 2008). In the northern Gulf, all Bryde's whale sightings reported by Davis et al. (1998, 2002) were in relatively shallow water, although Mullin and Fulling (2004) reported four sightings in northeast slope waters, where depths were 200–2000 m. Two Bryde's whale sightings have also been reported in waters >200 m deep during spring–summer surveys in 2003–2004 (Mullin 2007). Almost all sightings occur in or near the De Soto Canyon and the West Florida Terrace during spring (DoN 2007a). One sighting, in spring, was recorded near the proposed survey area (DoN 2007a).

(2) Odontocetes

Sperm Whale (*Physeter macrocephalus*)

The sperm whale is considered common in the GOM. It the most abundant large whale there (Würsig et al. 2000) and is the cetacean species most likely to be encountered in the study area in all seasons. NMFS provisionally considers the sperm whale population in the northern GOM as a stock distinct from the U.S. Atlantic stock (Waring et al. 2010). Recent analysis of movement patterns, genetic structure, photo-identification data, and vocalizations support the distinct stock concept (Jochens et al. 2008).

Baumgartner et al. (2001) and Davis et al. (2002) noted that in the Gulf, sperm whales are most often seen along the lower continental slope in water depths >1000 m. Mate and Ortega-Ortiz (2004) reported that most of the sperm whales that they satellite-tagged frequented waters 700–1000 m deep, although some were seen in waters >3000 m deep. Mate and Ortega-Ortiz (2004) suggested that there could be an offshore deep-water stock as well as a nearshore-slope population.

Sperm whales occur in the Gulf year-round (Mate and Ortega-Ortiz 2004; Mullin et al. 2004), and site fidelity has been suggested to be high (Weller et al. 2000; Jochens et al. 2008). The most common months for sperm whale sightings are spring and summer; however, there is no definitive seasonal distribution pattern (Jefferson and Schiro 1997; Mullin et al. 2004). The lower number of fall and winter sightings for sperm whales and several other species could be a result at least in part of reduced effort and/or poorer sighting conditions in those seasons. The seasonal distribution of sperm whales in the Gulf of Mexico could be affected by individual variability or year-to-year variation in the environment, such as an El Niño event, as well as individual variability (Mate 2003).

Concentrations of sperm whales occur south of the Mississippi River Delta, where upwelling is known to occur (Mullin et al. 1991; Mullin and Hoggard 2000; Würsig et al. 2000; Biggs et al. 2003), and ~300 km east of the Texas–Mexico border (Würsig et al. 2000). Satellite-tagged sperm whales were tracked from the DeSoto Canyon in the northeastern Gulf along the slope edge to the Texas/Mexico border (Mate and Ortega-Ortiz 2004). Several tagged animals traversed deep waters and visited the Gulf of Campeche, Mexico, and the northwest coast of Cuba (Mate 2003; Mate and Ortega-Ortiz 2004). Identified sperm whales in the GOM have been resighted after periods of several years within a few miles of their original locations (e.g., Weller et al. 2000), although Jochens et al. (2008) reported that the median distance between resightings in the study area for the sperm whale seismic study was ~72 km.

Sperm whales have been sighted near the proposed survey areas in all seasons (Davis and Fargion 1996; DoN 2007a).

Pygmy Sperm Whale (*Kogia breviceps*)

The pygmy sperm whale is considered common in the GOM, and occurs there year-round (Würsig et al. 2000; Mullin et al. 2004). It strands frequently along the coast of the Gulf, especially in autumn and winter; this may be associated with calving (Würsig et al. 2000). In the northern Gulf, pygmy sperm whales are typically sighted in waters 100–2000 m deep (Würsig et al. 2000). Würsig et al. (2000) noted that densities of pygmy sperm whales were highest in spring and summer and lower in fall and winter. Sightings are primarily along the continental shelf break and over the continental slope (Davis et al. 1998; Baumgartner et al. 2001). The species has been sighted near the proposed survey areas during winter, spring, and summer (DoN 2007a). There is an area of predicted high SPUE (sightings per unit effort) during summer near ~26.8ºN, 91.4ºW, which likely reflects a cluster of sightings at a concentrated food resource at one time rather than a recurring area of concentration for *Kogia* spp. (DoN 2007a).

Dwarf Sperm Whale (*Kogia sima*)

The dwarf sperm whale is thought to be common in the GOM (Würsig et al. 2000). It strands frequently along the coast, but not as frequently as the pygmy sperm whale (Würsig et al. 2000). Mullin et al. (2004) reported year-round sightings of this species in the Gulf. Sightings are primarily along the continental shelf edge and over deeper waters off the shelf (Hansen et al. 1994; Davis et al. 1998). During GulfCet surveys in 1992–1994, dwarf sperm whales were sighted near the proposed survey areas during spring and summer (Davis and Fargion 1996). DoN (2007a) reported the highest numbers of *Kogia* spp. sightings in spring and summer. The lack of sightings in the area during fall and winter could reflect the low level of effort during those seasons.

Cuvier's Beaked Whale (*Ziphius cavirostris*)

In the GOM, beaked whale sightings have occurred in water depths 420–3487 m (Ward et al. 2005 *in* DoN 2007a). The northern Gulf continental shelf has been described as a 'key area' for beaked whales (MacLeod and Mitchell 2006).

Cuvier's beaked whale is considered rare in the GOM. During GulfCet surveys, Cuvier's beaked whales have been sighted on the lower continental slope, where depths are ~2000 m (Davis and Fargion 1996; Mullin and Hoggard 2000). Cuvier's beaked whale has been sighted in all seasons in the Gulf, including waters near the proposed survey areas during spring (Davis and Fargion 1996; DoN 2007a). Most Cuvier's beaked whale strandings in the Gulf are in the eastern area, especially Florida (Würsig et al. 2000). Causes of strandings in the Gulf are unknown, but they could include old age, illness, disease, pollution, exposure to certain strong noises, and perhaps geomagnetic disturbance.

Gervais' Beaked Whale (*Mesoplodon europaeus*)

Gervais' beaked whale is considered uncommon in the Gulf of Mexico. It is mainly oceanic and occurs in tropical and warmer temperate waters of the Atlantic Ocean including the Gulf (Jefferson et al. 2008). Its distribution is primarily known from stranding records. Strandings may be associated with calving, which takes place in shallow water (Würsig et al. 2000). This species has only rarely been identified positively at sea, and then mostly in the eastern Atlantic; however, in the Gulf, many *Mesoplodon* sightings are believed to have been Gervais' beaked whale (Jefferson et al. 2008). Gervais' beaked whale strandings were reported for western Florida, Texas, the northeastern Gulf, Cuba, and southern Mexico (Würsig et al. 2000). However, most records for the Gervais' beaked whale are from Florida (Debrot and Barros 1992). The species has been sighted during spring off the southern end of the West Florida Shelf (DoN 2007a). It has not been documented near the proposed survey areas, although there have been a number of unidentified beaked whale sightings there in all seasons that could potentially have been this species (DoN 2007a).

Blainville's Beaked Whale (*Mesoplodon densirostris*)

Blainville's beaked whale is considered rare in the GOM. Knowledge of Blainville's beaked whale distribution there is mainly derived from strandings, although there have been a number of visual sightings during spring (DoN 2007a). Stranding records exist for Texas, Louisiana, Mississippi/Alabama, and Florida (Würsig et al. 2000) and the Yucatán (Ortega-Ortiz 2002). It has been sighted in the northern Gulf (Würsig et al. 2000) and near the proposed survey areas during spring (Davis and Fargion 1996; DoN 2007a).

Rough-toothed Dolphin (*Steno bredanensis*)

The rough-toothed dolphin is considered common in the GOM. It has been sighted throughout the northern Gulf in waters >200 m deep (DoN 2007a). It has been sighted in the Gulf during all seasons, with more sightings in spring and summer (Mullin et al. 2004; DoN 2007a). The number of sightings is high on the West Florida Shelf (DoN 2007a). Rough-toothed dolphins usually inhabit deep waters, but at least in late summer/early autumn, they also occur in continental shelf waters in the northern Gulf (Fulling et al. 2003). Rough-toothed dolphins have been sighted near the proposed survey areas during spring and summer (DoN 2007a).

Common Bottlenose Dolphin (*Tursiops truncatus*)

The bottlenose dolphin is considered common in the GOM. Bottlenose dolphins in the northern GOM are thought to consist of 35 inshore or coastal stocks in waters <20 m, a continental shelf stock, and an oceanic stock (Waring et al. 2011). In the Gulf, the oceanic population occurs in deep, offshore waters over the continental shelf (Würsig et al. 2000). In oceanic waters (>200 m), Mullin (2007) reported an overall density of ~1/100 km^2, with much higher density in the NE slope (5/100 km^2) than the NW slope waters (0.35/100 km^2) or deep water (0; Mullin 2007).

Although bottlenose dolphins occur year-round, seasonal variation in abundance has been reported. Hubard et al. (2004) reported this for the Mississippi Sound area, with lower densities in fall than in summer. Similarly, Shane (2004) noted that sighting rates were highest during spring in southwestern Florida. Site fidelity has also been noted for this species (Hubard et al. 2004; Irwin and Würsig 2004). It has been sighted near the proposed survey areas during spring, summer, and fall (Davis and Fargion 1996; DoN 2007a).

Pantropical Spotted Dolphin (*Stenella attenuata*)

The pantropical spotted dolphin is considered common in the GOM. It is the most common species of cetacean in deep waters of the GOM (Davis and Fargion 1996; Würsig et al. 2000), and is rare over the continental shelf or continental shelf edge (Davis et al. 1998). It was the most abundant species during spring and summer surveys in oceanic waters (>200 m deep) in the GOM, with densities of 24/100 km^2 in 1996–2001 (Mullin and Fulling 2004) and 9/100 km^2 in 2003–2004 (Mullin 2007). Fairfield-Walsh et al. (2005) also reported this as the most frequently sighted cetacean in the eastern Gulf in waters >200 m deep. During 1989–1997, it was mainly seen in the north-central Gulf from south of the Mississippi Delta to west of Florida (Würsig et al. 2000). There is a predicted area of high SPUE during spring at ~26ºN, 89ºW (DoN 2007a), southeast of the proposed survey areas. This species has been sighted in the Gulf year-round with fewest sightings in fall (Mullin et al. 2004). It has been sighted during all seasons in or near the proposed survey area (DoN 2007a).

Atlantic Spotted Dolphin (*Stenella frontalis*)

The Atlantic spotted dolphin is considered common in the GOM (Würsig et al. 2000). It usually inhabits shallow waters on the continental shelf inshore of the 250-m isobath (Davis et al. 1998, 2002; Fulling et al. 2003). Although spotted dolphins occur year-round, Griffin and Griffin (2004) reported significant seasonal variations in densities along the continental shelf. Griffin and Griffin (2004) and Griffin et al. (2005) reported that abundance was lower in nearshore waters during summer, and densities were higher during winter. Highest densities occur during summer on the West Florida Shelf (DoN 2007a). Fulling et al. (2003) reported that the Atlantic spotted dolphin was the most abundant species sighted during a survey in waters 20–200 m deep, with higher densities in the northeast Gulf (20/100 km^2) than in the northwest Gulf (3/100 km^2). None were sighted in waters >200 m deep during shipboard surveys in spring and summer 2003–2004 (Mullin 2007). However, other authors report that the species has been sighted near the proposed survey areas during spring (Davis and Fargion 1996).

Spinner Dolphin (*Stenella longirostris*)

The spinner dolphin is considered common in the GOM. It typically inhabits deep water (Davis et al. 1998). Almost all sightings occurred east and southeast of the Mississippi Delta, in waters deeper than 100 m (Würsig et al. 2000). Mullin and Fulling (2004) reported a density of ~3/100 km^2 in oceanic waters (>200 m deep). No spinner dolphins were sighted over the NW Slope during spring/summer shipboard surveys in 2003–2004 (Mullin 2007). Spinner dolphins have not been sighted near the proposed survey areas (Davis and Fargion 1996; DoN 2007a). The highest predicted SPUE occurs in the De Soto Canyon and on the West Florida Shelf (DoN 2007a).

Clymene Dolphin (*Stenella clymene*)

The Clymene dolphin is considered common in the GOM. It is widely distributed in the western oceanic GOM during spring, and in the northeastern Gulf during summer and winter (Würsig et al. 2000). Mullin and Fulling (2004) also reported that it was sighted primarily in the western Gulf in the spring, with an estimated density of ~5/100 km^2. All sightings during spring and summer shipboard surveys in 2003–2004 were over the NW slope and in abyssal waters (Mullin 2007). Clymene dolphins inhabit areas where water depths range from 704 to 4500 m or deeper (Mullin et al. 1994a; Davis et al. 1998; Culik 2002; Fertl et al. 2003). Clymene dolphins have been sighted near the proposed survey areas during winter, spring, and summer (DoN 2007a).

Striped Dolphin (*Stenella coeruleoalba*)

The striped dolphin is considered common in the GOM. It is pelagic and seems to prefer deep water along and seaward of the edge of the continental shelf (Davis et al. 1998). Mullin (2007) reported a mean density of ~1/100 km^2 for oceanic Gulf waters (>200 m deep). The density was higher over the NE Slope (~2/100 km^2) than over the NW Slope (0.2/100 km^2). The species has been sighted in winter and spring near the proposed survey areas (Davis and Fargion 1996; DoN 2007a). The area of highest SPUE is predicted for the De Soto Canyon. A second area of high density was predicted over the abyssal plain at ~26.5ºN, 89ºW during spring (DoN 2007a).

Fraser's Dolphin (*Lagenodelphis hosei*)

Fraser's dolphin is considered rare in the GOM. The distribution of Fraser's dolphin in the Atlantic and its adjacent seas is poorly known, but it is believed to be most abundant in the deep water of the GOM (Dolar 2009). Fraser's dolphins have been sighted in the northwestern Gulf and have been found stranded in Florida and Texas (Würsig et al. 2000). A density of 0.2/100 km^2 was estimated for oceanic waters of the Gulf (Mullin and Fulling 2004). Sightings occurred in winter and spring (Mullin et al. 2004). Of the few sightings recorded in the Gulf, some have been near the proposed survey areas in spring and summer (Davis and Fargion 1996; DoN 2007a).

Risso's Dolphin (*Grampus griseus*)

Risso's dolphin is considered common in the GOM. It has been sighted off Florida and in the western Gulf off the coast of Texas, and stranding records also exist for Texas and Florida (Würsig et al. 2000). Mullin et al. (2004) reported sightings in the Gulf during all seasons, with the highest number of sightings in winter and spring.

Risso's dolphins usually occur on the upper continental slope, in waters 200–1530 m deep (Baumgartner 1997; Davis et al. 1998; Würsig et al. 2000). In recent years, most sightings in the northern Gulf were in water ~200 m deep south of the Mississippi Delta (Würsig et al. 2000). Mullin (2007) reported a density of 1.3/100 km^2 in the NE Slope waters >200 m deep, and 0.30/100 km^2 in the NW Slope waters. The species has been sighted in waters up to 2088 m depth (Mullin et al. 2004). A small area of high density is predicted off the southeast edge of the West Florida Terrace (~26ºN, 84ºW) during summer and fall (DoN 2007a). Risso's dolphins have been sighted near the proposed survey areas in winter, spring, and summer (DoN 2007a).

Melon-headed Whale (*Peponocephala electra*)

The melon-headed whale is considered common in the GOM, mainly in the northwest from Texas to Mississippi (Würsig et al. 2000). Mullin and Fulling (2004) reported three sightings west of Mobile Bay, Alabama, during spring surveys. In the Gulf, they usually occur in water >200 m deep and away from the continental shelf (Mullin et al. 1994b; Würsig et al. 2000). The melon-headed whale has been sighted near the proposed survey areas in all seasons (Davis and Fargion 1996; DoN 2007a).

Pygmy Killer Whale (*Feresa attenuata*)

The pygmy killer whale is considered uncommon in the GOM. Strandings have been reported from Florida to Texas, mostly in the winter (Würsig et al. 2000). Sightings occur year-round in the Gulf (DoN 2007a), including off Texas and in the west-central portion of the northern Gulf in water 500–1000 m deep (Würsig et al. 2000). The pygmy killer whale has been sighted near the proposed survey areas during spring (DoN 2007a).

False Killer Whale (*Pseudorca crassidens*)

The false killer whale is considered uncommon in the GOM, where it has been sighted in the northern Gulf, especially in the eastern regions, during spring (Mullin and Hoggard 2000; DoN 2007a; Mullin 2007) and in the deep waters of the western Gulf during late winter/early spring (Vázquez Castán et al. 2009). Würsig et al. (2000) noted that they typically occur in waters 200–2000 m deep. Mullin and Fulling (2004) reported that they were only seen east of Mobile Bay, Alabama (~88ºW). Sightings have been reported near the proposed survey areas during spring and summer (Davis and Fargion 1996).

Killer Whale (*Orcinus orca*)

The killer whale is considered uncommon in the GOM. It appears to prefer coastal areas, but is also known to occur in deep water (Dahlheim and Heyning 1999; Mullin 2007). Most sightings have been in 200–2000 m depths southwest of the Mississippi Delta (Würsig et al. 2000). Mullin and Fulling (2004) reported five sightings in the northwestern Gulf during the spring and one sighting during summer. No sightings have been reported for fall or winter (DoN 2007a). One sighting has been reported near the proposed survey areas during spring (DoN 2007a).

Short-finned Pilot Whale (*Globicephala macrorhynchus*)

The short-finned pilot whale is considered common in the GOM. It occurs year-round and is known to strand frequently (Mullin et al. 2004). The species is generally found in deep water at the edge of the continental shelf and over deep submarine canyons (Davis et al. 1998; Jefferson et al. 2008). In the northern Gulf, it is most commonly seen in the central and western areas in waters 200–1000 m deep, i.e., along the continental slope (Würsig et al. 2000), although it has also been sighted in waters 1876 m deep (Mullin et al. 2004). Mullin and Fulling (2004) noted that, during a spring survey, short-finned pilot whales were primarily seen west of Mobile Bay, Alabama (~88ºW). There is a predicted area of high SPUE during winter at ~27ºN, 96ºW (DoN 2007a). This species has been sighted near the proposed survey areas during all seasons (Davis and Fargion 1996; DoN 2007a).

(3) Other Marine Mammals

West Indian Manatee (*Trichechus manatus*)

The West Indian manatee is common in Florida and rare elsewhere in the Gulf of Mexico. It has a patchy coastal distribution that is dependent on suitable habitat. The West Indian manatee is subdivided into two subspecies, the Florida manatee (*Trichechus manatus latirostris*) and the Antillean manatee (*T. m. manatus*). The Florida manatee occurs in the northern Gulf of Mexico, and the Antillean manatee is found in the southern Gulf. Except along the Florida coast, manatees are considered rare in the Gulf of Mexico (Würsig et al. 2000). Nonetheless, there has been a recent increase in manatee sightings for waters off Alabama, Louisiana, Mississippi, and Texas (Fertl et al. 2005). Fertl et al. (2005) considered all historical and recent records (up to August 2004) and found that all sightings were shoreward of the 20-m isobath. Manatees are very unlikely to occur in the deep waters of the proposed survey areas.

Sea Turtles

Five species of sea turtles, all of which are considered under the ESA to be ***endangered*** or ***threatened***, occur in the GOM. The olive ridley turtle (*Lepidochelys olivacea*) has never been sighted in the Gulf but its presence has been confirmed by genetic analysis of stranded carcasses in the Gulf (Foley et al. 2003). General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of sea turtles are given in § 3.4.1 of the NSF/USGS PEIS. The rest of this section deals specifically with their distribution in the GOM.

Of the five species, three (hawksbill, Kemp's ridley, and green, all ***endangered***) are not expected to be common in the deep waters characteristic of the survey areas. No hawksbill, Kemp's ridley, or green sea turtles have been reported as bycatch in the GOM pelagic longline fishery (Garrison 2003, 2005; Walsh and Garrison 2006). Hawksbill turtles, the most tropical of the group, are closely associated with shallow (<20 m deep) coral reefs and other hard-bottom habitats. They also use inlets, bays, and coastal lagoons, i.e., shallow-water habitats. Similarly, the green turtle is mainly a herbivorous species. Its distribution is closely allied with seagrass beds and other coastal habitats supporting macroalgae. Kemp's ridley is also a coastal species that uses nearshore coastal waters as its principal foraging and developmental habitat. All three species, however, might occasionally occur in the survey areas as either pelagic-stage juveniles or as adults migrating between foraging and nesting areas. Abundances of these three species would be expected to be very low in the survey areas.

The other two species of sea turtles occurring in the GOM, the leatherback (***endangered***) and loggerhead (***threatened***) turtles, are more common in deep waters. Leatherback turtles are the most pelagic of the sea turtles and are regularly taken in the study area as bycatch in the GOM pelagic longline fishery (Garrison 2003, 2005; Walsh and Garrison 2006). Leatherbacks use the deep, offshore waters of the GOM for feeding, resting, and as migratory corridors (Davis et al. 2000). Available sighting and fisheries bycatch records mapped in DoN (2007a) show no leatherback sightings in the immediate area of the proposed surveys, but several nearby, only in summer and fall.

Loggerhead turtles have been observed routinely in deep waters of the shelf and continental slope of the Gulf. They are also taken in the study area as longline bycatch but their numbers are far lower than those of leatherbacks. Available sighting and fisheries bycatch records mapped in DoN (2007a) show no loggerhead sightings in the immediate area of the proposed surveys, but several nearby, only in summer and fall.

Seabirds

The only ESA-listed seabird that occurs in the GOM is the roseate tern, which is listed as ***endangered*** for populations along the U.S. Atlantic Coast from Maine to North Carolina and ***threatened*** in Florida (BOEM 2012). The species commonly occurs in oceanic waters, but in the northern GOM it has only been reported at the extreme southwest tip of Florida.

Fish, Essential Fish Habitat, and Habitat Areas of Particular Concern

There are two ESA-listed fish species in the GOM: the Gulf sturgeon *Acipenser oxyrinchus desotoi* (***threatened***) and the smalltooth sawfish *Pristis pectinata* (***endangered***). The Gulf sturgeon is anadromous (spawns in freshwater and feeds in estuarine/marine waters). When in marine waters, it usually occurs near the mouths of rivers and in bays, and is thought to remain in nearshore waters with depths <10 m when it overwinters in marine waters (USFWS and NOAA 2003). The smalltooth sawfish usually occurs in shallow subtropical-tropical estuarine and marine waters, but can also be found in large rivers; smaller individuals typically stay close to shore in water depths <1 m, whereas larger individuals occur in deeper water, as deep as 122 m (DoN 2007a).

DoN (2007a) provided maps of Habitats of Particular Concern (HAPC) and Essential Fish Habitat (EFH) as designated by the Gulf of Mexico Fishery Management Council (GMFMC) for all life stages of all managed species from the coastal migratory pelagics, reef fish, coral and coral reef, red drum, shrimp, spiny lobster, and stone crab Fishery Management Plans (FMPs). All HAPCs and EFH are on the continental shelf or just beyond the shelf break, which is at ~200 m depth.

IV. ENVIRONMENTAL CONSEQUENCES

Proposed Action

(1) Direct Effects on Marine Mammals and Sea Turtles and Their Significance

The material in this section includes a brief summary of the anticipated potential effects (or lack thereof) on marine mammals and sea turtles of the airgun system to be used by USGS. A more comprehensive review of the relevant background information appears in § 3.4.1, § 3.6.4.3, § 3.7.4.3, and Appendix E of the NSF/USGS PEIS. This section also includes estimates of the numbers of marine mammals that could be affected by the proposed seismic surveys scheduled to occur during April–May 2013. A description of the rationale for USGS' estimates of the numbers of individuals exposed to received sound levels ≥160 dB re 1 μPa_{rms} is also provided.

Summary of Potential Effects of Airgun Sounds

The effects of sounds from airguns could include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and at least in theory, temporary or permanent hearing impairment, or non-auditory physical or physiological effects (Richardson et al. 1995; Gordon et al. 2004; Nowacek et al. 2007; Southall et al. 2007). Permanent hearing impairment (PTS), in the unlikely event that it occurred, would constitute injury, but temporary threshold shift (TTS) is not an injury (Southall et al. 2007). Although the possibility cannot be entirely excluded, it is unlikely that the project would result in any cases of temporary or permanent hearing impairment, or any significant non-auditory physical or physiological effects. If marine mammals encounter the survey while it is underway, some behavioral disturbance could result, but this would be localized and short-term. As a result of the monitoring and mitigation measures, no marine mammals are expected to be exposed to sounds from the survey at levels causing behavioral disturbance.

***Tolerance*.—**Numerous studies have shown that pulsed sounds from airguns are often readily detectable in the water at distances of many kilometers. Several studies have shown that marine mammals at distances more than a few kilometers from operating seismic vessels often show no apparent response. That is often true even in cases when the pulsed sounds must be readily audible to the animals based on measured received levels and the hearing sensitivity of that mammal group. Although various baleen whales and toothed whales, 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. The relative responsiveness of baleen and toothed whales are quite variable.

***Masking*.—** Masking effects of pulsed sounds (even from large arrays of airguns) on marine mammal calls and other natural sounds are expected to be limited, although there are very few specific data on this. Because of the intermittent nature and low duty cycle of seismic pulses, animals can emit and receive sounds in the relatively quiet intervals between pulses. However, in exceptional situations, reverberation occurs for much or all of the interval between pulses (e.g., Simard et al. 2005; Clark and Gagnon 2006), which could mask calls. Some baleen and toothed whales are known to continue calling in the presence of seismic pulses, and their calls usually can be heard between the seismic pulses. The sounds important to small odontocetes are predominantly at much higher frequencies than are the dominant components of airgun sounds, thus limiting the potential for masking. In general, masking effects of seismic pulses are expected to be minor, given the normally intermittent nature of seismic pulses. We are not aware of any information concerning masking of hearing in sea turtles.

***Disturbance Reactions*.—** Disturbance includes a variety of effects, including subtle to conspicuous changes in behavior, movement, and displacement. Based on NMFS (2001, p. 9293), NRC (2005), and Southall et al. (2007), we believe 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 marine mammals would be present within a particular distance of industrial activities and/or exposed to a particular level of industrial sound. In most cases, this approach likely overestimates the numbers of marine mammals that would be affected in some biologically important manner.

The sound criteria used to estimate how many marine mammals might be disturbed to some biologically important degree by a seismic program are based primarily on behavioral observations of a few species. Detailed studies have been done on humpback, gray, bowhead, and sperm whales. Less detailed data are available for some other species of baleen whales and small toothed whales, but for many species, there are no data on responses to marine seismic surveys.

Baleen Whales

Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to pulses from large arrays of airguns at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, 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.

Responses of *humpback whales* to seismic surveys have been studied during migration, on summer feeding grounds, and on Angolan winter breeding grounds; there has also been discussion of effects on the Brazilian wintering grounds. Off Western Australia, 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; there was localized displacement during migration of 4–5 km by traveling pods and 7–12 km by more sensitive resting pods of cow-calf pairs. However, some individual humpback whales, especially males, approached within distances of 100–400 m.

In the Northwest Atlantic, sighting rates were significantly greater during non-seismic periods compared with periods when a full array was operating, and humpback whales were more likely to swim away and less likely to swim towards a vessel during seismic vs. non-seismic periods. On their summer feeding grounds in southeast Alaska, 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. It has been suggested that South Atlantic humpback whales wintering off Brazil may be displaced or even strand upon exposure to seismic surveys, but data from subsequent years, indicated that there was no observable direct correlation between strandings and seismic surveys.

There are no data on reactions of *right whales* to seismic surveys, but results from the closely related *bowhead whale* show that their responsiveness can be quite variable depending on their activity (migrating vs. feeding). Bowhead whales migrating west across the Alaskan Beaufort Sea in autumn, in particular, are unusually responsive, with substantial avoidance occurring out to distances of 20–30 km from a medium-sized airgun source. However, more recent research on bowhead whales corroborates earlier evidence that, during the summer feeding season, bowheads are not as sensitive to seismic sources.

Reactions of migrating and feeding (but not wintering) *gray whales* to seismic surveys have been studied. Off St. Lawrence Island in the northern Bering Sea, it was estimated, based on small sample sizes, that 50% of feeding gray whales stopped feeding at an average received pressure level of 173 dB re 1 μPa on an (approximate) rms basis, and that 10% of feeding whales interrupted feeding at received levels of 163 dB re 1 μPa_{rms}. Those findings were generally consistent with the results of experiments conducted on larger numbers of gray whales that were migrating along the California coast, and western Pacific gray whales feeding off Sakhalin Island, Russia.

Various species of *Balaenoptera* (blue, sei, fin, and minke whales) have occasionally been seen in areas ensonified by airgun pulses; sightings by observers on seismic vessels off the United Kingdom from 1997 to 2000 suggest that, during times of good sightability, sighting rates for mysticetes (mainly fin and sei whales) were similar when large arrays of airguns were shooting vs. silent, although there was localized avoidance. Singing fin whales in the Mediterranean moved away from an operating airgun array.

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

Toothed Whales

Little systematic information is available about reactions of toothed whales to sound pulses. However, there are recent systematic studies on sperm whales, and there is an increasing amount of information about responses of various odontocetes to seismic surveys based on monitoring studies. 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. 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. The beluga, however, is a species that (at least at times) shows long-distance (10s of km) avoidance of seismic vessels. 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, but the animals tolerated high received levels of sound before exhibiting aversive behaviors.

Most studies of *sperm whales* exposed to airgun sounds indicate that the sperm whale shows considerable tolerance of airgun pulses; in most cases the whales do not show strong avoidance, and they continue to call, but foraging behavior can be altered upon exposure to airgun sound. There are almost no specific data on the behavioral reactions of *beaked whales* to seismic surveys. However, some northern bottlenose whales remained in the general area and continued to produce high-frequency clicks when exposed to sound pulses from distant seismic surveys. Most beaked whales tend to avoid approaching vessels of other types, and may also dive for an extended period when approached by a vessel. In any event, it is likely that most beaked whales would also show strong avoidance of an approaching seismic vessel, although this has not been documented explicitly.

Odontocete reactions to large arrays of airguns are variable and, at least for delphinids, seem to be confined to a smaller radius than has been observed for the more responsive of the mysticetes and some other odontocetes. A ≥170 dB disturbance criterion (rather than ≥160 dB) is considered appropriate for delphinids, which tend to be less responsive than the more responsive cetaceans.

Sea Turtles

The limited available data indicate that sea turtles will hear airgun sounds and sometimes exhibit localized avoidance (see NSF/USGS PEIS). Based on available data, it is likely that sea turtles will exhibit behavioral changes and/or avoidance within an area of unknown size near a seismic vessel. To the extent that there are any impacts on sea turtles, seismic operations in or near areas where turtles concentrate are likely to have the greatest impact. There are no specific data that demonstrate the consequences to sea turtles if seismic operations with large or small arrays of airguns occur in important areas at biologically important times of year.

***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. However, there has been no specific documentation of TTS let alone permanent hearing damage, i.e., 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 dB and 190 dB re 1 μPa_{rms}, respectively (NMFS 2000). These 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.

Recommendations for science-based noise exposure criteria for marine mammals, frequency-weighting procedures, and related matters were published by Southall et al. (2007). Those recommendations have not, as of autumn 2012, been formally adopted by NMFS for use in regulatory processes and during mitigation programs associated with seismic surveys. However, some aspects of the recommendations have been taken into account in certain environmental impact statements and small-take authorizations. NMFS has indicated that it may issue new noise exposure criteria for marine mammals that account for the now-available scientific data on TTS, the expected offset between the TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive (e.g., M-weighting or generalized frequency weightings for various groups of marine mammals, allowing for their functional bandwidths), and other relevant factors.

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

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might (in theory) occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, and other types of organ or tissue damage. It is possible that some marine mammal species (i.e., beaked whales) may be especially susceptible to injury and/or stranding when exposed to strong transient sounds. However, there is no definitive evidence that any of these effects occur even for marine mammals in close proximity to large arrays of airguns. Such effects, if they occur at all, would presumably be limited to short distances and to activities that extend over a prolonged period. Marine mammals that show behavioral avoidance of seismic vessels, including most baleen whales, some odontocetes, and some pinnipeds, are especially unlikely to incur non-auditory physical effects. The brief duration of exposure of any given mammal, the deep water in the study area, and the planned monitoring and mitigation measures will further reduce the probability of exposure of marine mammals to sounds strong enough to induce non-auditory physical effects.

Sea Turtles

Thus, there is substantial overlap in the frequencies that sea turtles detect vs. the frequencies in airgun pulses. We are not aware of measurements of the absolute hearing thresholds of any sea turtle to waterborne sounds similar to airgun pulses. In the absence of relevant absolute threshold data, we cannot estimate how far away an airgun array might be audible. Moein et al. (1994) and Lenhardt (2002) reported TTS for loggerhead turtles exposed to many airgun pulses (see NSF/USGS PEIS). This suggests that sounds from an airgun array might cause temporary hearing impairment in sea turtles if they do not avoid the (unknown) radius where TTS occurs. However, exposure duration during the proposed survey would be much less than during the aforementioned studies. Also, recent monitoring studies show that some sea turtles do show localized movement away from approaching airguns. At short distances from the source, received sound level diminishes rapidly with increasing distance. In that situation, even a small-scale avoidance response could result in a significant reduction in sound exposure.

As noted above, the PSOs stationed on the *Pelican* will also watch for sea turtles, and airgun operations will be shut down if a turtle enters the designated exclusion zone.

(2) Mitigation Measures

Several mitigation measures are built into the proposed seismic survey as an integral part of the planned activities. These measures include the following: ramp ups; typically two, however a minimum of one dedicated observer maintaining a visual watch during all daytime airgun operations; two observers for 30 min before and during ramp ups during the day and at night; and shut downs when mammals or turtles are detected in or about to enter designated exclusion zones. These mitigation measures are described earlier in this document, in § II(3). The fact that the GI airgun, as a result of its design, directs the majority of the energy downward, and less energy laterally, is also an inherent mitigation measure.

Previous and subsequent analysis of the potential impacts take account of these planned mitigation measures. It would not be meaningful to analyze the effects of the planned activities without mitigation, as the mitigation (and associated monitoring) measures are a basic part of the activities.

(3) Potential Numbers of Marine Mammals Exposed to Received Sound Levels ≥160 dB

All anticipated takes would be "takes by harassment" as described in § I, involving temporary changes in behavior. The mitigation measures to be applied will minimize the possibility of injurious takes. (However, as noted earlier and in the PEIS, there is no specific information demonstrating that injurious "takes" would occur even in the absence of the planned mitigation measures.) In the sections below, we describe methods to estimate the number of potential exposures to sound levels >160 dB re 1 μPa_{rms}, and present estimates of the numbers of marine mammals that could be affected during the proposed seismic program. The estimates are based on consideration of the number of marine mammals that could be disturbed appreciably by ~1480 km of seismic surveys in the northwestern GOM. The main sources of distributional and numerical data used in deriving the estimates are described in the next subsection.

(a) Basis for Estimating Exposure

The estimates are based on a consideration of the number of marine mammals that could be within the area around the operating airgun array where the received levels (RLs) of sound >160 dB re 1 μPa_{rms} are predicted to occur (see Table 1). The estimated numbers are based on the densities (numbers per unit area) of marine mammals expected to occur in the area in the absence of a seismic survey. To the extent that marine mammals tend to move away from seismic sources before the sound level reaches the criterion level and tend not to approach an operating airgun array, these estimates are likely to overestimate the numbers actually exposed to the specified level of sounds. The overestimation is expected to be particularly large when dealing with the higher sound-level criteria, e.g., 180 dB re 1 μPa_{rms}, as animals are more likely to move away before RL reaches 180 dB than they are to move away before it reaches (for example) 160 dB re 1 μPa_{rms}. Likewise, they are less likely to approach within the ≥180 dB re 1 μPa_{rms} radius than they are to approach within the considerably larger ≥160 dB radius.

We used spring densities reported in Table A-9 of Appendix A of BOEMRE's Request for Incidental Take regulations governing seismic surveys on the Outer Continental Shelf (OCS) of the Gulf of Mexico (BOEMRE 2011). Those densities were calculated from the U.S. Navy's "OPAREA Density Estimates" (NODE) database (DoN 2007b). The density estimates are based on the NMFS-SEFSC shipboard surveys conducted from 1994 to 2006, and were derived using a model-based approach and statistical analysis of the existing survey data. The outputs from the NODE database are four seasonal surface density plots of the Gulf of Mexico for each of the marine mammal species occurring there. Each of the density plots was overlaid with the boundaries of the 9 acoustic model regions used in Appendix A of BOEMRE (2011). We used the densities for Acoustic Model Region 8, which corresponds roughly with the deep waters (>1000 m) of the BOEMRE GOM Central Planning Area, and includes the GC955 and WR313 study sites.

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

It should be noted that the following estimates of exposures to various sound levels assume that the proposed survey will be completed; in fact, the ensonified areas calculated using the planned number of line-kilometers ***have been increased by 25%*** to accommodate turns, lines that may need to be repeated, equipment testing, etc. As is typical during offshore ship surveys, inclement weather and equipment malfunctions are likely to cause delays and may limit the number of useful line-kilometers of seismic operations that can be undertaken. Also, any marine mammal sightings within or near the designated exclusion zones will result in the shut down of seismic operations as a mitigation measure. Thus, the following estimates of the numbers of marine mammals potentially exposed to 160-dB re 1 μPa_{rms} sounds are precautionary and probably overestimate the actual numbers of marine mammals that could be involved. These estimates assume that there will be no weather, equipment, or mitigation delays, which is highly unlikely.

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

(b) Potential Number of Marine Mammals Exposed

The number of different individuals that could be exposed to GI-airgun sounds with received levels ≥160 dB re 1 μPa_{rms} on one or more occasions can be estimated by considering the total marine area that would be within the 160-dB radius around the operating seismic source on at least one occasion, along with the expected density of animals in the area. The number of possible exposures (including repeated exposures of the same individuals) can be estimated by considering the total marine area that would be within the 160-dB radius around the operating airguns, including areas of overlap. During the proposed survey, the transect lines in the square grid are closely spaced (100 m apart at the GC955 site and 250 m apart at the WR313 site) relative to the 160-dB distance (670 m). Thus, the area including overlap is 6.5 x the area excluding overlap at GC955 and 5.3 x the area excluding overlap at WR313, so a marine mammal that stayed in the survey areas during the entire survey could be exposed ~6 or 7 times, on average. However, it is unlikely that a particular animal would stay in the area during the entire survey.

The numbers of different individuals potentially exposed to ≥160 dB re 1 μPa_{rms} were calculated by multiplying the expected species density times the anticipated area to be ensonified to that level during GI-airgun operations excluding overlap. The area expected to be ensonified was determined by entering the planned survey lines into a MapInfo GIS, using the GIS to identify the relevant areas by "drawing" the applicable 160-dB buffer (see Table 1) around each seismic line, and then calculating the total area within the buffers.

Applying the approach described above, ~356 km² (~445 km² including the 25% contingency) would be within the 160-dB isopleth on one or more occasions during the proposed survey. Because this approach does not allow for turnover in the mammal populations in the area during the course of the survey, the actual number of individuals exposed may be underestimated, although the conservative (i.e., probably overestimated) line-kilometer distances used to calculate the area may offset this. Also, the approach assumes that no cetaceans will move away or toward the trackline as the R/V *Pelican* approaches in response to increasing sound levels before the levels reach 160 dB. Another way of interpreting the estimates that follow is that they represent the number of individuals that are expected (in the absence of a seismic program) to occur in the waters that will be exposed to ≥160 dB re 1 μPa_{rms}.

Table 3 shows the density estimates from BOEMRE (2011) and the estimates of the number of different individual marine mammals that potentially could be exposed to ≥160 dB re 1 μPa_{rms} during the

TABLE 3. Densities and estimates of the possible numbers of individuals that might be exposed to ≥160 dB during USGS' proposed seismic survey in northwest GOM in April–May 2013. The proposed sound source consists of a pair of 105-in³ GI airguns. Received levels of seismic sounds are expressed in dB re 1 µPa (rms, averaged over pulse duration), consistent with NMFS' practice. Not all marine mammals will change their behavior when exposed to these sound levels, but some may alter their behavior when levels are lower (see text). Species in italics are listed under the ESA as endangered. The column of numbers in boldface shows the numbers of "takes" for which authorization is requested.

Species	Density (#/1000 km²)	Ensonified area (km²)	Calculated Take[1]	% of GOM Pop'n[2]	Requested Take Authorization
Mysticetes					
Bryde's whale	0.10	445.4	0	0	**0**
Odontocetes					
Sperm whale	*4.90*	445.4	*2*	*0.13*	***3***[3]
Pygmy/dwarf sperm whale	2.10	445.4	1	0.21	**2**[3]
Beaked whales	3.70	445.4	2	0.49	**2**
Rough-toothed dolphin	6.70	445.4	3	0.20	**16**[3]
Bottlenose dolphin	4.80	445.4	2	0.06	**18**[3]
Pantropical spotted dolphin	582.60	445.4	259	0.76	**259**
Atlantic spotted dolphin	2.20	445.4	1	<0.01	**15**[3]
Spinner dolphin	72.60	445.4	32	1.63	**99**[3]
Clymene dolphin	45.60	445.4	20	0.31	**75**[3]
Striped dolphin	51.50	445.4	23	0.69	**45**[3]
Fraser's dolphin	1.90	445.4	1	0.12	**117**[3]
Risso's dolphin	10.00	445.4	4	0.28	**9**[3]
Melon-headed whale	9.10	445.4	4	0.18	**118**[3]
Pygmy killer whale	1.10	445.4	0	0	**0**
False killer whale	2.70	445.4	1	0.15	**36**[3]
Killer whale	0.40	445.4	0	0	**0**
Short-finned pilot whale	6.30	445.4	3	0.39	**19**[3]

[1] Calculated take is density times the area ensonified to >160 dB around the planned seismic lines, increased by 25%
[2] Regional populations are from the northern U.S. GOM (Table 2), except beaked whales (Ziphiidae), from Waring et al. 2010
[3] Requested Take Authorization increased to mean group size (see text)

seismic survey if no animals moved away from the survey vessel. The *Requested Take Authorization* is given in the far right column of Table 3. The ***Requested Take Authorization*** has been increased to the average mean group sizes in the GOM in 1996–2001 (Mullin and Fulling 2004) and 2003 and 2004 (Mullin 2007) in cases where the calculated number of individuals exposed was between 1 and the mean group size.

The estimate of the number of individual cetaceans that could be exposed to seismic sounds with received levels ≥160 dB re 1 μPa_{rms} during the proposed survey is 358 (Table 3). That total includes 2 ***Endangered*** sperm whales, representing 0.13% of the regional population. Most (98.6%) of the cetaceans potentially exposed are delphinids; pantropical spotted, spinner, striped, and Clymene dolphins are estimated to be the most common species in the area, with estimates of 259 (0.76% of the regional population), 32 (1.63%), 128 (0.69%), and 20 (0.31%) exposed to ≥160 dB re 1 μPa_{rms}, respectively. It should be noted that the "regional" population sizes are only for the U.S. waters of the northern GOM, so percentages of actual population sizes (including non-U.S. waters of the GOM) exposed are over-estimated.

(4) Conclusions for Marine Mammals and Sea Turtles

The proposed seismic project will involve towing a pair of GI airguns, a single GI gun, and a sparker that introduce pulsed sounds into the ocean. Routine vessel operations, other than the proposed seismic operations, are conventionally assumed not to affect marine mammals sufficiently to constitute "taking".

(a) Cetaceans

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

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

Taking into account the mitigation measures that are planned (see § II), effects on cetaceans are generally expected to be limited to avoidance of the area around the seismic operation and short-term changes in behavior, falling within the MMPA definition of "Level B harassment". Furthermore, the estimated numbers of animals potentially exposed to sound levels sufficient to cause appreciable disturbance are very low percentages of the regional population sizes (Table 3).

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

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

(b) Sea Turtles

Five species—the leatherback, loggerhead, green, hawksbill, and Kemp's ridley turtles—could be encountered in the proposed survey area. Mostly foraging or migrating individuals would occur. Although it is possible that some turtles will be encountered during the survey, it is anticipated that the proposed seismic survey will have, at most, a short-term effect on behavior and no long-term impacts on individual sea turtles or their populations.

(5) Direct Effects on Invertebrates, Fish, Fisheries, and EFH and Their Significance

Effects of seismic sound on marine invertebrates (crustaceans and cephalopods), marine fish, and their fisheries are discussed in § 3.2.4 and § 3.3.4 and Appendix D of the NSF/USGS PEIS. The PEIS concluded that there could be changes in behavior and other non-lethal, short-term, temporary impacts, and injurious or mortal impacts on a small number of individuals within a few meters of a high-energy acoustic source, but that there would be no significant impacts of NSF-funded or USGS marine seismic research on populations, fisheries, and associated EFH. Furthermore, there are no ESA-listed fish species or EFH in the deep, offshore waters of the survey areas.

A total of 50 OBSs will be deployed before and recovered after the proposed surveys. The OBSs have a height of ~1 m and a maximum diameter of 50 cm. The anchor is an iron plate weighing ~40 kg with dimensions ~30×30×8 cm. OBS anchors will be left behind upon equipment recovery. Although OBS placement will disrupt a very small area of seafloor habitat and could disturb benthic invertebrates, the impacts are expected to be localized and transitory. There are no HAPCs in the deep, offshore waters of the survey areas.

(6) Direct Effects on Seabirds and Their Significance

Effects of seismic sound and other aspects of seismic operations (collisions, entanglement, and ingestion) on seabirds are discussed in § 3.5.4 of the NSF/USGS PEIS. The PEIS concluded that there could be transitory disturbance, but that there would be no significant impacts of NSF-funded or USGS marine seismic research on seabirds or their populations.

(7) Indirect Effects on Marine Mammals, Sea Turtles, and Their Significance

The proposed seismic operations will not result in any permanent impact on habitats used by marine mammals or sea turtles, or to the food sources they use. The main impact issue associated with the proposed activities will be temporarily elevated noise levels and the associated direct effects on marine mammals and sea turtles, as discussed above.

During the proposed seismic survey, only a small fraction of the available habitat would be ensonified at any given time. Disturbance to fish species and invertebrates would be short-term, and fish would return to their pre-disturbance behavior once the seismic activity ceased [see § IV (5), above]. Thus, the proposed survey would have little impact on the abilities of marine mammals or sea turtles to feed in the area where seismic work is planned.

(8) Cumulative Effects

Under CEQ regulations (40 CFR §§1500–1508) implementing the provisions of NEPA, as amended (42 USC §§4321 *et seq.*), cumulative impacts are defined as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions." (40 CFR §1508.7). Causal agents of cumulative effects can include multiple causes, multiple effects, effects of activities in more than one locale, and recurring events.

The results of the cumulative impacts analysis in the NSF/USGS PEIS indicated that there would not be any significant cumulative effects to marine resources from the proposed NSF-funded or USGS marine seismic research. However, the PEIS also stated that, "A more detailed, cruise-specific cumulative effects analysis would be conducted at the time of the preparation of the cruise-specific EAs, allowing for the identification of other potential activities in the area of the proposed seismic survey that may result in cumulative impacts to environmental resources."

BOEM (2012) included a comprehensive discussion of ongoing and reasonably foreseeable actions in the GOM in § 4.6.1.2, including

- ongoing oil and gas exploration, development, and production;
- existing oil and gas infrastructure;
- commercial fishing;
- alternate energy development;
- military operations;
- marine vessel traffic;
- scientific research;
- recreation and tourism; and
- marine mining and disposal areas.

BOEM (2012) also provided maps of oil and natural gas-related infrastructure, military areas, shipping channels, and marine mining and ocean-dredged material disposal sites in the GOM. The proposed survey areas are farther offshore than any mapped infrastructure, shipping channel, mining and disposal sites, and military areas, although the survey areas are just south of Military Warning Area W92. Operations conducted in these Warning Areas include all weather flight training, refueling, test flights, bombing, fleet training, independent unit training, ASW, aircraft carrier, ship and submarine operations, and surface gunnery.

DoN (2007a) provided maps of fishing effort for shrimp trawl fisheries; reef-fish handline, bottom-longline, trap, and spear fisheries; coastal pelagic handline fisheries; stone crab and lobster trap fisheries; and shark bottom-longline fisheries in the GOM. The proposed survey areas are farther offshore than any type of fishery, all of which are on the continental shelf or just beyond the shelf break, which is at ~200 m depth.

Thus, it appears that there is little overlap between the proposed seismic surveys and other activities, and little chance of significant cumulative effects. As previously discussed, airgun operations are unlikely to cause any large-scale or prolonged effects in marine mammals or sea turtles, and the duration of the proposed surveys is very short (96 h).

(9) Unavoidable Impacts

Unavoidable impacts to the species of marine mammals and turtles occurring in the proposed survey area will be limited to short-term, localized changes in behavior of individuals. For cetaceans, some of the changes in behavior may be sufficient to fall within the MMPA definition of "Level B Harassment" (behavioral disturbance; no serious injury or mortality). TTS, if it occurs, will be limited to a few individuals, is a temporary phenomenon that does not involve injury, and is unlikely to have long term consequences for the few individuals involved. No long-term or significant impacts are expected on any of these individual marine mammals or turtles, or on the populations to which they belong. Effects on recruitment or survival are expected to be (at most) negligible.

(10) Coordination with Other Agencies and Processes

This document will be used as supporting documentation for an IHA application submitted by USGS to NMFS, under the U.S. MMPA, for "taking by harassment" (disturbance) of small numbers of marine mammals during this proposed seismic project. Potential impacts to endangered species and critical habitat have also been assessed in the document; therefore, it will be used to support the ESA Section 7 consultation process with NMFS and USFWS.

USGS will coordinate the planned marine mammal monitoring program associated with the seismic survey with any parties that express interest in this survey activity. USGS have coordinated, and will continue to coordinate, with other applicable Federal agencies as required, and will comply with their requirements.

Alternative Action: Another Time

An alternative to issuing the IHA for the period requested, and to conducting the project then, is to issue the IHA for another time, and to conduct the project at that alternative time. The proposed dates for the cruise (15 days in April–May 2013) are the dates when the personnel and equipment essential to meet the overall project objectives are available.

Marine mammals and sea turtles are expected to be found throughout the proposed survey area and throughout the time period during which the project may occur. A number of marine mammal species (see Table 2) are year-round residents in the GOM, so altering the timing of the proposed project likely would result in no net benefits for those species (see § III, above). Other species …

No Action Alternative

An alternative to conducting the proposed activities is the "No Action" alternative, i.e. do not issue an IHA and do not conduct the operations. If the research were not conducted, the "No Action" alternative would result in no disturbance to marine mammals or sea turtles attributable to the proposed activities, however valuable data about the marine environment would be lost. Research that will contribute to the characterization of marine gas hydrates in order to better understand their potential as an energy resource would also be lost. The development and calibration of improved geophysical techniques for gas hydrate characterization would not be achieved.

V. LIST OF PREPARERS

LGL Ltd., environmental research associates

William E. Cross, M.Sc., King City, Ont.*
Nathalie Patenaude, Ph.D., King City, Ont.
Patrick Abgrall, Ph.D., King City, Ont.
Meike Holst, M.Sc., Sidney, B.C.
John Christian, M.Sc., St. John's, Nfld.
Mark Fitzgerald, B.Sc., King City, Ont.
William R. Koski, M.Sc., King City, Ont.
W. John Richardson, Ph.D., King City, Ont.

Lamont Doherty Earth Observatory

John Diebold, Ph.D., Palisades, NY (deceased)

U.S. Geological Survey

Carolyn Ruppel, Ph.D., Woods Hole, MA
Patrick Hart, M.S., Menlo Park, CA
Seth Haines, Ph.D., Denver, CO

* Principal preparers of this specific document. Others listed above contributed to a lesser extent, or contributed substantially to previous related documents from which material has been excerpted.

VI. LITERATURE CITED

ACS (American Cetacean Society). 2005. American Cetacean Society fact sheet: Sei whale and Bryde's whale. Accessed in July 2011 at http://www.acsonline.org/factpack/SeiBrydesWhales.htm.

Baumgartner, M.F., K.D. Mullin, L.N. May, and T.D. Leming. 2001. Cetacean habitats in the northern Gulf of Mexico. **Fish. Bull.** 99(2):219-239.

Biggs, D.C. 1992. Nutrients, plankton, and productivity in a warm-core ring in the western Gulf of Mexico. **J. Geophys. Res.** 97:2143-2154.

Biggs, D.C., M.K. Howard, A.E. Jochens, S.F. DiMarco, R. Leben, and C. Hu. 2003. Ship and satellite studies of sperm whale habitat. p. 108-114 *In:* A.E. Jochens and D.C. Biggs (eds.), Sperm whale seismic study in the Gulf of Mexico; Annual Report: Year 1. U.S. Dept. of the Interior, Minerals Manage. Serv., Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2003-069. 139 p.

BOEM (Bureau of Ocean Energy Management). 2012. Outer Continental Shelf Oil and Gas Leasing Program: 2012-2017. Final Programmatic Environmental Impact Statement. July 2012.

BOEMRE (Bureau of Ocean Energy Management, Regulation, and Enforcement). 2011. Request to National Oceanic and Atmospheric Administration (NOAA) for Incidental Take regulations governing seismic surveys on the Outer Continental Shelf (OCS) of the Gulf of Mexico (GOM) (A response to Subpart I — MMPA Request Requirements at 50 CFR §216.104). Revision to original request package submitted December 20, 2002. 18 April 2011. 36 p. + appendices.

Clark, C.W. and G.C. Gagnon. 2006. Considering the temporal and spatial scales of noise exposures from seismic surveys on baleen whales. Working Pap. SC/58/E9, Int. Whal. Comm., Cambridge, U.K. 9 p.

Culik, B.M. 2002. Review on small cetaceans: distribution, behaviour, migration and threats. Compiled for the Convention on Migratory Species (CMS). Bonn.

Dahlheim, M.E. and J.E. Heyning. 1999. Killer whale *Orcinus orca* (Linnaeus, 1758). p. 281-322 *In*: S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 6: The second book of dolphins and the porpoises. Academic Press, San Diego, CA. 486 p.

Davis, R.W. and G.S. Fargion (eds.) 1996. Distribution and abundance of cetaceans in the north-central and western Gulf of Mexico: final report. Volume II: technical report. OCS Study MMS 96-0027. Rep. from Texas Instit. Oceanogr. and Nat. Mar. Fish. Serv. Minerals Manage. Serv., Gulf of Mexico OCS Region, New Orleans, LA. 357 p.

Davis, R.W., G.S. Fargion, N. May, T.D. Leming, M. Baumgartner, W.E. Evans, L.J. Hansen, and K. Mullin. 1998. Physical habitat of cetaceans along the continental slope in the north-central and western Gulf of Mexico. **Mar. Mamm. Sci.** 14(3):490-507.

Davis, R.W., W.E. Evans, and B. Würsig (eds.) 2000. Cetaceans, sea turtles and seabirds in the northern Gulf of Mexico: distribution, abundance and habitat associations. Volume II: technical report. USGS/BRD/CR-1999-0006 and OCS Study MMS 2000-003. Minerals Manage. Serv., Gulf of Mexico OCS Region, New Orleans, LA.

Davis, R.W., J.G. Ortega-Ortiz, C.A. Ribic, W.E. Evans, D.C. Biggs, P.H. Ressler, R.B. Cady, R.R. Leben, K.D. Mullin, and B. Würsig. 2002. Cetacean habitat in the northern oceanic Gulf of Mexico. **Deep-Sea Res. I** 49(1):121-142.

Debrot, A.O. and N.B. Barros. 1992. Notes on a Gervais' beaked whale, *Mesoplodon europaeus*, and a dwarf sperm whale, *Kogia simus*, stranded in Curaçao, Netherlands Antilles. **Mar. Mamm. Sci.** 8(2):172-178.

Dolar, M.L.L. 2009. Fraser's dolphin *Lagenodelphis hosei*. p. 469-471 *In:* W.F. Perrin, B. Würsig and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd edit. Academic Press, San Diego, CA. 1316 p.

DoN (Department of Navy). 2007a. Marine resources assessment for the Gulf of Mexico. Department of the Navy, U.S. Fleet Forces Command, Norfolk, VA. Contract #N62470-02-D-9997, CTO 0030. Rep. from Geo-Marine, Inc., Hampton, VA. 621 p.

DoN (Department of Navy). 2007b. Navy OPAREA density estimates (NODE) for the GOMEX OPAREA. Rep. from GeoMarine Inc., Hampton, VA, for Department of the Navy, Naval Facilities Engineering Command, Atlantic, Norfolk, VA. Contract N62470-02-D-9997, Task Order 0046.

Fertl, D., T.A. Jefferson, I.B. Moreno, A.N. Zerbini, and K.D. Mullin. 2003. Distribution of the Clymene dolphin *Stenella clymene*. **Mamm. Rev.** 33(3):253-271.

Fertl, D., A.J. Schiro, G.T. Regan, C.A. Beck, N. Adimey, L. Price-May, A. Amost, G.A.J. Worthy, and R. Crossland. 2005. Manatee occurrence in the northern Gulf of Mexico, west of Florida. **Gulf Carib. Res.** 17:69-94.

Fulling, G.L., K.D. Mulling, and C.W. Hubbard. 2003. Abundance and distribution of cetaceans in outer continental shelf waters of the U.S. Gulf of Mexico. **Fish. Bull.** 101(4):923-932.

Garrison, L.P. 2003. Estimated bycatch of marine mammals and turtles in the U.S. Atlantic pelagic longline fleet during 2001–2002. NOAA Tech. Memo. NMFS-SEFSC-515. Nat. Mar. Fish. Serv., Southeast Fish Sci. Center, Miami, FL. 52 p.

Garrison, L.P. 2005. Estimated bycatch of marine mammals and turtles in the U.S. Atlantic pelagic longline fleet during 2004. NOAA Tech. Memo. NMFS-SEFSC-531. Nat. Mar. Fish. Serv., Southeast Fish Sci. Center, Miami, FL. 52 p.

Gordon, J., D. Gillespie, J. Potter, A. Frantzis, M.P. Simmonds, R. Swift, and D. Thompson. 2004. A review of the effects of seismic surveys on marine mammals. **Mar. Technol. Soc. J.** 37(4):16-34.

Greene, C.R., Jr. 1997. Physical acoustics measurements. p. 3-1 to 3-63 *In*: W.J. Richardson (ed.), Northstar marine mammal monitoring program, 1996: marine mammal and acoustical monitoring of a seismic program in the Alaskan Beaufort Sea. LGL Rep. 2121-2. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Explor. (Alaska) Inc., Anchorage, AK, and Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 245 p.

Griffin, R.B. and N.J. Griffin. 2004. Temporal variation in Atlantic spotted dolphin (*Stenella frontalis*) and bottlenose dolphin (*Tursiops truncatus*) densities on the West Florida continental shelf. **Aquat. Mamm.** 30(3):380-390.

Griffin, R.B., C. Hu, and N.J. Griffin. 2005. Movement patterns of Atlantic spotted dolphins (*Stenella frontalis*) and bottlenose dolphins (*Tursiops truncatus*) in relation to oceanographic fronts. Abstr. 16th Bien. Conf. Biol. Mar. Mamm., San Diego, CA, 12–16 Dec. 2005.

Hauser, D.D.W., M Holst, and V.D. Moulton. 2008. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program in the Eastern Tropical Pacific, April–August 2008. LGL Rep. TA4656/7-1. Rep. from LGL Ltd., St. John's, Nfld., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 98 p.

Holst, M. and J. Beland. 2008. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's seismic testing and calibration study in the northern Gulf of Mexico, November 2007–February 2008. LGL Rep. TA4295-2. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 77 p.

Holst, M. and M.A. Smultea. 2008. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program off Central America, February–April 2008. LGL Rep. TA4342-2. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 133 p.

Holst, M., M.A. Smultea, W.R. Koski, and B. Haley. 2005. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program in the Eastern Tropical Pacific Ocean off Central America, November–December 2004. LGL Rep. TA2822-30. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 125 p.

Hubard, C.W., K. Maze-Foley, K.D. Mullin, and W.W. Schroeder. 2004. Seasonal abundance and site fidelity of bottlenose dolphins (*Tursiops truncatus*) in Mississippi Sound. **Aquat. Mamm.** 30(2):299-310.

Irwin, L.J. and B. Würsig. 2004. A small resident community of bottlenose dolphins, *Tursiops truncatus*, in Texas: monitoring recommendations. **Gulf Mex. Sci.** 22(1):13-21.

IUCN (The World Conservation Union). 2011. IUCN Red List of Threatened Species, Version 2011.1. Accessed on 31 July 2011 at http://www.iucnredlist.org.

Jefferson, T.A. and A.J. Schiro. 1997. Distribution of cetaceans in the offshore Gulf of Mexico. **Mamm. Rev.** 27:27-50.

Jefferson, T.A., M.A. Webber, and R.L. Pitman. 2008. Marine mammals of the world: a comprehensive guide to their identification. Elsevier, Academic Press, Amsterdam, Holland. 573 p.

Jochens, A., D. Biggs, K. Benoit-Bird, D. Engelhaupt, J. Gordon, C. Hu, N. Jaquet, M. Johnson, R. Leben, B. Mate, P. Miller, J. Ortega-Ortiz, A. Thode, P. Tyack, and B. Würsig. 2008. Sperm whale seismic study in the Gulf of Mexico: synthesis report. OCS Study MMS 2008-006. Rep. from Dep. Oceanogr., Texas A & M Univ., College Station, TX, for U.S. Minerals Manage. Serv., Gulf of Mexico OCS Reg., New Orleans, LA. 341 p.

Lohrenz, S.E., M.J. Dagg, and T.E. Whitledge. 1990. Enhanced primary production at the plume/oceanic interface of the Mississippi River. Cont. Shelf Res. 10:639-664.

Lusseau, D. and L. Bejder. 2007. The long-term consequences of short-term responses to disturbance/experience from whalewatching impact assessment. **Int. J. Compar. Psychol.** 20(2-3):228-236.

MacLeod, C.D. and G. Mitchell. 2006. Key areas for beaked whales worldwide. **J. Cetac. Res. Manage.** 7(3):309-322.

Mate, B. 2003. Identifying the seasonal distribution of sperm whales in the Gulf of Mexico with satellite-monitored radio tags. p. 95-99 *In*: A.E. Jochens and D.C. Biggs (eds.), Sperm whale seismic study in the Gulf of Mexico; Annual Report: Year 1. Minerals Manage. Serv., Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2003-069. 139 p.

Mate, B. and J. Ortega-Ortiz. 2004. Status report on satellite-monitored radio tag. p. 85-86 *In*: A.E. Jochens and D.C. Biggs (eds.), Sperm whale seismic study in the Gulf of Mexico; Annual Report: Year 2. Minerals Manage. Serv., Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2004-067. 167 p.

McCauley, R.D., M.-N. Jenner, C. Jenner, K.A. McCabe, and J. Murdoch. 1998. The response of humpback whales (*Megaptera novaeangliae*) to offshore seismic survey noise: preliminary results of observations about a working seismic vessel and experimental exposures. **APPEA (Austral. Petrol. Product. Explor. Assoc.) J.** 38:692-707.

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch, and K. McCabe. 2000. Marine seismic surveys: analysis of airgun signals; and effects of air gun exposure on humpback whales, sea turtles, fishes and squid. Rep. from Centre for Marine Science and Technology, Curtin Univ., Perth, W.A., for Austral. Petrol. Prod. Assoc., Sydney, N.S.W. 188 p.

Mullin, K.D. 2007. Abundance of cetaceans in the oceanic Gulf of Mexico based on 2003–2004 ship surveys. 26 p. Available from NMFS, Southeast Fish. Sci. Center, P.O. Drawer 1207, Pascagoula, MS 39568.

Mullin, K.D. and G.L. Fulling. 2004. Abundance of cetaceans in the oceanic northern Gulf of Mexico, 1996–2001. **Mar. Mamm. Sci.** 20(4):787-807.

Mullin, K.D. and W. Hoggard. 2000. Visual surveys of cetaceans and sea turtles from aircraft and ships. p. 111-171 *In*: R.W. Davis, W.E. Evans, and B. Würsig (eds.), Cetaceans, sea turtles and seabirds in the northern Gulf of Mexico: distribution, abundance and habitat associations, Vol. II: technical report. U.S. Dep. Interior, Geol. Surv., Biol. Resour. Div., USGS/BRD/CR-1999-0006, and Minerals Manage. Serv., OCS Study MMS 2000-003.

Mullin, K.D., W. Hoggard, C.L. Roden, R.R. Loheofener, C.M. Rogers, and B. Taggart. 1991. Cetaceans on the upper continental slope in the north-central Gulf of Mexico. OCS Study/MMS 91-0027. Minerals Manage. Serv., Gulf of Mexico OCS Region, New Orleans, LA. 108 p.

Mullin, K.D., L.V. Higgins, T.A. Jefferson, and L.J. Hansen. 1994a. Sightings of the Clymene dolphin (*Stenella clymene*) in the Gulf of Mexico. **Mar. Mamm. Sci.** 10(4):464-470.

Mullin, K.D., T.A. Jefferson, L.J. Hansen, and W. Hoggard. 1994b. First sightings of melon-headed whales (*Peponocephala electra*) in the Gulf of Mexico. **Mar. Mamm. Sci.** 10(3):342-348

Mullin, K.D., W. Hoggard, C.L. Roden, R.R. Loheofener, C.M. Rogers, and B. Taggart. 1994c. Cetaceans on the upper continental slope in the north-central Gulf of Mexico. **Fish. Bull.** 92(4):773-787.

Mullin, K.D., W. Hoggard, and L.J. Hansen. 2004. Abundance and seasonal occurrence of cetaceans in outer continental shelf and slope waters of the north-central and northwestern Gulf of Mexico. **Gulf Mex. Sci.** 22:62-73.

NMFS (National Marine Fisheries Service). 2000. Small takes of marine mammals incidental to specified activities; marine seismic-reflection data collection in southern California/Notice of receipt of application. **Fed. Regist.** 65(60, 28 Mar.):16374-16379.

NMFS (National Marine Fisheries Service). 2001. Small takes of marine mammals incidental to specified activities; oil and gas exploration drilling activities in the Beaufort Sea/Notice of issuance of an incidental harassment authorization. **Fed. Regist**. 66(26, 7 Feb.):9291-9298.

Nowacek, D.P., L.H. Thorne, D.W. Johnston, and P.L. Tyack. 2007. Responses of cetaceans to anthropogenic noise. **Mamm. Rev.** 37(2):81-115.

NRC (National Research Council). 2005. Marine mammal populations and ocean noise/Determining when noise causes biologically significant effects. U.S. Nat. Res. Counc., Ocean Studies Board, Committee on Characterizing Biologically Significant Marine Mammal Behavior (Wartzok, D.W., J. Altmann, W. Au, K. Ralls, A. Starfield, and P.L. Tyack). Nat. Acad. Press, Washington, DC. 126 p.

Ortega-Ortiz, J.G. 2002. Multiscale analysis of cetacean distribution in the Gulf of Mexico. Ph.D. Thesis. Texas A&M University, TX. 170 p.

Richardson, W.J., C.R. Greene, Jr., C.I. Malme, and D.H. Thomson. 1995. Marine mammals and noise. Academic Press, San Diego, CA. 576 p.

Sea Around Us Project. 2012. Sea Around Us Project. Fisheries ecosystems and biodiversity: LME, Gulf of Mexico. Accessed in October 2012 at http://www.seaaroundus.org/lme/5.aspx.

Shane, S.H. 2004. Residence patterns, group characteristics, and association patterns of bottlenose dolphins near Sanibel Island, Florida. **Gulf Mex. Sci.** 22(1):1-12.

Simard, Y., F. Samaran, and N. Roy. 2005. Measurement of whale and seismic sounds in the Scotian Gully and adjacent canyons in July 2003. p. 97-115 *In:* K. Lee, H. Bain, and C.V. Hurley (eds.), Acoustic monitoring and marine mammal surveys in The Gully and outer Scotian Shelf before and during active seismic surveys. Environ. Stud. Res. Funds Rep. 151. 154 p. (Published 2007).

Simmonds, M. P. and L.F. Lopez-Jurado. 1991. Whales and the military. **Nature** 351(6326):448.

Smultea, M.A., M. Holst, W.R. Koski, and S. Stoltz. 2004. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic program in the southeast Caribbean Sea and adjacent Atlantic Ocean, April–June 2004. LGL Rep. TA2822-26. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 106 p.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene Jr., D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J. Richardson, J.A. Thomas, and P.L. Tyack. 2007. Marine mammal noise exposure criteria: initial scientific recommendations. **Aquat. Mamm.** 33(4):411-522.

Tolstoy, M., J.B. Diebold, S.C. Webb, D.R. Bohenstiehl, E. Chapp, R.C. Holmes, and M. Rawson. 2004. Broadband calibration of R/V *Ewing* seismic sources. **Geophys. Res. Let.** 31:L14310. doi: 10.1029/2004GL020234.

Tolstoy, M., J. Diebold, L. Doermann, S. Nooner, S.C. Webb, D.R. Bohnenstiehl, T.J. Crone and R.C. Holmes. 2009. Broadband calibration of the R/V *Marcus G. Langseth* four-string seismic sources. **Geochem. Geophys. Geosyst.** 10(8):1-15. Q08011.

UNEP-WCMC (United Nations Environment Programme-World Conservation Monitoring Centre). 2011. Convention on International Trade in Endangered Species of Wild Flora and Fauna. Appendices I, II, and II. Valid from 27 April 2011. Accessed on 20 July 2011 at http://www.cites.org/eng/app/E-Apr27.pdf.

USFWS (U.S. Fish and Wildlife Service) and NOAA (National Oceanic and Atmospheric Administration). 2003. Endangered and threatened wildlife and plants; Designation of critical habitat for the Gulf sturgeon. **Fed. Regist.** 68(53, 19 Mar.):13370-13495.

Walsh, C.F. and L.P. Garrison. 2006. Estimated bycatch of marine mammals and turtles in the U.S. Atlantic pelagic longline fleet during 2005. NOAA Tech. Memo. NMFS-SEFSC-539. 52 p.

Waring, G.T., E. Josephson, C.P. Fairfield-Walsh, K. Maze-Foley, and P.E. Rosel (eds.) 2010. U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments, 2010. NOAA Tech. Memo. NMFS-NE-219. Nat. Mar. Fish. Serv., Southeast Fish Sci. Center, Miami, FL. 415 p.

Wartzok, D., A.N. Popper, J. Gordon, and J. Merrill. 2004. Factors affecting the responses of marine mammals to acoustic disturbance. **Mar. Technol. Soc. J.** 37(4):6-15.

Weilgart, L.S. 2007. A brief review of known effects of noise on marine mammals. **Int. J. Comp. Psychol.** 20:159-168.

Weir, C.R. and S.J. Dolman. 2007. Comparative review of the regional marine mammal mitigation guidelines implemented during industrial seismic surveys, and guidance towards a worldwide standard. **J. Int. Wildl. Law Policy**. 10(1):1-27.

Weller, D.W., B. Würsig, S.K. Lynn, and A.J. Schiro. 2000. Preliminary findings on the occurrence and site fidelity of photo-identified sperm whales (*Physeter macrocephalus*) in the northern Gulf of Mexico. **Gulf Mex. Sci.** 18:35-39.

Whitehead, H. 2002. Estimates of the current global population size and historical trajectory for sperm whales. **Mar. Ecol. Prog. Ser.** 242:295-304.

Würsig, B., T.A. Jefferson, and D.J. Schmidly. 2000. The marine mammals of the Gulf of Mexico. Texas A&M University Press, College Station, TX. 232 pp.