MARINE MAMMAL AND SEA TURTLE MONITORING DURING LAMONT-DOHERTY EARTH OBSERVATORY'S SHATSKY RISE MARINE SEISMIC PROGRAM IN THE NORTHWEST PACIFIC OCEAN, JULY – SEPTEMBER 2010

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and

National Marine Fisheries Service, Office of Protected Resources

1315 East-West Hwy, Silver Spring, MD 20910-3282

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14 December 2010

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ACRONYMS AND ABBREVIATIONS

asl	above sea level
Bf	Beaufort Wind Force
CFR	(U.S.) Code of Federal Regulations
CIBRA	Centro Interdisciplinare di Bioacustica e Ricerche Ambientali (Univ. of Pavia, Italy)
CITES	Convention on International Trade in Endangered Species
cm	centimeter
CPA	Closest (Observed) Point of Approach
CV	Coefficient of Variation
cu. in.	cubic inches
dB	decibels
EA	Environmental Assessment
ESA	(U.S.) Endangered Species Act
$f(0)$	sighting probability density at zero perpendicular distance from survey track; equivalently, 1/(effective strip width)
ft	feet
GIS	Geographic Information System
GMT	Greenwich Mean Time
GPS	Global Positioning System
$g(0)$	probability of seeing a group located directly on a survey line
h	hours
hp	horsepower
Hz	Hertz (cycles per second)
IHA	Incidental Harassment Authorization (under U.S. MMPA)
in^3	cubic inches
ITS	Incidental Take Statement
IUCN	International Union for the Conservation of Nature
kHz	kilohertz
km	kilometer
km^2	square kilometers
km/h	kilometers per hour
kt	knots (1 knot = 1.853 km/h)
L-DEO	Lamont-Doherty Earth Observatory (of Columbia University)
µPa	microPascal
m	meters
MBES	Multibeam Bathymetric Echosounder
MCS	Multichannel Seismic
min	minutes
MMC	(U.S.) Marine Mammal Commission
MMO	Marine Mammal (and Sea Turtle) Observer
MMPA	(U.S.) Marine Mammal Protection Act
n	sample size
n.mi.	nautical miles (1 n.mi. = 1.853 km)
NMFS	(U.S.) National Marine Fisheries Service
NSF	(U.S.) National Science Foundation

OBS	Ocean Bottom Seismometer
PAM	Passive Acoustic Monitoring
PD	Power down of the airguns to one operating airgun
pk-pk	peak-to-peak
psi	pounds per square inch
PTS	Permanent Threshold Shift
re	in reference to
RL	received (sound) level
rms	root-mean-square
rpm	revolutions per minute
s	seconds
SBP	Sub-bottom Profiler
SD	Shut Down of all the airguns not associated with mitigation
s.d.	standard deviation
SPL	Sound Pressure Level
SZ	Shut Down of all the airguns because of a marine mammal sighting near or within the safety radius
TTS	Temporary Threshold Shift
UNEP	United Nations Environmental Programme
U.K.	United Kingdom
U.S.	United States of America
"Useable"	Visual effort or sightings made under the following observation conditions: daylight periods within the study area, excluding periods 90 s to 6 h (for cetaceans) or 90 s to 2 h (for sea turtles) after airguns were turned off (post-seismic), nighttime observations, poor visibility conditions (visibility <3.5 km), and periods with Beaufort Wind Force >5 (>2 for cryptic species). Also excluded were periods when the *Langseth*'s speed was <3.7 km/h (2 kt) or with >60º of severe glare between 90º left and 90º right of the bow. Sightings outside of the truncation distance (used for density calculations) were also considered "non-useable".

EXECUTIVE SUMMARY

Introduction

This document serves to meet reporting requirements specified in an Incidental Harassment Authorization (IHA) issued to Lamont-Doherty Earth Observatory (L-DEO) of Columbia University by the National Marine Fisheries Service (NMFS) on 16 July 2010. The IHA (Appendix A) authorized non-lethal takes of certain marine mammals incidental to a marine seismic survey by the R/V *Marcus G. Langseth* at the Shatsky Rise in the Northwest Pacific Ocean, July–September 2010. Behavioral disturbance to marine mammals is considered to be "take by harassment" under the provisions of the U.S. Marine Mammal Protection Act (MMPA). NMFS considers that marine mammals exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} might be sufficiently disturbed to be "taken by harassment". "Taking" would also occur if marine mammals close to the seismic activity experienced a temporary or permanent reduction in their hearing sensitivity, or reacted behaviorally to the airgun sounds in a biologically significant manner.

It has not been confirmed whether, under realistic field conditions, seismic exploration sounds are strong enough to cause temporary or permanent hearing impairment in any marine mammals that occur close to the seismic source. Nonetheless, NMFS requires measures to minimize the possibility of any injurious effects (auditory or otherwise), and to document the extent and nature of any disturbance effects. In particular, NMFS requires that seismic programs conducted under IHAs include provisions to monitor for marine mammals and turtles, and to power down the airgun array to a single operating airgun or shut down all airguns when mammals or turtles are detected within designated safety radii.

Seismic Program Described

L-DEO conducted a seismic survey at the Shatsky Rise in the Northwest Pacific Ocean. The seismic survey took place in international waters deeper than 1000 m. The main purpose of the study was to decipher the crustal structure of the Shatsky Rise. The study area was located between 30–36°N and between 154–161°E. The Shatsky Rise cruise took place from 17 July to 13 September 2010.

During the Shatsky Rise survey, a 36-airgun array with a total discharge volume of 6600 in^3 was towed behind the *Langseth* at a depth of 9–12 m. The acoustic receiving system consisted of one 6-km streamer containing hydrophones, which was towed behind the *Langseth*, and/or Ocean Bottom Seismometers (OBSs) deployed from the *Langseth*. A 12-kHz multibeam bathymetric echosounder (MBES) and a lower energy 3.5 kHz sub-bottom profiler (SBP) were also operated from the *Langseth* throughout most of the study. As part of the marine mammal monitoring effort, passive acoustic monitoring (PAM) for vocalizing cetaceans also took place from the *Langseth* through the use of a towed hydrophone array.

Monitoring and Mitigation Description and Methods

Trained marine mammal observers (MMOs) were aboard the *Langseth* during the period of operations for visual and acoustic monitoring. The primary purposes of the monitoring and mitigation effort were the following: ***(A)*** Document the occurrence, numbers and behaviors of marine mammals and sea turtles near the seismic source. ***(B)*** Implement a power down or shut down of the airguns when marine mammals or turtles were sighted near or within the designated safety radii. ***(C)*** Monitor for marine mammals and sea turtles before and during ramp-up periods.

At least one MMO watched for marine mammals and sea turtles at all times while airguns operated during daylight periods including ramp ups and whenever the vessel was underway in daytime but the airguns were not firing. The visual MMOs used 7x50 binoculars, 25x150 Big-eye binoculars, and/or the naked eye to scan the surface of the water around the vessel for marine mammals and sea turtles. The distance from the observer to the sighting was estimated using reticles in the binoculars. When a marine mammal or turtle was detected within or approaching the safety radius, the MMO called for a power down or shut down of the airguns.

MMOs also conducted PAM during daytime and nighttime seismic operations. The primary purpose of the acoustic monitoring was to aid visual observers by detecting vocalizing cetaceans. The acoustic MMO listened with headphones to sounds received from the hydrophones and simultaneously monitored a real-time spectrogram display.

Primary mitigation procedures, as required by the IHA, included the following: ***(A)*** Ramp ups consisting of a gradual increase in the volume of the operating airguns, whenever the airguns were started after periods without airgun operations or after prolonged operations with one airgun. ***(B)*** Immediate power downs or shut downs of the airguns whenever marine mammals or sea turtles were detected within or about to enter the then-applicable safety radius. The safety radii for cetaceans and sea turtles during the survey were based on the distances within which the received levels of airgun sounds were expected to diminish to 180 dB re 1 μPa_{rms}, averaged over the pulse duration with no frequency weighting.

Monitoring Results

The *Langseth* traveled a total of 21,292 km (1371 h) during the Shatsky Rise cruise; 7300 km (655 h) occurred within the Shatsky Rise study area, 8333 km (425 h) occurred in transit to and from Hawaii, and 5659 km (291 h) took place during transit to and from Japan (Table ES.1). A total of 3297 km of seismic operations and a total of 4003 km of non-seismic operations took place within the seismic survey area (Table ES.1). Overall, 718 h of visual observations took place during the Shatsky Rise cruise, of which 357 h occurred within the study area (Table ES.1). MMOs were on visual watch during all daylight seismic operations, including ramp ups. All visual effort occurred during daylight periods; there were no nighttime ramp ups. In addition, ~383 h of PAM occurred during seismic periods, and ~2 took place during non-seismic periods; no acoustic detections of cetaceans were made (Table ES.1).

Mitigation decisions were based on all marine mammal and sea turtle sightings, but analyses of marine mammal data focused on sightings and survey effort in the study area during "useable" survey conditions. "Useable" conditions represented ~80% of the total visual effort in km in the study area (Table ES.1). "Useable" effort excluded periods 90 s to 6 h after airguns were turned off (referred to as post-seismic), poor visibility (<3.5 km) conditions, and periods with Beaufort Wind Force >5. Also excluded from the "useable" category were periods when the *Langseth*'s speed was <3.7 km/h (2 kt) or with >60º of severe glare between 90º left and right of the bow, and sightings of cryptic species in BF>2 (e.g., minke whale).

During the Shatsky Rise cruise, 27 cetacean sightings totaling 781 individuals were made; the sperm whale was the most frequently encountered species (nine groups). Within the study area, 5 cetacean sightings of 13 individuals were made; 4 groups (totaling 10 individuals) were considered "useable" (Table ES.1). Sightings within the study area included 3 groups of sperm whales, one group of unidentified dolphins, and one unidentified whale. Other species identified during the Shatsky Rise cruise included the minke whale, false killer whale, short-finned pilot whale, pantropical spotted dolphin, and Risso's dolphin. Four unidentified sea turtles were also sighted during the cruise, two of which were seen within the study area. One power down for cetaceans and no power downs or shut downs for sea turtles were implemented during the Shatsky Rise survey; (Table ES.1).

TABLE ES.1. Summary of *Langseth* operations, visual and passive acoustic monitoring (PAM) effort, and marine mammal and sea turtle sightings during the Shatsky Rise seismic survey, 17 July to 13 September 2010.

	Shatsky Rise Study Area									
	Non-seismic				Seismic					
		Post-Seismic[b]								
	Useable[a]	Recently Exposed	Potentially Exposed	Other Non-Useable	Useable[a]	Non-Useable	Total Useable[a]	Transits to/from Hawaii	Tranits to/from Japan	Overall Total
Operations effort in h										
Langseth Darkness	0	0.3	0	96.8	0	173.5	0	170.1	102.1	542.7
Langseth Daylight	96.8	7.6	16.0	55.1	187.2	21.9	284.0	254.5	188.9	828.0
***Langseth* Total**	96.8	7.9	16.0	151.9	187.2	195.4	284.0	424.7	291.0	1370.7
Observer Darkness	0	0	0	0	0	0	0	0	0	0
Observer Daylight	96.8	5.4	8.0	37.3	187.2	21.9	284.0	217.2	143.8	717.6
Observer Total	96.8	5.4	8.0	37.3	187.2	21.9	284.0	217.2	143.8	717.6
PAM Total[c]	1.8				382.6			0	0	384.4
Operations effort in km										
Langseth Darkness	0	1.6	0	1433.6	0	1484.4	0	3345.7	2018.3	8283.5
Langseth Daylight	1716.6	52.4	205.9	593.3	1624.2	188.5	3340.8	4986.8	3640.5	13008.1
***Langseth* Total**	1716.6	54.0	205.9	2026.9	1624.2	1672.8	3340.8	8332.5	5658.7	21291.6
Observer Darkness	0	0	0	0	0	0	0	0	0	0
Observer Daylight	1716.6	36.0	88.1	299.8	1624.2	188.5	3340.8	4250.7	2858.6	11062.5
Observer Total	1716.6	36.0	88.1	299.8	1624.2	188.5	3340.8	4250.7	2858.6	11062.5
No. Cetacean Sightings	3	0	0	1	1	0	4	3	19	27
No. Cetacean Acoustic	0				0		0	N/A	N/A	0
No. Turtle Sightings	2	0	0	0	0	0	0	0	2	4
No. Power/Shut Downs										1/0

N/A means not applicable.

[a]See *Acronyms and Abbreviations* for the definition of "useable" effort. Total represents useable effort in the seismic study area.

[b]Effort from 90 s to 6 h after airguns were turned off is considered post-seismic and non-useable; total useable effort is shown for cetaceans when Bf ≤5 is considered "useable."

[b]Effort from 90 s to 6 h after airguns were turned off is considered post-siesmic and non-ueseable; total useable effort is shown for cetaceans.

[c]Effort during all non-seismic categories was combined, as was effort during all seismic activity.

The sighting rate of cetaceans per 1000 km of useable non-seismic survey effort was 1.7/1000 km, whereas during useable seismic periods, the sighting rate was 0.6/1000 km. However, cetacean density was greater during seismic compared with non-seismic periods. The closest observed point of approach (CPA) of sperm whales was farther during non-seismic periods (2000 m, n = 2) compared with seismic periods (1031 m, n = 1). However, all these calculations are based on limited sightings (n = 4) in the study area.

Number of Marine Mammals Present and Potentially Affected

During the Shatsky Rise study, the "safety radii" for cetaceans were the best estimates of the 180-dB re 1 μPa_{rms} radius for the 36-airgun array. One group of seven sperm whales was sighted during the Shatsky Rise survey when the airguns were operating. This group occurred within the ≥160-dB re 1 μPa_{rms} radius of the then-operating airgun array, but was likely exposed to sound levels up to 170 dB before mitigation measures (a power down) could be implemented.

Minimum and maximum numbers of marine mammals potentially exposed to ≥160 dB re 1 μPa_{rms} were also estimated based on densities of marine mammals derived by line-transect procedures. These estimates allowed for animals not seen by MMOs. Based on observations during daytime non-seismic periods in the Shatsky Rise study area, up to 18 cetaceans might, prior to the approach of the *Langseth*, have been in the areas later exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms}. This estimate includes up to 12 sperm whale exposures. These estimates based on actual density data are lower than the "harassment takes" estimated for the Shatsky Rise survey area prior to the cruise.

Some cetaceans are expected to show avoidance of the approaching seismic vessel before entering the safety zone. With a relatively large sound source such as the one used during this project, some cetaceans are expected to show avoidance before they would be close enough to be visible (if at the surface) to MMOs. As sample sizes were small, it is not possible to make any clear determinations as to the effects that the Shatsky Rise survey may have had on cetaceans. However, cetacean density was greater during seismic periods compared with non-seismic periods, and the mean CPA for sperm whales was closer during seismic than non-seismic periods. Given the limited number of sightings, these differences should be interpreted very cautiously. However, these data contribute to the overall accumulation of similar data across this and other L-DEO seismic surveys. The estimated total number of cetaceans potentially affected by L-DEO's survey was much lower than that authorized by NMFS. Given the mitigation measures that were applied, any effects were likely localized and transient, without significant impact on either individual marine mammals or their populations.

1. INTRODUCTION

Lamont-Doherty Earth Observatory (L-DEO) of Columbia University conducted a marine seismic program in international waters at the Shatsky Rise in the Northwest Pacific Ocean from 17 July to 13 September 2010. The project was conducted aboard the R/V *Marcus G. Langseth*, which is owned by the U.S. National Science Foundation (NSF) and operated by L-DEO. The goal of the study was to decipher the crustal structure of the Shatsky Rise. The survey used a 36-airgun array as an energy source, with a maximum discharge volume of 6600 in^3. The geophysical investigation was under the direction of Drs. Jun Korenaga (Yale University, New Haven, CT), William Sager (Texas A&M University, College Station, TX), and the late John Diebold (L-DEO, Palisades, NY).

Marine seismic surveys emit strong sounds into the water (Greene and Richardson 1988; Tolstoy et al. 2004a,b, 2009; Breitzke et al. 2008) and have the potential to affect marine mammals, given the known auditory and behavioral sensitivity of many such species to underwater sounds (Richardson et al. 1995; Gordon et al. 2004; Nowacek et al. 2007; Southall et al. 2007). The effects could consist of behavioral and/or distributional changes, and perhaps (for animals close to the sound source), temporary or permanent reduction in hearing sensitivity. Either behavioral/distributional effects or (if they occur), auditory effects could constitute "taking" under the provisions of the U.S. Marine Mammal Protection Act (MMPA) and the U.S. Endangered Species Act (ESA), at least if the effects are considered to be "biologically significant".

Numerous species of marine mammals inhabit the open waters of Northwest Pacific Ocean, including several that are listed as endangered under the ESA: North Pacific right, sperm, humpback, sei, fin, and blue whales. With the exception of humpback and sperm whales, these species are also considered ***endangered*** by the International Union for Conservation of Nature and Natural Resources (IUCN) 2010 Red List of Threatened species. The ESA-listed ***endangered*** leatherback and hawksbill turtles, and the ***threatened*** green, olive ridley, and loggerhead turtles, are also known to occur in the Northwest Pacific Ocean.

On 2 February 2010, L-DEO requested that the U.S. National Marine Fisheries Service (NMFS) issue an Incidental Harassment Authorization (IHA) to authorize non-lethal "takes" of marine mammals incidental to the airgun operations at the Shatsky Rise (LGL Ltd. 2010a). The IHA was requested pursuant to Section 101(a)(5)(D) of the MMPA. An Environmental Assessment (EA) was prepared to evaluate the potential impacts of the Shatsky Rise survey (LGL Ltd. 2010b). NSF, the federal agency sponsoring the seismic study, reviewed and concurred with the conclusions of the EA that the proposed seismic survey would not have a significant impact on the environment and a Finding of No Significant Impact was issued. The IHA was issued by NMFS on 16 July 2010 (Appendix A).

The IHA authorized "potential take by harassment" of marine mammals during the seismic program described in this report. The *Langseth* departed from Honolulu, HI, on 17 July 2010, for the ~9 day transit to the Shatsky Rise study area. After the program was completed, the vessel returned to Honolulu, HI, for arrival on 13 September 2010.

This document serves to meet reporting requirements specified in the IHA, and to provide general information on the monitoring and mitigation program as relevant to other interested groups. The primary purposes of this report are to describe the Shatsky Rise seismic program, to describe the associated marine mammal and sea turtle monitoring and mitigation programs and their results, and to estimate the numbers of marine mammals potentially affected by the project.

Incidental Harassment Authorization

IHAs issued under provisions of the U.S. MMPA to seismic operators include provisions to minimize the possibility that marine mammals close to the seismic source might be exposed to levels of sound high enough to cause hearing damage or other injuries, and to reduce other effects insofar as practical. During this project, sounds were generated by the airguns used during the seismic study and also by a multibeam bathymetric echosounder (MBES), a sub-bottom profiler (SBP), an acoustic release transponder used to communicate with Ocean Bottom Seismometers (OBSs), and general vessel operations. No serious injuries or deaths of marine mammals (or sea turtles) were anticipated from the seismic survey, given the nature of the operations and the mitigation measures that were implemented, and no injuries or deaths were attributed to the seismic operations insofar as this could be determined. Nonetheless, the seismic survey operations described in Chapter 2 had the potential to disturb some marine mammals. Behavioral disturbance to marine mammals is considered to be "take by harassment" under the provisions of the U.S. MMPA, at least if it involves behavior outside the normal range of variability for the situation in question. Appendix B provides further background on the issuance of IHAs relative to seismic operations and "take".

Under NMFS guidelines (e.g., NMFS 2000), "safety radii" for marine mammals around airgun arrays are customarily defined as the distances within which the received pulse levels are ≥180 dB re 1 μPa_{rms}[1] for cetaceans and ≥190 dB re 1 μPa_{rms} for pinnipeds. Those safety radii are based on an assumption that seismic pulses received at lower received levels are unlikely to injure these mammals or impair their hearing abilities, but that higher received levels *might* have some such effects. The mitigation measures required by IHAs are, in large part, designed to avoid or minimize exposure of cetaceans and pinnipeds to sound levels exceeding 180 and 190 dB re 1 μPa_{rms}, respectively. In addition, for this project, the 180 dB re 1 μPa_{rms} criterion was also used as the safety (shut-down) criterion for sea turtles.

Disturbance to marine mammals could occur at distances beyond the safety (=shut down) radii if the mammals were exposed to moderately strong pulsed sounds generated by the airgun array (Richardson et al. 1995). NMFS assumes that marine mammals exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} are likely to be disturbed appreciably. That assumption is based mainly on data concerning behavioral responses of baleen whales, as summarized by Richardson et al. (1995) and Gordon et al. (2004). Delphinids, some porpoises, and most pinnipeds are generally less responsive (e.g., Stone 2003; Gordon et al. 2004; Bain and Williams 2006), and 170 dB re 1 μPa_{rms} may be a more appropriate criterion of behavioral disturbance for those groups (see LGL Ltd. 20010a,b). In general, disturbance effects are expected to depend on the species of marine mammal, the activity of the animal at the time, its distance from the sound source, and the received level of the sound and the associated water depth. Some individuals respond behaviorally at received levels somewhat below 160- or 170-dB re 1 μPa_{rms}, but others tolerate levels somewhat above those levels without reacting in a substantial manner.

A notice regarding the proposed issuance of an IHA for the Shatsky Rise seismic study was published by NMFS in the U.S. *Federal Register* on 21 May 2010, and public comments were invited (NMFS 2010a). The U.S. Marine Mammal Commission (MMC) submitted comments.

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[1] "rms" means "root mean square", and represents a form of average across the duration of the sound pulse as received by the animal. Received levels of airgun pulses measured on an "rms" basis are generally 10–12 dB lower than those measured on the "zero-to-peak" basis, and 16–18 dB lower than those measured on a "peak-to-peak" basis (Greene 1997; McCauley et al. 1998, 2000). The latter two measures are the ones commonly used by geophysicists. Unless otherwise noted, all airgun pulse levels quoted in this report are rms levels with equal weighting for all frequencies.

On 16 July 2010, L-DEO received the IHA that had been requested for the seismic study. On 29 July 2010, NMFS published a notice in the *Federal Register* to announce the issuance of the IHA (NMFS 2010b). This notice responded to the received comments and provided additional information concerning the IHA. A copy of the IHA, as well as the Biological Opinion's Incidental Take Statement (ITS), are included in this report as Appendix A.

The IHA was granted to L-DEO on the assumptions that

- the numbers of marine mammals potentially harassed (as defined by NMFS criteria) during seismic operations would be "small",
- the effects of such harassment on marine mammal populations would be negligible,
- no marine mammals would be seriously injured or killed, and
- the agreed upon monitoring and mitigation measures would be implemented.

Mitigation and Monitoring Objectives

The objectives of the mitigation and monitoring program were described in detail in L-DEO's IHA Application (LGL Ltd. 2010a) and in the IHA issued by NMFS to L-DEO (Appendix A). Explanatory material about the monitoring and mitigation requirements was published by NMFS in the *Federal Register* (NMFS 2010a,b).

The main purpose of the mitigation program was to avoid or minimize potential effects of L-DEO's seismic study on marine mammals and sea turtles. This required that — during daytime airgun operations — L-DEO detect marine mammals and sea turtles within or about to enter the safety radius, and in such cases initiate an immediate power down (or shut down if necessary) of the airguns. A power down involves reducing the source level of the operating airguns, generally by ceasing the operation of all but one airgun. A shut down involves ceasing the operation of all airguns. An additional mitigation objective was to detect marine mammals or sea turtles within or near the safety radii prior to starting the airguns, or during ramp up to full power. In these cases, the start of airgun operations was to be delayed or ramp up discontinued until the safety radii were free of marine mammals or sea turtles (see Appendix A and Chapter 3).

The primary objectives of the monitoring program were as follows:

- Provide real-time sighting data needed to implement the mitigation requirements.
- Use real-time passive acoustic monitoring (PAM) to monitor for vocalizing cetaceans and to notify visual observers of nearby cetaceans.
- Estimate the numbers of marine mammals potentially exposed to strong seismic pulses.
- Determine the reactions (if any) of potentially exposed marine mammals and sea turtles.

Specific mitigation and monitoring objectives identified in the IHA are listed in Appendix A. Mitigation and monitoring measures that were implemented during the seismic study are described in detail in Chapter 3.

Report Organization

The primary purpose of this report is to describe the Shatsky Rise seismic study that took place in the Northwest Pacific Ocean from 17 July to 13 September 2010, including the associated monitoring and mitigation program, and to present results as required by the IHA and ITS (see Appendix A). This report includes four chapters:

1. Background and introduction (this chapter);
2. Description of the seismic program;
3. Description of the marine mammal and sea turtle monitoring and mitigation requirements and methods, including safety radii; and
4. Results of the marine mammal and sea turtle monitoring program, including estimated numbers of marine mammals potentially exposed to various received sound levels and "taken by harassment" according to NMFS conventions.

Those chapters are followed by Acknowledgements and Literature Cited sections.

In addition, there are seven Appendices. Details of procedures that are more-or-less consistent across L-DEO's seismic surveys are provided in the Appendices and are only summarized in the main body of this report. The Appendices include:

A. a copy of the IHA and ITS issued to L-DEO for this study;
B. background on development and implementation of safety radii;
C. characteristics of the *Langseth*, the airgun array, and the echosounders;
D. details on visual and acoustic monitoring, mitigation, and data analysis methods;
E. conservation status and densities of marine mammals in the project region;
F. monitoring effort and a list of marine mammals and sea turtles seen during this cruise; and
G. a passive acoustic monitoring report for the Shatsky Rise cruise.

2. SEISMIC PROGRAM DESCRIBED

The seismic survey took place at the Shatsky Rise in the Northwest Pacific Ocean (Fig. 2.1). Procedures used to obtain seismic data during the study were similar to those used during previous seismic surveys by L-DEO. A 36-airgun array was used as the energy source, and the acoustic receiving system consisted of a 6-km long hydrophone streamer and/or OBSs.

In addition to the airgun operations, a 12-kHz MBES and a lower energy 3.5 kHz SBP were used to map the bathymetry and sub-bottom conditions. An acoustic release transponder was also used to communicate with the OBSs. The *Langseth* also towed a hydrophone array to detect calling cetaceans by PAM methods (see Chapter 3).

The following sections briefly describe the seismic survey, the equipment used for the study, and its mode of operation, insofar as necessary to satisfy the reporting requirements of the IHA (Appendix A). More detailed information on the *Langseth* and the equipment is provided in Appendix C.

Operating Areas, Dates, and Navigation

The study occurred within the area 30–36°N and 154–161°E (Fig. 2.1); water depths in the survey area were deeper than 1000 m. The ship departed Honolulu, HI, on 17 July 2010, for the ~9-day transit to the study area. After ~2 days of OBS, streamer, and airgun deployment, seismic operations commenced on 28 July and took place along the gray-shaded lines ("Ship Track Exposed") as shown in Figure 2.1. Airgun operations occurred during the day and at night. All vessel operations ceased on 30 July due to a medical emergency on board the *Langseth*. The vessel transited to Yokohama, Japan, for the medevac, and returned to the study area on 7 August, when seismic operations recommenced. Operations had to be aborted again on 15 August for another medevac to Yokohama, Japan. Seismic operations recommenced on 22 August and were completed on 29 August. After ~4 days of OBS and other equipment recovery, the vessel conducted a 2-day multibeam survey. The *Langseth* left the study area on 4 September and arrived in Honolulu on 13 September. In total, ~18 days of seismic operations took place.

A summary of the total distances traveled by the *Langseth* during the Shatsky Rise survey, distinguishing periods with and without seismic operations, is presented in Table ES.1 (in *Executive Summary*). All dates and times throughout the report are local unless noted otherwise.

Throughout the study, position, speed, and activities of the *Langseth* were logged digitally every minute. In addition, the position of the *Langseth,* water depth, and information on the airgun array were logged for every airgun shot while the *Langseth* was collecting geophysical data. The geophysics crew kept a written log of events, as did the marine mammal observers (MMOs) while on duty. The MMOs, when on duty, also recorded the number and volume of airguns that were firing when the *Langseth* was offline (e.g., turning from one line to the next), or was online but not recording data (e.g., during airgun or computer problems).

Airgun Array Characteristics

A 36-airgun array with a total discharge volume of 6600 in^3 was used during the Shatsky Rise survey. The array consisted of 36 Bolt 1500LL and Bolt 1900LLX airguns with volumes ranging from 40 to 360 in^3 per airgun. During firing, a brief (~0.1 s) pulse of sound was emitted. Compressed air supplied by compressors aboard the *Langseth* powered the airgun array; the firing pressure of the array was 1900 psi.

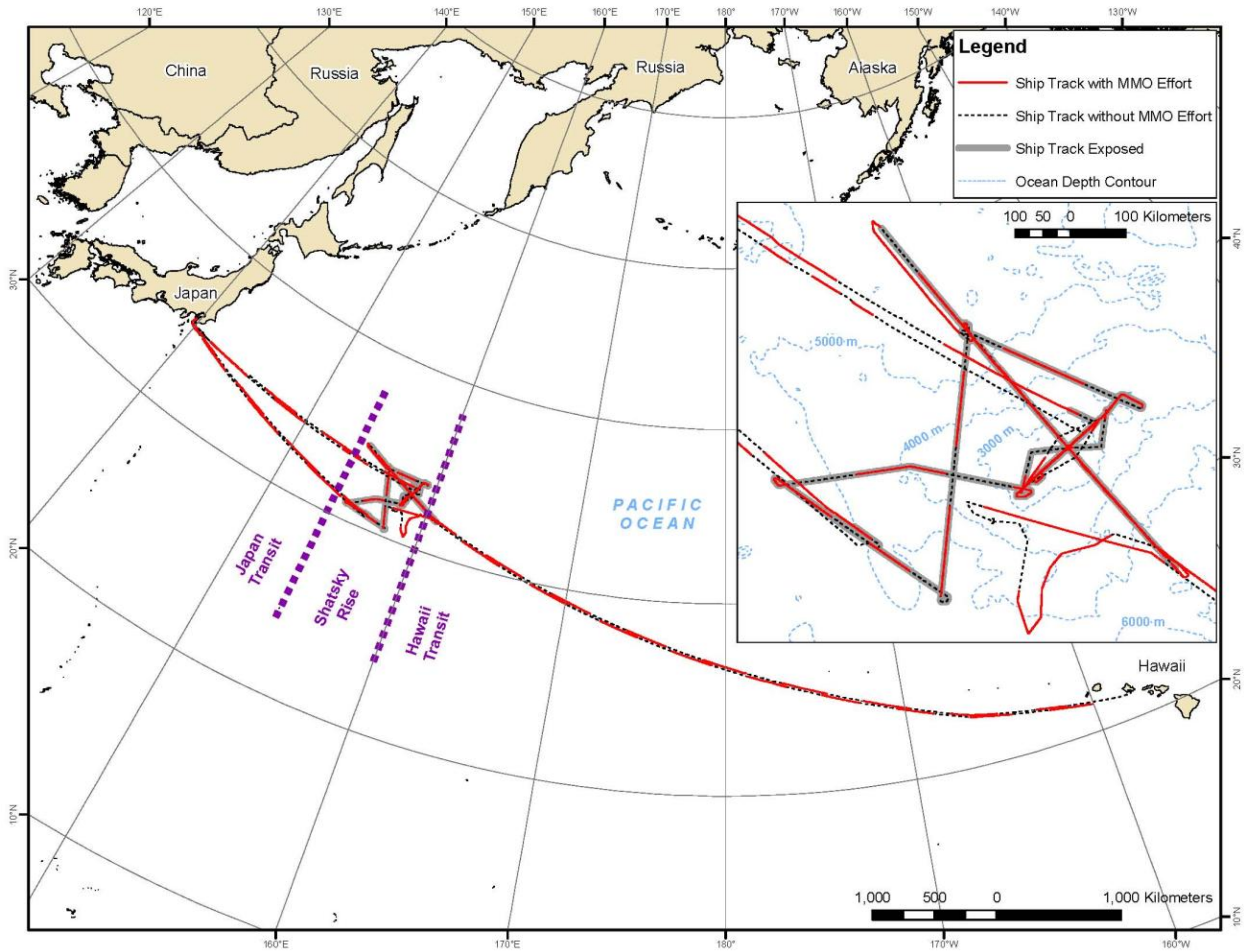

FIGURE 2.1. Map of the Shatsky Rise study area showing ship tracks and acquired seismic lines ("Ship track exposed") during 17 July – 13 September 2010.

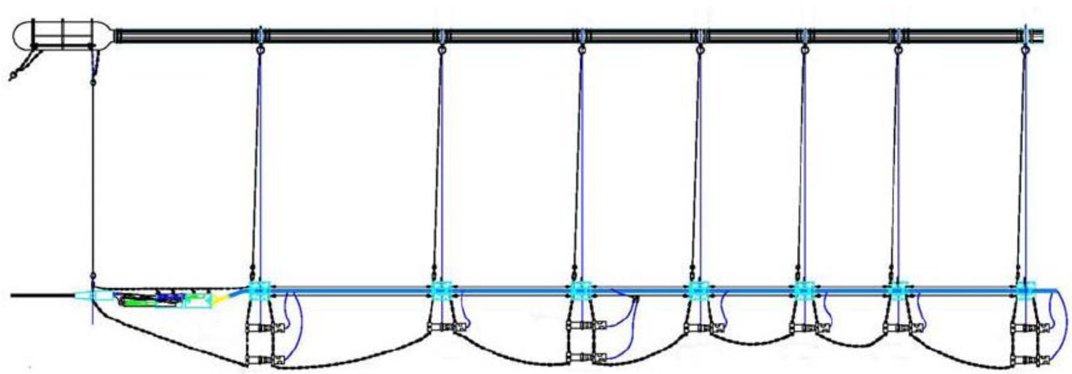

FIGURE 2.2. One of the four linear airgun arrays or strings with ten airguns. Nine airguns per string are active during seismic operations.

The airguns were configured as four identical linear arrays or "strings" (Fig. 2.2). Each string had 10 airguns; the first and last airguns in the strings were spaced 16 m apart. Nine airguns in each string fired simultaneously, whereas the tenth was kept in reserve as a spare, to be turned on in case of failure of another airgun. The four airgun strings were distributed across an approximate area of 24×16 m behind the *Langseth*. The array was towed ~215 m behind the vessel at a speed of ~4.7 kt (8.7 km/h). The airguns were suspended in the water from air-filled floats (see Appendix C). The airguns were towed at a depth 9 m for the multichannel seismic (MCS) lines with the streamer and at a depth of 12 m for the OBS lines. The shot spacing was ~20 s for multichannel seismic surveying with the hydrophone streamer and ~70 s when recording data on the OBSs.

The nominal source level for downward propagation of low-frequency energy from the 36-airgun array is shown in Table 2.1. The nominal source level would be somewhat higher if the small amount of energy at higher frequencies were considered. Because an airgun array is a distributed sound source (many airguns) rather than a single point source, the highest sound level measurable at any location in the water is considerably less than the nominal source level (Caldwell and Dragoset 2000). In addition, the effective source level for sound propagating in near-horizontal directions is substantially lower than the nominal source level applicable to downward propagation because of the directional nature of the dominant low-frequency sound from the airgun array. The source level expressed on the rms basis used elsewhere in this report would be lower than the peak-to-peak and zero-to-peak source levels listed in Table 2.1, but source levels of airguns and airgun arrays are not normally determined on an rms basis by airgun manufacturers or geophysicists.

Other Airgun Operations

Airguns operated during certain other periods besides seismic acquisition (line shooting), including periods during ramp ups, after power downs, and during line changes. Ramp ups were required by the IHA (see Chapter 3 and Appendix A). Ramp ups involved a systematic increase in the number of airguns firing; airguns were added every 5 min, to ensure that the source level of the array increased in steps not exceeding 6 dB per 5-min period. Ramp ups occurred when operations with the airgun array commenced after a period without airgun operations, and after periods when only one airgun had been firing (e.g., after a power down for a marine mammal or turtle in or near the safety zone).

Multibeam Bathymetric Echosounder and Sub-bottom Profiler

Along with the airgun operations, two additional acoustic systems operated during the cruise. A 12-kHz Simrad EM120 MBES and a 3.5-kHz SBP operated throughout most of the cruise to map the bathymetry and sub-bottom conditions, as necessary to meet the geophysical science objectives. During seismic operations, these sources typically operated simultaneously with the airgun array. The echo-sounders are described in Appendix C. In brief, the MBES has a beamwidth of 1º fore-aft and 150º athwartship, a source level of 242 dB re 1 μPa_{rms}, and (for each beam) emits pings ≤15 ms in duration at intervals of 5–20 s. The SBP emits downward-directed pulses with source level ≤204 dB re 1 μPa · m at 1-s intervals. In addition, an acoustic release transponder was used to communicate with the OBSs.

TABLE 2.1. Specification of the 36-airgun array used during L-DEO's Shatsky Rise survey.

Energy source	Thirty-six 1900 psi Bolt airguns of 40–360 in^3
Source output (downward) [a]	0-pk is 84 bar-m (259 dB re 1 μPa · m); pk-pk is 177 bar-m (265 dB)
Total air discharge volume	~6600 in^3

[a] Source level estimates are based on a filter bandwidth of ~0–250 Hz; dominant frequency components are 2–188 Hz. Because the airgun array is a distributed source, the maximum level measureable anywhere in the water would be less.

3. MONITORING AND MITIGATION METHODS

This chapter describes the marine mammal and sea turtle monitoring and mitigation measures implemented for L-DEO's seismic study, addressing the requirements specified in the IHA (Appendix A). The section begins with a brief summary of the monitoring tasks relevant to mitigation for marine mammals and sea turtles. The acoustic measurements and modeling results used to identify the safety radii for marine mammals and turtles are then described. A summary of the mitigation measures required by NMFS and implemented by L-DEO is then presented. The chapter ends with a description of the monitoring methods implemented for this cruise from aboard the *Langseth*, and a description of data analysis methods.

Monitoring Tasks

The main purposes of the vessel-based monitoring were to ensure that the provisions of the IHA and ITS issued to L-DEO by NMFS were satisfied, effects on marine mammals and sea turtles were minimized, and residual effects on animals were documented. The monitoring objectives of the monitoring program were listed in Chapter 1, *Mitigation and Monitoring Objectives*. Tasks specific to monitoring are listed below (also see Appendix A):

- Provide qualified MMOs for the *Langseth* source vessel throughout the seismic study.
- Visually monitor the occurrence and behavior of marine mammals and sea turtles near the airgun array during daytime whether the airguns were operating or not.
- Record (insofar as possible) the effects of the airgun operations and the resulting sounds on marine mammals and turtles.
- Use PAM to detect calling marine mammals (day and night) and notify visual observers (when on duty) of nearby marine mammals.
- Use the monitoring data as a basis for implementing the required mitigation measures.
- Estimate the number of marine mammals potentially exposed to airgun sounds.

Safety and Potential Disturbance Radii

Under NMFS guidelines (e.g., NMFS 2000), "safety radii" for marine mammals around airgun arrays are customarily defined as the distances within which received pulse levels are ≥180 dB re 1 μPa_{rms} for cetaceans and ≥190 dB re 1 μPa_{rms} for pinnipeds. These safety criteria are based on an assumption that seismic pulses received at lower received levels are unlikely to injure these animals or impair their hearing abilities, but that higher received levels *might* have some such effects. Marine mammals exposed to ≥160 dB re 1 μPa_{rms} are assumed by NMFS to be potentially subject to behavioral disturbance. However, for certain groups (delphinids, some porpoises, and some pinnipeds), this is unlikely to occur unless received levels are higher, perhaps ≥170 dB re 1 μPa_{rms} for an average animal. In this report, all quoted sound levels are based on equal weighting of all frequencies (i.e., the levels are flat-weighted).

Radii within which received levels from various airgun configurations were expected to diminish to certain values (i.e., 190, 180, 170, and 160 dB re 1 μPa_{rms}) were estimated by L-DEO (Table 3.1) and incorporated into the IHA (Appendix A). The 180-dB distance was used as the safety radius for cetaceans and sea turtles; pinnipeds were not expected to occur in the study area and none were seen. The radii depend on water depth (see Tolstoy et al. 2004a,b, 2009) as well as tow depth of the airgun array. Tow depths of ~9 and 12 m were used to estimate the safety radii for the Shatsky Rise survey, and those were the actual tow depths used during the survey. Background on the sound modeling is provided in Appendix B.

TABLE 3.1. Predicted distances to which airgun sound levels ≥190, 180, 170, and 160 dB re 1 μPa$_{rms}$ were estimated to be received in deep (>1000 m) water during the Shatsky Rise seismic survey. Distances for the 36-airgun array are based on measured radii for the array (Tolstoy et al. 2009), and predicted radii for a single airgun were based on L-DEO's model (see Appendix B).

Source and Volume	Tow depth (m)	Predicted RMS Distances (m) in deep (>1000 m) water			
		190 dB	180 dB	170 dB	160 dB
Single Bolt airgun, 40 in^3	9-12	12	40	120	385
4 strings, 36 airguns, 6600 in^3	9	400	940	2200	3850
4 strings, 36 airguns, 6600 in^3	12	460	1100	2510	4400

Mitigation Measures as Implemented

The primary mitigation measures that were implemented during the Shatsky Rise seismic study included ramp up and power down (or shut down, if necessary) of the airguns. These measures are standard procedures employed during L-DEO seismic cruises and are described below and in more detail in Appendix D.

Standard mitigation measures implemented during the study included the following:

1. The configuration of the array directed more sound energy downward, and to some extent fore and aft, than to the side of the track. This reduced the exposure of marine animals, especially to the side of the track, to airgun sounds.
2. Safety radii implemented for the 36-airgun array during the seismic study were based on empirical data from Tolstoy et al. (2009) for the *Langseth*'s array (see Appendix B),
3. Power-down or shut-down procedures were implemented when a marine mammal or sea turtle was seen within or near the applicable safety radius while the airguns were operating.
4. A change in vessel course and/or speed alteration was identified as a potential mitigation measure if a marine mammal was detected outside the safety radius and, based on its position and motion relative to the ship track, was judged likely to enter the safety radius. However, substantial alteration of vessel course or speed was not practical during the seismic study, given the length of the streamer(s) that was towed, and the design of the survey. Power downs or shut downs were the preferred and most practical mitigation measures when mammals were sighted within or about to enter the safety radii.
5. Ramp-up procedures were implemented whenever the airgun array was powered up, to gradually increase the size of the operating source at a rate no greater than 6 dB per 5 min, the maximum ramp-up rate authorized by NMFS in the IHA and during past L-DEO seismic cruises. Ramp up from a shut-down position could not be initiated in low-light (fog) or nighttime conditions.
6. Ramp up could not proceed if marine mammals were known to be within the safety radius, or if there had been visual detection(s) inside the safety zone within the following periods: 30 min for mysticetes and large odontocetes, including sperm whales, pygmy sperm, dwarf sperm,

killer, and beaked whales, and 15 min for small odontocetes or pinnipeds. Likewise, ramp up could not proceed if a sea turtle was within the safety radius.

7. PAM was conducted during all seismic operations.
8. If concentrations of beaked whales had been observed (by visual or passive acoustic detection) at a site such as on the continental slope, submarine canyon, seamount, or other underwater geological feature just prior to or during the airgun operations, operations were to be powered/shut down and/or moved to another location along the site, if possible, based on recommendations by the on-duty MMO aboard the *Langseth*.
9. If a visual detection of a North Pacific right whale had been made, the airgun(s) were to be shut down immediately, regardless of the distance from the *Langseth*. The array was not to resume firing until 30 min after the last whale sighting.

No beaked whales or North Pacific right whales were seen during the Shatsky Rise cruise.

Visual Monitoring Methods

Visual monitoring methods were designed to meet the requirements identified in the IHA (see above and Appendix A). The primary purposes of MMOs aboard the *Langseth* were as follows: ***(1)*** Conduct monitoring and implement mitigation measures to avoid or minimize exposure of cetaceans or sea turtles to airgun sounds with received levels >180 dB re 1 μPa_{rms}, and to implement the other requirements of the IHA. ***(2)*** Document numbers of marine mammals and sea turtles present, and any reactions to seismic activities. The data collected were used to estimate the number of marine mammals potentially affected by the project. Results of the monitoring program for marine mammals and sea turtles are presented in Chapter 4.

The visual monitoring methods that were implemented during this cruise were similar to those during previous L-DEO seismic cruises. In chronological order, those were described by Smultea and Holst (2003), Smultea et al. (2003), MacLean and Haley (2004), Holst (2004), Smultea et al. (2004), Haley and Koski (2004), MacLean and Koski (2005), Smultea et al. (2005), Holst et al. (2005a,b), Holst and Beland (2008), Holst and Smultea (2008), Hauser et al. (2008), Hauser and Holst (2009), Holst (2009a,b), and Holst and Beland (2010). The standard visual observation methods are described in Appendix D.

In summary, during the seismic study, up to five trained MMOs were aboard the *Langseth* for visual observations. A single observer was on watch for 58% of visual observation periods, and two or more MMOs were on watch during 42% of watches. Visual observations were conducted from the *Langseth*'s observation tower. Observers focused search effort forward of the vessel but also searched aft of the vessel while it was underway. Watches were conducted with the naked eye, Fujinon 7×50 reticle binoculars, and mounted 25×150 Big-eye binoculars. Nighttime visual watches were only required before and during any nighttime startups of the airguns; however, no such startups occurred during the Shatsky Rise cruise. Appendix D provides further details regarding visual monitoring methods.

Passive Acoustic Monitoring Methods

To complement the visual monitoring program, PAM took place as required by the IHA (Appendix A). A requirement for PAM during large-source seismic cruises was first specified by IHAs issued to L-DEO in 2004. Visual monitoring typically is not effective during periods of bad weather or at night, and even with good visibility, is unable to detect marine mammals when they are below the surface or beyond visual range. Acoustical observations can be used in addition to visual observations to improve detection, identification, localization, and tracking of cetaceans.

In practice, acoustic monitoring (when effective) serves to alert visual observers when vocalizing cetaceans are in the area. The PAM system aboard the *Langseth* can detect calling cetaceans before they are seen by visual observers or when they are not sighted by visual observers (e.g., Smultea et al. 2004, 2005; Holst et al. 2005a,b). This helps to ensure that cetaceans are not nearby when seismic operations are underway or about to commence. During this cruise, the acoustical system was monitored in real time so the visual observers (when on duty) could be advised when cetaceans were heard, as directed in the IHA. This approach had been implemented successfully during some previous L-DEO seismic cruises.

The Right Waves 4-channel hydrophone array was used during the Shatsky Rise study (see Appendices D & G for a description of this system). Acoustic monitoring software developed by CIBRA (University of Pavia, Italy) was used to display and record cetacean calls detected by the hydrophones (see Appendix D). One MMO monitored the acoustic detection system by listening to the signals via headphones and by watching a real-time spectrogram display for frequency ranges produced by cetaceans. MMOs monitoring the acoustical data were usually on shift for 1–6 h.

If a cetacean call had been detected, the visual observer (if on duty) would have been notified immediately of the presence of calling marine mammals. Each acoustic "encounter" was to be assigned a chronological identification number. An acoustic encounter is defined as including all calls of a particular species or species-group separated by <1 h (Manghi et al. 1999).

Analyses

Categorization of Data

Visual effort and marine mammal sightings were divided into several analysis categories related to vessel and seismic activity. The categories used were similar to those used during other L-DEO seismic studies (e.g., Haley and Koski 2004; MacLean and Koski 2005; Smultea et al. 2005; Holst et al. 2005a,b; Holst and Beland 2008, 2010; Holst and Smultea 2008; Hauser et al. 2008; Hauser and Holst 2009; Holst 2009a,b). These categories are defined briefly below, with more details in Appendix D.

In general, data were categorized as "seismic", "non-seismic", or "post-seismic". "Seismic" included all data collected while the airguns were operating, including ramp ups, and periods up to 90 s (1.5 min) after the airguns were shut off. Non-seismic included all data obtained before airguns were activated (pre-seismic) or >6 h after the airguns were turned off. Data collected during post-seismic periods from 1.5 min to 6 h after cessation of seismic were considered either "recently exposed" (1.5 min–2 h) or "potentially exposed" (2–6 h) to seismic. The "recently exposed" sub-category was not included in either the "seismic" or "non-seismic" category. The "potentially exposed" sub-category was included under "non-seismic" for sea turtles, but both post-seismic categories were excluded from all marine mammal analyses. The 6-h post-seismic cut-off is the same cut-off used during previous L-DEO cruises that used moderate-sized or large (10–36 airgun) airgun arrays (e.g., Smultea et al. 2004, 2005; Holst et al. 2005b; Holst and Beland 2008, 2010; Holst and Smultea 2008; Hauser et al. 2008; Hauser et al. 2009; Holst 2009a,b). A shorter (i.e., 2-h) post-seismic cut off was used during other cruises where the seismic sources and safety radii were much smaller (Haley and Koski 2004; MacLean and Koski 2005; Holst et al. 2005a).

This categorization system was designed primarily to distinguish situations with ongoing seismic surveys from those where any seismic surveys were sufficiently far in the past that it can be assumed that they had no effect on current behavior and distribution of animals. Since the rate of recovery to "normal" behavior is unknown, the post-seismic period was defined so as to be sufficiently long (6 h for cetaceans and 2 h for turtles) to ensure that any carry-over effects of exposure to the sounds from the large airgun array surely would have waned to zero or near-zero. The reasoning behind these categories was explained in MacLean and Koski (2005) and Smultea et al. (2005) and is discussed in Appendix D.

Since the Shatsky Rise cruise covered a large region with changing oceanographic features and cetacean distribution, the data were categorized into three different areas: the Shatsky Rise study area, transit to and from Hawaii, and transit to and from Japan. The Shatsky Rise study area was defined as the area located between 154° and 161°E. Transits to and from Hawaii occurred 161°E, and transits to and from Japan occurred west of 154°E.

Line Transect Estimation of Densities

Sightings during the "seismic" and "non-seismic" periods were used to calculate sighting rates (#/1000 km). Sighting rates were then used to calculate the corresponding densities (#/km^2) of marine mammals near the survey ship during seismic and non-seismic periods. Density calculations were based on line transect principles (Buckland et al. 2001). Because of assumptions associated with line-transect surveys [sightability, *f*(0), *g*(0), etc.], only "useable" effort and sightings were included in density calculations. Effort and sightings were defined as "useable" when made under the following conditions: daylight periods within the seismic survey area, excluding post-seismic periods 90 s to 6 h after airguns were turned off, or when ship speed <3.7 km/h (2 kt), or with seriously impaired sightability. The latter included all nighttime observations, and daytime periods with one or more of the following: visibility <3.5 km, Beaufort Wind Force (Bf)>5, or >60º of severe glare between 90º left and 90º right of the bow. Also, sightings beyond the truncation distance (used for density calculations) were considered non-useable. Although "non-useable" sightings (and associated survey effort) were not considered when calculating densities of marine mammals, such sightings were taken into account when determining the need for real-time mitigation measures (power downs, shut downs).

Correction factors for missed cetaceans, i.e., *f*(0) and *g*(0), were taken from other related studies (i.e., Koski et al. 1998; Barlow 1999). This was necessary because the number of sightings of any individual species during the present study was too low to allow direct estimation of *f*(0), and because *g*(0), the trackline sighting probability, cannot be assessed during a study of this type. Densities that allow for these factors are listed here as "corrected" densities. It is acknowledged that *f*(0) and *g*(0) values derived from other studies probably are not exactly applicable to the circumstances of the present study. However, use of "best available" approximate *f*(0) and *g*(0) factors from other studies is expected to result in more realistic density estimates than would be obtained by using uncorrected ("raw") densities without any allowance for *f*(0) and *g*(0) effects.

Densities during non-seismic periods were used to estimate the numbers of animals that presumably would have been present in the absence of seismic activities. Densities during seismic periods were used to estimate the numbers of animals present near the seismic operation and exposed to various sound levels. The difference between the two estimates could be taken as an estimate of the number of animals that moved in response to the operating seismic vessel, or that changed their behavior sufficiently to affect their detectability to visual observers. Further details on the line transect methodology used during the survey are provided in Appendix D.

Estimating Numbers of Marine Mammals Potentially Affected

For purposes of the IHA, NMFS assumes that any marine mammal that might have been exposed to airgun pulses with received sound levels ≥160 dB re 1 μPa_{rms} may have been disturbed. When calculating the number of mammals potentially affected, the nominal 160-dB radii for the airgun configurations in use were applied (Table 3.1).

Two approaches were applied to estimate the numbers of marine mammals that either were exposed to sound levels ≥160 dB re 1 μPa_{rms}, or avoided such exposure by moving away:

1. Estimates of the numbers of potential *exposures* of marine mammals, and
2. Estimates of the number of different *individual* mammals exposed (one or more times).

The first method ("exposures") was obtained by multiplying the "corrected" densities of marine mammals (as estimated by line transect methods) by the area assumed to be ensonified to ≥160 dB re 1 μPa_{rms}. The second approach ("individuals") involved multiplying the same corrected density of marine mammals by the area exposed to ≥160 dB re 1 μPa_{rms} one or more times during the course of the study. In the latter method, areas ensonified to ≥160 dB on more than one occasion, e.g., when seismic lines crossed or were repeated, were counted only once.

The two approaches can be interpreted as providing maximum and minimum (respectively) estimates of the number of marine mammals exposed to sound levels ≥160 dB re 1 μPa_{rms}, or that would have been so exposed had they not moved away from the approaching seismic vessel. The actual number exposed and/or moving away is probably somewhere between these two estimates. This approach was originally developed to estimate numbers of seals potentially affected by seismic surveys (Harris et al. 2001). The approach has been used in various L-DEO reports to NMFS (e.g., Haley and Koski 2004; Smultea et al. 2004, 2005; MacLean and Koski 2005; Holst et al. 2005a,b; Holst and Beland 2008, 2010; Holst and Smultea 2008; Hauser et al. 2008; Hauser and Holst 2009; Holst 2009a,b). The methodology is described in detail in these past reports and in Appendix D.

4. MONITORING RESULTS

Introduction

This chapter provides background information on the occurrence of marine mammals and sea turtles in the project area, and describes results of the marine mammal and sea turtle monitoring program. In addition, this chapter estimates numbers of marine mammals that were exposed to (or avoided) various sound levels and were potentially affected during project operations.

Status of Marine Mammals in the Study Area

Thirty-three cetacean species, including 26 odontocete (dolphins and small- and large-toothed whales) species and seven mysticetes (baleen whales) may occur at the Shatsky Rise. In addition, the southern extent of the pelagic range for the northern fur seal overlaps the area. Several of these species are listed under the ESA as ***endangered***, including the North Pacific right, sperm, humpback, fin, sei, and blue whales. Additional information on the occurrence, distribution, population size, and conservation status for each of the 34 marine mammal species is presented in Appendix E.

Status of Sea Turtles in the Study Area

Five species of sea turtle may occur at the Shatsky Rise. In order of decreasing likelihood they are: the loggerhead (*Caretta caretta*), leatherback (*Dermochelys coriacea*), olive ridley (*Lepidochelys olivacea*), green (*Chelonia mydas*), and hawksbill (*Eretmochelys imbricata*) turtles (Chan et al. 2007). Loggerhead and leatherback turtles can spend substantial amounts of time offshore during migrations or feeding between breeding seasons, including the North Pacific and specifically in the vicinity of Shatsky Rise. Olive ridley turtles tend to remain in coastal areas or offshore at lower latitudes than the Shatsky Rise; however, this species is widespread and little is known of its offshore habits. Green and hawksbill turtles are unlikely to inhabit the Shatsky Rise region in favor of more tropical latitudes. The leatherback and hawksbill turtles are listed as ***endangered*** under the ESA, and the green, olive ridley, and loggerhead turtles are listed as ***threatened***.

Visual Monitoring Effort and Sightings

This section summarizes the visual monitoring effort and sightings from the *Langseth* during the Shatsky Rise cruise, 17 July to 13 September 2010. This section summarizes the monitoring results and Appendix F provides detailed data summaries including visual survey effort subdivided by seismic activity and Beaufort wind force. Table ES.1 shows a general summary of effort and sightings.

Visual Survey Effort

The *Langseth* traveled a total of 21,292 km (1371 h) during the Shatsky Rise cruise; 7300 km (655 h) occurred within the Shatsky Rise study area, 8333 km (425 h) occurred in transit to and from Hawaii, and 5659 km (291 h) took place during transit to and from Japan (Table ES.1). A total of 718 h of visual observations were obtained, with 357 h occurring with the study area (Table ES.1). One or more observers were on watch during all daytime airgun operations and during most daytime periods when the vessel was underway but not firing the airguns; no visual observations occurred during nighttime seismic operations. The number of hours of observation per day varied according to the schedule of operations.

Nearly half of all visual effort (~45%) in the study area took place during seismic periods (Fig. 4.1). Most (85%) seismic operations took place with the 36-airgun array; the remaining operations occurred during ramp up, power down, line changes, or seismic testing with fewer airguns (see Appendix F). Survey conditions were considered "useable" for systematic analysis during ~85% of total visual effort in the study area (Table ES.1). "Useable" effort within the study area excluded nighttime observations, periods 90 s to 6 h after airguns were turned off, poor visibility conditions (visibility <3.5 km or extensive glare), Bf >5, and ship speed <3.7 km/h (2 kt). Also, sightings whose lateral distances from the trackline were outside the truncation distance (used to determine densities) were considered "non-useable", as were sightings of cryptic species (e.g., minke whale) in BF>2. Beaufort wind force during observations aboard the *Langseth* ranged from one to six; most "useable" observations within the study area (64%) took place during Bf 3–4 (Fig. 4.2; Appendix F). Sightings and survey effort during "non-useable" conditions were excluded when calculating densities, but were included when determining when power downs or shut downs were necessary because of marine mammals within the safety zone.

Sightings of Marine Mammals

A total of 781 cetaceans in 27 groups were sighted during the Shatsky Rise cruise (Fig. 4.3; Table 4.1; Appendix F). The sperm whale was the most frequently sighted species (9 of 27 sightings, totaling 31 individuals; Table 4.1). Five sightings of 13 individuals were made in the study area (Fig. 4.4), nineteen sightings of 415 individuals were made during transits to and from Japan (Fig. 4.5), three sightings of 353 cetaceans were made during transits to and from Hawaii (Fig. 4.3). Four groups (totaling 10 individuals) were considered "useable" within the study area, including three sperm whale groups and one unidentified whale (Table ES.1). Only "useable" sightings in the study area, along with the corresponding effort data, are considered in the ensuing analyses of behavior, detection rates, and densities of marine mammals. At least five other species were seen during the cruise, including the minke whale, short-finned pilot whale, false killer whale, pantropical spotted dolphin, and Risso's dolphin.

Marine Mammal Sightings by Seismic State within the Study Area

One of the four "useable" sightings during the Shatsky Rise survey was made during seismic periods; three were made during non-seismic periods (Table 4.1). One power down was implemented due to cetaceans being observed within the applicable safety radii around the active airgun array. Further details on these encounters are provided later (see Table 4.4 under *Mitigation Measures Implemented*).

Marine Mammal Detection Rate within the Study Area

The detection rates (number of cetacean groups sighted per 1000 km of "useable" effort) were based on ~3341 km of useable effort, of which 1717 km was non-seismic and 1624 km was seismic. Considering useable sightings and effort during all activities, ~1.2 marine mammal groups were detected per 1000 km (n = 4). The detection rate was 1.7 groups/1000 km during non-seismic effort and 0.6 groups/1000 km during seismic periods.

Marine Mammal Density

Calculated densities for the study area were based on the number of "useable" sightings during non-seismic and seismic periods of the Shatsky Rise survey (Table 4.2). Densities for sightings made during transits to and from Japan and Hawaii were also calculated using only "useable" data. Within the study area, sperm whale density was higher during seismic than during non-seismic periods (Table 4.2). However, sperm whale density and overall cetacean density was greater for transits to and from Japan compared with densities in the Shatsky Rise study area (Table 4.2).

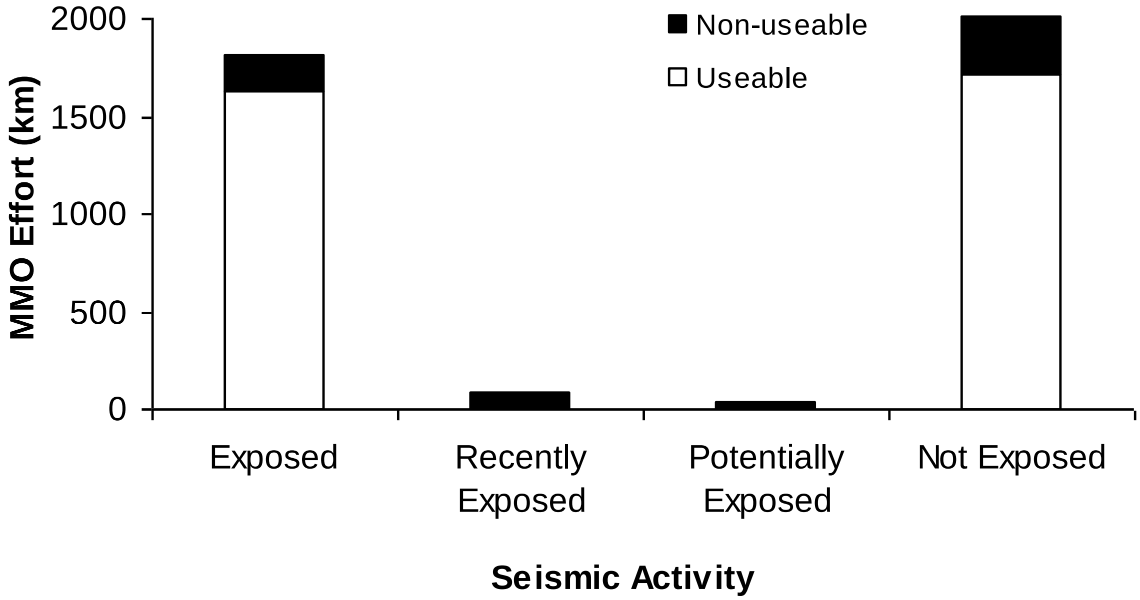

FIGURE 4.1. Total observer effort, categorized by seismic activity, during operations of the *Langseth* in the Shatsky Rise study area, 17 July to 13 September 2010. Recently Exposed includes periods 90 s to 2 h after airguns were turned off. Potentially Exposed includes periods 2−6 h after airguns were turned off.

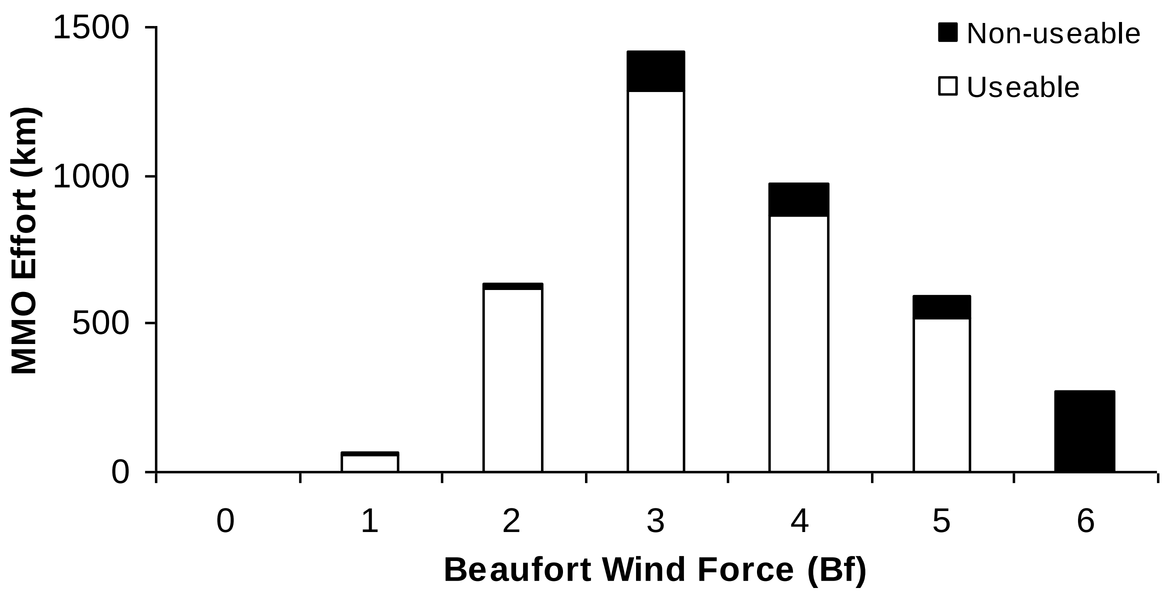

FIGURE 4.2. Total observer effort, categorized by Beaufort wind force, during operations of the *Langseth* in the Shatsky Rise study area, 17 July to 13 September 2010. Sightings of cryptic species in Bf>2 are considered non-useable, although there were no such sightings in the study area.

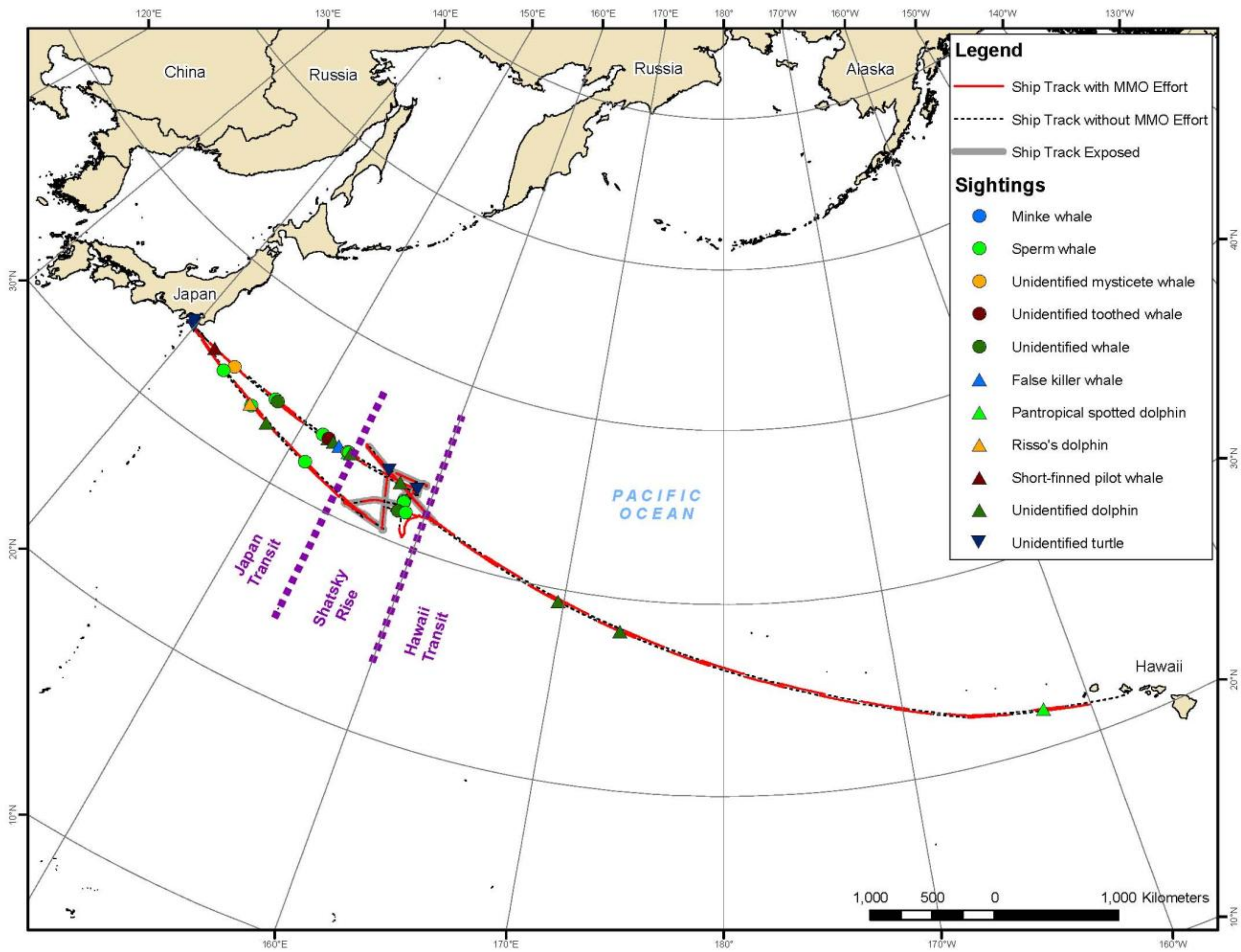

FIGURE 4.3. Sightings of cetaceans and sea turtles during the Shatsky Rise cruise, 17 July to 13 September 2010. Airguns operated along the shaded lines ("Ship track exposed").

Sea Turtle Sightings

A total of four unidentified turtles were sighted during the survey. Two of these were seen at Shatsky Rise and another two were sighted during transit to Japan (Fig. 4.3).

Other Vessels

No vessels were seen within 5 km of the *Langseth* when a cetacean or sea turtle sighting was made. Only one container ship was seen ~8 km away from the *Langseth* while at the Shatsky Rise study site.

Distribution and Behavior

The data collected during visual observations provide information about behavioral responses of marine mammals to the seismic survey. The relevant data collected from the *Langseth* include the closest observed point of approach (CPA) to the airguns, movement relative to the vessel, and behavior of animals at the time of the initial sighting.

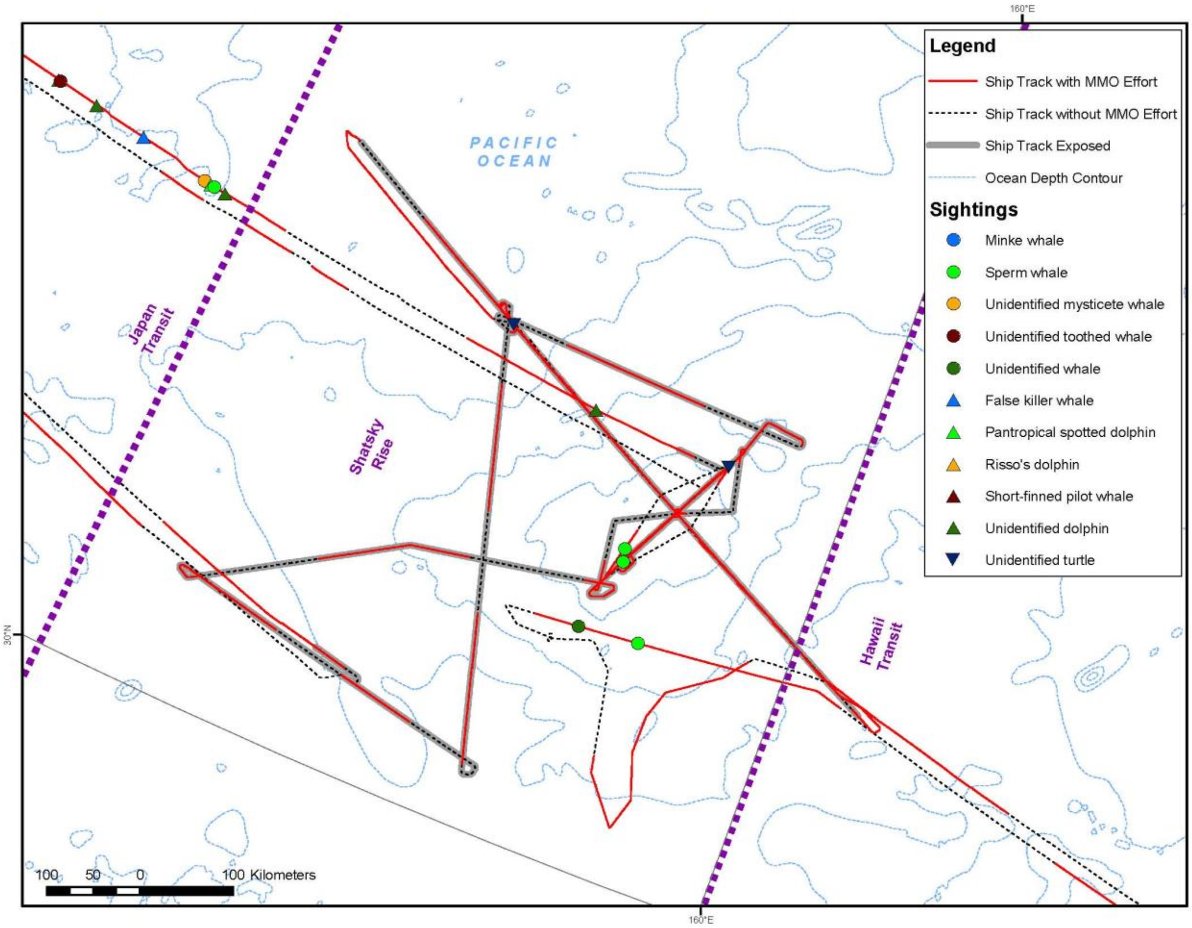

FIGURE 4.4. The Shatsky Rise survey showing the ship track, seismic lines, and sightings of cetaceans and sea turtles, 17 July to 13 September 2010. Airguns operated along the shaded lines ("Ship track exposed").

Marine mammal behavior is difficult to observe, especially from a seismic vessel, because individuals and/or groups are often at the surface only briefly, and there may be avoidance behavior. This causes difficulties in resighting those animals and in determining whether two sightings some minutes apart are repeat sightings of the same individual(s). Also, low sample sizes during any single cruise (including this one) make many of the results from an individual cruise difficult to interpret. However, at least some of these results will be meaningful when combined with similar results from other related seismic surveys.

The position of the MMOs on the vessel, and where they focused their observation efforts, yielded a distribution of animal sightings relative to the *Langseth* that was skewed toward the front of the vessel. Most (24 of 27) initial sightings were of cetaceans in the forward 180º relative to the vessel.

Closest Point of Approach

Within the study area, the mean CPA for sperm whales was closer during seismic periods (1031 m, $n = 1$) compared with the CPA during non-seismic (2000 m, $n = 2$). No meaningful comparisons of mean CPAs could be made, as sample sizes were small. The CPA for one unidentified whale seen during non-seismic in the study area was 3132 m. For useable sightings during transits to and from Japan, the mean CPA for sperm whales was 2237 m ($n = 5$).

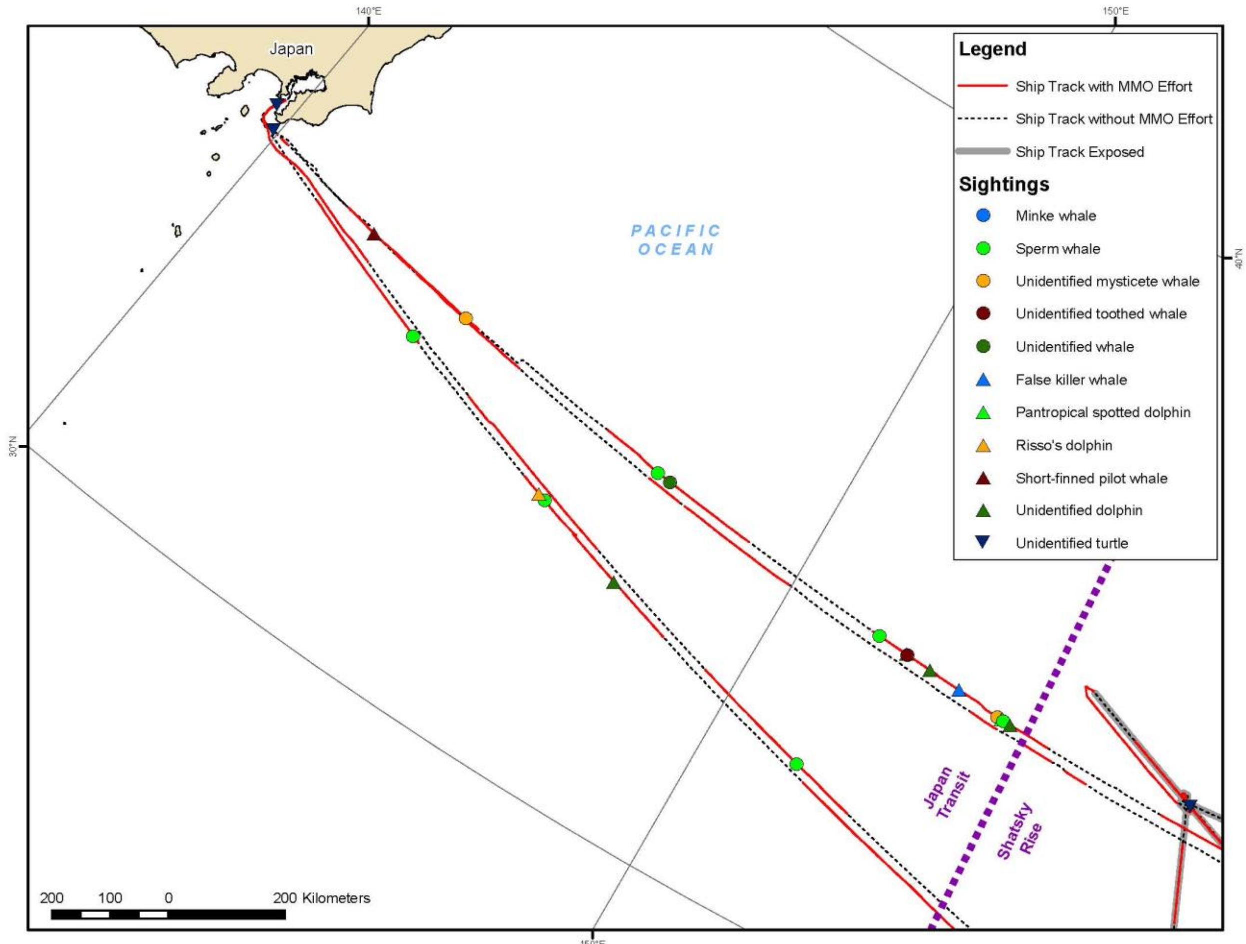

FIGURE 4.5. Sightings of cetaceans and sea turtles during the transit to and from Japan during the Shatsky Rise cruise, 17 July to 13 September 2010.

First Observed Behavior

The seven sperm whales sighted during seismic operations were recorded as swimming. The other two groups of sperm whales seen during non-seismic in the study area were seen logging and blowing. The behavior of the single unidentified whale seen during non-seismic was unknown. The behavior for the five 'useable' sightings of sperm whales during the Japan transits were recorded as swimming ($n = 3$), traveling ($n = 1$), and resting ($n = 1$).

Movement

The one group of sperm whales sighted during seismic operations was seen swimming parallel to the vessel. The movement for the groups of sperm whales seen during non-seismic periods within the study area was coded as no movement and unknown. The movement relative to the ship of the unidentified whale seen during non-seismic was also unknown. For the five 'useable' sightings during transits to and from Japan, sperm whale groups were seen swimming parallel to the vessel ($n = 3$), swimming away ($n = 1$), or swimming across the vessel path ($n = 1$).

TABLE 4.1. Numbers of marine mammals observed from the *Langseth* during the Shatsky Rise cruise, 17 July to 13 September 2010. There were no sightings during recently-exposed and potentially-exposed periods.

	Study Area									
	Seismic		Non-seismic		Hawaii		Japan		Total	
Species	Groups	Indiv.	Groups	Indiv.	Groups	Indiv.	Group	Indiv.	Groups	Indiv.
All Sightings										
Minke whale	-	-	-	-	-	-	1	1	**1**	**1**
Unidentified mysticete whale	-	-	-	-	-	-	2	3	**2**	**3**
Sperm whale	1	7	2	2	-	-	6	22	**9**	**31**
Unidentified whale	-	-	1	1	-	-	1	2	**2**	**3**
Short-finned pilot whale	-	-	-	-	-	-	1	3	**1**	**3**
False killer whale	-	-	-	-	-	-	1	4	**1**	**4**
Unidentified toothed whale	-	-	-	-	-	-	1	1	**1**	**1**
Pantropical spotted dolphin	-	-	-	-	1	3	1	3	**2**	**6**
Risso's dolphin	-	-	-	-	-	-	1	1	**1**	**1**
Unidentified dolphin	-	-	1	3	2	350	4	375	**7**	**728**
Total	**1**	**7**	**4**	**6**	**3**	**353**	**19**	**415**	**27**	**781**
Useable Sightings[a]										
Minke whale	-	-	-	-	-	-	-	-	**0**	**0**
Unidentified mysticete whale	-	-	-	-	-	-	2	3	**2**	**3**
Sperm whale	1	7	2	2	-	-	5	19	**8**	**28**
Unidentified whale	-	-	1	1	-	-	1	2	**2**	**3**
Short-finned pilot whale	-	-	-	-	-	-	1	3	**1**	**3**
False killer whale	-	-	-	-	-	-	1	4	**1**	**4**
Unidentified toothed whale	-	-	-	-	-	-	1	1	**1**	**1**
Pantropical spotted dolphin	-	-	-	-	1	3	1	3	**2**	**6**
Risso's dolphin	-	-	-	-	-	-	1	1	**1**	**1**
Unidentified dolphin	-	-	-	-	-	-	2	75	**2**	**75**
Total	**1**	**7**	**3**	**3**	**1**	**3**	**15**	**111**	**20**	**124**

[a]Useable sightings are those made during useable daylight periods of visual observation, as defined in *Acronyms and Abbreviations*, and exclude sightings during post-seismic periods.

Occurrence

Most cetacean sightings occurred outside of the study area during transits to and from Japan. Only five sightings of cetaceans were made at Shatsky Rise, including three groups of eight sperm whales, one unidentified whale, and one group of three unidentified dolphins.

Acoustic Monitoring Effort and Detections

During the Shatsky Rise survey, ~383 h of PAM took place during seismic operations; 2 h occurred during non-seismic periods. However, no acoustic detections of cetaceans were made. More details regarding the acoustic monitoring program can be found in Appendix G.

TABLE 4.2. Sightings and densities of cetaceans during "useable" survey effort during the Shatsky Rise cruise, 17 July to 13 September 2010, in (A) the Shatsky Rise study area, (B) transits to and from Japan, and (C) transits to and from Hawaii. All densities are for deep (>1000 m) water. Effort is shown for seismic/non-seismic periods. Cetacean densities were corrected for *f*(0) and *g*(0) using values from Koski et al. (1998) and Barlow (1999).

	Seismic				Non-seismic			
	Number of Sightings	Mean group size	Average corrected density (#/km) Density	CV[a]	Number of Sightings	Mean group size	Average corrected density (#/km) Density	CV[a]
(A) Shatsky Rise (1624 km / 1717 km)								
Sperm whale	1	7	0.001737	0.94	2	1	0.000469	0.83
Unidentified whale	0	-	-	-	1	1	0.000226	0.94
	1		**0.001737**	**0.94**	**3**		**0.000695**	**0.76**
(B) Japan (0 / 2660 km)								
Short-finned pilot whale	-	-	-	-	1	3	0.000879	0.94
Unidentified mysticete wha	-	-	-	-	2	1.5	0.000438	0.83
Sperm whale	-	-	-	-	5	3.8	0.002878	0.68
Unidentified whale	-	-	-	-	1	2	0.000292	0.94
Unidentified toothed whale	-	-	-	-	1	1	0.000293	0.94
Unidentified dolphin	-	-	-	-	2	37.5	0.007274	0.83
False killer whale	-	-	-	-	1	4	0.001171	0.94
Pantropical spotted dolphin	-	-	-	-	1	3	0.000879	0.94
Risso's dolphin	-	-	-	-	1	1	0.000293	0.94
	0		**0**		**15**		**0.014397**	**0.50**
(C) Hawaii (0 / 4113 km)								
Pantropical spotted dolphin	-	-	-	-	1	3	0.00057	0.94
	0		**0**		**1**		**0.00057**	**0.94**

[a] The CV (Coefficient of Variation) is a measure of each density's variability. The larger the CV, the higher the variability. It is estimated as indicated in Koski et al. (1998), but likely underestimates the true variability.

Mitigation Measures Implemented

Ramp ups and power downs of the airgun array were implemented as mitigation measures during the Shatsky Rise study (associated visual and acoustic monitoring procedures are outlined in Chapter 3). Full shut downs were not necessary during the Shatsky Rise cruise because no marine mammals or sea turtles were sighted sufficiently close to the airguns to require a full shut down. Ramp ups were conducted during daylight whenever the airguns were started up after a prolonged (≥8 min) period of inactivity or during the day when there was a requirement to increase the number of operating airguns by a factor exceeding 2× (e.g., from 1 to 36 airguns). The latter occurred subsequent to each power down for a marine mammal or sea turtle seen within or near the relevant safety radius. No ramp ups occurred at night.

One power down to a single airgun (40 in^3) was necessary during the Shatsky Rise cruise, due to a group of sperm whales that was seen just outside the relevant safety radius, for the airgun array towed at a depth of 9 m. The group of seven sperm whales was sighted on 26 August at 05:05 GMT during operations with the full airgun array, at a distance of 1031 m. A power down was implemented immediately. As the sperm whales were seen just outside the 180 dB re 1 μPa_{rms} radius around the full array (~940 m), it is likely that they were, when below the surface, exposed to sound levels ≥170 dB re 1 μPa_{rms} (flat-weighted) but less than 180 dB. Received levels when the animals were at or near the surface would have been substantially lower due to the effects of pressure-release at the surface. The array was ramped up again after the sperm whales had left the safety radius. Thus, it is estimated that a total of seven sperm whales were exposed during airgun operations. However, this estimate is a minimum; it does not allow for animals present during daytime airgun operations but not seen by the MMOs, or for animals approached during airgun operations at night. Estimates of numbers potentially exposed to various sound levels under those and other circumstances, allowing for missed animals, are provided in a subsequent section.

Implementation of the Terms and Conditions of the Biological Opinion's Incidental Take Statement

In order to minimize the incidental 'taking' of ESA-listed species, L-DEO implemented the above-mentioned mitigation measures for marine mammals and sea turtles sighted near or within the safety radius. Humpback, blue, fin, sei, and North Pacific right whales, and sea turtles were not seen during seismic operations at the Shatsky Rise; therefore few if any individuals of these species are likely to have occurred within the safety radii. However, nine groups of sperm whales totaling 31 individuals were seen during the Shatsky Rise survey; one sighting of seven individuals occurred during seismic operations. As this group was seen within the safety radius, it is likely that these individuals were exposed to received sound levels >160 dB.

In addition to the typical monitoring and mitigation measures such as ramp ups, power downs, and shut downs (see Chapter 3), the Biological Opinion also specified that an immediate shut down of airguns must occur in the event a North Pacific right whale was detected, at any distance from the vessel. Right whales were not seen during the survey. All mitigation measures specified in the IHA and Biological Opinion were followed and implemented as specified.

Estimated Number of Marine Mammals Potentially Affected

It is difficult to obtain meaningful estimates of "take by harassment" for several reasons: ***(1)*** The relationship between numbers of marine mammals that are observed and the number actually present is uncertain. ***(2)*** The most appropriate criteria for "take by harassment" are uncertain and presumably variable among species and situations. ***(3)*** The distance to which a received sound level exceeds a specific criterion such as 190 dB, 180 dB, 170 dB, or 160 dB re 1 μPa_{rms} is variable. It depends on water depth, airgun depth, and aspect for directional sources (e.g., Greene 1997; Greene et. al. 1998; Burgess and Greene 1999; Caldwell and Dragoset 2000; Tolstoy et al. 2004a,b, 2009). ***(4)*** The sounds received by marine mammals vary depending on their depth in the water, and will be considerably reduced for animals at or near the surface (Greene and Richardson 1988; Tolstoy et al. 2004a,b, 2009).

Disturbance and Safety Criteria

Any cetacean that might have been exposed to airgun pulses with received sound levels ≥160 dB re 1 μPa_{rms} (flat-weighted) was assumed to have been potentially disturbed. Such disturbance was authorized by the IHA issued to L-DEO. However, the 160-dB criterion was developed by NMFS from studies of baleen whale reactions to seismic pulses (Richardson et al. 1995). That criterion likely is not scientifically defensible for delphinids. The hearing of small odontocetes is relatively insensitive to low frequencies, and behavioral reactions of most small odontocetes to airgun sounds indicate that they are usually less responsive than are some baleen whales (Richardson et al. 1995; Gordon et al. 2004). We estimate the numbers of all cetaceans that were exposed to ≥160 dB re 1 μPa_{rms} as required by the IHA. If delphinids had been seen, we would have also estimated numbers of delphinids that might have been exposed to ≥170 dB re 1 μPa_{rms}, an alternative and more realistic criterion of disturbance to delphinids.

Table 3.1 shows the predicted received sound levels at various distances from the airgun(s) deployed from the *Langseth*. The ≥160-dB radius is an assumed behavioral disturbance criterion. As discussed above, the 170 dB-radius is an alternative criterion for estimating potential disturbance of delphinids. The ≥180 dB-radius is a safety radius, used in determining when mitigation measures are required. During this and other recent L-DEO projects, NMFS has required that mitigation measures be applied to avoid, or minimize, the exposure of cetaceans to impulse sounds with received levels ≥180 dB re 1 μPa_{rms}. During this study, one power down was required (as described above) due to marine mammals being sighted within or near the applicable safety radius around the operating airguns. However, additional estimates of the numbers of marine mammals potentially exposed to various received sound levels were also derived based on observed densities and the assumed 160-dB radii. These additional estimates allow for animals not seen by the MMOs as well as for the animals that were seen.

This section applies two methods to estimate the number of marine mammals possibly exposed to seismic sound levels strong enough that they might have caused disturbance or other potential impacts. The procedures include ***(A)*** minimum estimates based on the direct observations of marine mammals by MMOs, and ***(B)*** estimates based on marine mammal densities obtained during this study. The actual numbers of individual marine mammals exposed to, and potentially affected by seismic survey sounds likely were between the minimum and maximum estimates provided in the following sections. The estimates provided here are based on observations during this project. In contrast, the estimates provided in the IHA Application and EA for this project (LGL Ltd. 2010a,b) were based on survey and other information available prior to the fieldwork.

Estimates from Direct Observations

The number of marine mammals observed close to the *Langseth* during the seismic study provides a minimum estimate of the number potentially affected by seismic sounds. This is likely an under-estimate of the actual number potentially affected. Some animals probably moved away before coming within visual range of MMOs, and it is unlikely that MMOs were able to detect all of the marine mammals near the vessel trackline. During daylight, animals are missed if they are below the surface when the ship is nearby. Some other marine mammals, even if they surface near the vessel, are missed because of limited visibility (e.g., fog), glare, or other factors limiting sightability. Also, sound levels were estimated to be ≥160 dB re 1 μPa_{rms} out to as far as ~4.4 km when the 36-airgun array was in use (see Table 3.1); thus, some smaller, less conspicuous cetaceans may have been missed. Furthermore, marine mammals cannot be seen effectively during periods of darkness. However, no marine mammal survey effort occurred at night during the Shatsky Rise survey.

Animals may have avoided the area near the seismic vessel while the airguns were firing (see Richardson et al. 1995, 1999; Gordon et al. 2004; Smultea et al. 2004; Stone and Tasker 2006; Weir 2008). Within the assumed ≥160 dB radii around the source (i.e., 4.4 km with the 36-airgun array), and perhaps farther away in the case of the more sensitive species and individuals, the distribution and behavior of cetaceans may have been altered as a result of the seismic survey. This could occur as a result of reactions to the airguns or as a result of reactions to the *Langseth* itself. The extent to which the distribution and behavior of cetaceans might be affected by the airguns beyond the distance at which they are detectable by MMOs is impossible to determine from shipboard MMO data.

Cetaceans Potentially Exposed to Sounds ≥180 dB re 1 µPa$_{rms}$.—During the Shatsky Rise survey, one sperm whale group of seven individuals was seen during seismic operations. This group was seen approaching the safety radius around the airguns, and a power down was implemented immediately. As this group was seen just outside the safety radius, the sperm whales likely did not receive sound levels ≥180 dB (flat-weighted). However, they were likely exposed to sound levels ≥170 dB for some of the airgun shots prior to the power down. This assumes that the animals, while inside the safety radius, were well below the surface when one or more of the airgun pulses were received.

The estimated 180-dB radii are the *maximum* distances from the airgun array where sound levels were expected to be ≥180 dB re 1 µPa$_{rms}$. These distances would apply at the water depth with maximum received level and in the direction (from the airgun array) where the sounds were strongest. Thus, there are complications in assessing the maximum level to which any specific individual mammal might have been exposed:

- Near the water surface, received sound levels are considerably reduced because of pressure-release effects. In many cases, it is unknown whether animals seen at the surface were earlier (or later) exposed to the maximum levels that they would receive if they dove.
- For bowriding dolphins observed at or near the surface for extended periods, the received airgun sounds are reduced relative to levels at deeper depths. However, dolphins observed bowriding may be at depth for portions of the time while within the safety radius.
- Because the airgun array was slightly wider (24 m) in the cross-track direction than in the along-track direction (16 m), the predominantly low-frequency sounds were slightly stronger in the fore-aft direction than in the cross-track direction. We have assumed that the 180-dB distance was as far to the side as it was fore and aft, which will overstate the levels to which certain animals were exposed.
- Some cetaceans may have been within the predicted 180-dB radii and/or within the safety radii while underwater and not visible to observers, and subsequently seen outside these radii. The direction of movement as noted by MMOs can give some indication of this.
- The MMO tower is located forward of the airguns. Therefore, the nominal safety zone was not centered on the observer's station, but rather on the center of the airgun array. This difference was accounted for in the observer's decisions regarding whether it was necessary to power/shut down the airguns for sightings immediately forward or astern.

Airgun operations occurred at night as well as during daytime, but MMOs were generally not on duty at night. During the Shatksy Rise study, ~45% of the airgun operations occurred at night. If cetaceans were encountered at similar rates by night as by day, then the total numbers exposed to various sound levels were presumably about two times the numbers estimated by direct observation in daytime. However, in the absence of the nighttime sighting data that would be needed as a basis for initiating power downs and shut downs at night, on a per-encounter basis, the frequency of exposure to high sound levels would be somewhat higher by night than by day.

Cetaceans Potentially Exposed to Sounds ≥160 dB re 1 µPa$_{rms}$.—One group of seven sperm whales was sighted during the Shatsky Rise survey when the airguns were operating (Table 4.1; Appendix F). All seven sperm whales occurred within the ≥160-dB radius (as specified in Table 3.1) of the then-operating airgun array. Because the 160-dB re 1 μPa_{rms} radii around the 36-airgun array were estimated to be up to 4.4 km, some smaller, less conspicuous cetaceans within these radii during daytime may not have been seen by observers. Additional cetaceans would likely be exposed during airgun operations at night and in periods of poor visibility. These missed animals are accounted for in estimates presented later in this section based on densities of animals during "useable" seismic and non-seismic periods. Most delphinids exposed to received levels of ~160−170 dB re 1 μPa_{rms} may not be disturbed significantly, as discussed below.

Delphinids Potentially Exposed to Sounds ≥170 dB 1 μPa_{rms}.—For delphinids, exposure to airgun sounds with received levels ≥170 dB may be a more appropriate criterion of disturbance than exposure to ≥160 dB. However, no delphinids were seen during seismic periods at Shatksy Rise.

Estimates Extrapolated from Marine Mammal Density

The methodology used to estimate the areas exposed to received levels ≥160 dB, ≥170 dB, and ≥180 dB re 1 μPa_{rms}, and to estimate corrected marine mammal densities, was described briefly in Chapter 3 *Analyses* and in further depth in Appendix D. Densities were based on the number of "useable" sightings during the survey and were calculated for both non-seismic and seismic periods. The former represent the densities of mammals expected to occur "naturally" within the area (assuming that, during non-seismic periods, there was little bias associated with avoidance of or attraction to the ship). The densities calculated from useable sightings and effort during seismic periods represent the densities of mammals that apparently remained within the area exposed to strong airgun pulses.

The corrected densities were used to estimate the number of marine mammal exposures to 160 dB, and the number of different individuals exposed. These numbers provide estimates of the number of animals potentially affected by seismic operations, as described in Chapter 3 and Appendix D.

***Estimated Numbers of Cetaceans Exposed to ≥160*.—**The numbers of cetaceans estimated to be exposed to ≥160 dB re 1 μPa_{rms} based on non-seismic and seismic periods are not considered to be "all-or-nothing" criteria; some individual mammals may react strongly at lower received levels, but others are unlikely to react strongly unless levels are substantially above 160 dB. The data used to calculate these numbers include the densities presented in Table 4.2 and the extent of ensonified areas, which in turn are based on the estimated 160 dB radii listed in Table 3.1. Ensonified areas are calculated two ways, with areas that were ensonified to ≥160 dB more than once being re-counted in the "With Overlap" category but not in the "No Overlap" category. Overlapping ensonified area was used for estimating the number of exposures, and non-overlapping ensonified area was used for estimating the number of individuals exposed. The ensonified area with overlap was 26,507 km^2 and without overlap, it was 19,616 km^2.

Estimates Based on Densities during Non-seismic Periods: "Corrected" estimates of the densities of cetaceans present during non-seismic periods are given in Table 4.2. These corrected densities were used to estimate the number of cetaceans that were exposed to ≥160 dB and thus potentially disturbed by seismic operations. Because of the very low number of sightings during non-seismic periods (Table 4.1), among other considerations, these estimates should be considered very approximate.

We estimate that there would have been ~12 exposures of ~9 different sperm whales and 6 exposures of 4 individual unidentified whales to ≥160 dB during the seismic survey if no cetaceans moved out of the ≥160-dB zone in response to the approaching airguns. The "exposures" estimate would be reasonable if cetaceans did not react to the approaching seismic vessel. The "individuals" estimate would be reasonable if there was no reaction, and if cetaceans remained largely stationary throughout the study. Both of these assumptions are unlikely. The actual numbers of individuals that were exposed to

≥160 dB re 1 μPa_{rms}, or that moved away in response to the approaching seismic vessel before levels reached 160 dB, are expected to be somewhere between the "exposures" and "individuals" estimates.

Estimates Based on Densities during Seismic Periods: Observers were able to monitor animals effectively only within ~3 km of the seismic vessel (during periods of good sightability), but received levels of seismic sounds may have exceeded 160 dB to ~4.4 km (Table 3.1). Thus, densities calculated from observations during seismic periods may underestimate numbers of animals exposed to ≥160 dB. Some animals may have moved >3 km from the source vessel but remained within the ≥160 dB zone. Nonetheless, results from seismic periods indicate that an estimated 46 exposures to levels ≥160 dB, totaling 34 sperm whales, may have occurred.

Cetaceans Potentially Exposed to Sounds ≥180 dB re 1 μPa_{rms}.—It is possible that some cetaceans within the radius would have been missed by the observers even during good-visibility daytime conditions or when animals were below the surface. Based on the densities of sperm whales estimated from observations during seismic periods, ~11 exposures and 9 individuals would have been expected to occur within the 180-dB radius around the operating airguns during the Shatsky Rise survey. This estimate is slightly higher than that indicated by direct observations; part of the difference no doubt results from the fact that the present (higher) estimates account for animals approached at night and in poor sightability conditions. However, the present estimates also exclude any animals near the seismic vessel during "useable" periods that were below the surface or were missed for other reasons, and those animals that avoided exposure to ≥180 dB by swimming away from the approaching seismic vessel.

Summary of Exposure Estimates.—Estimates of the numbers of exposures to strong sounds are considered *maximum* estimates of the number of mammals exposed. In this method, repeated exposures of some of the same animals are counted separately, with no allowance for overlapping survey lines. This method, when based on densities during non-seismic periods, also assumes that no mammals move away before received sound levels reach the sound level in question. Based on corrected densities of cetaceans during seismic periods, ~46 potential exposures to airgun sounds with received levels ≥160 dB re 1 μPa might have occurred during the survey, involving ~34 sperm whales. This estimate is lower (~18 exposures of ~13 individual whales) if densities from non-seismic periods are used.

Although the number of sperm whale estimated to have been exposed to sounds ≥160 dB, based on direct observation, was lower than the requested and authorized takes for sperm whales, the estimated number of takes based on densities during seismic periods was greater. Requested and authorized takes were based on ***best estimates*** of the numbers of marine mammals that might occur in the area during the survey period. The requested takes were calculated based on marine mammal densities found in the literature, rather than the actual densities observed during the 2010 study period at times when airguns were silent. Thus, the densities may not have been representative for the study area, although best available data were used to obtain the most accurate estimates. Note that the estimates *do* include approximate allowance for animals missed by the observers during daytime. That allowance is based on application of "best available" correction factors for missed animals [i.e., $f(0)$ and $g(0)$ factors] during daytime. The estimates also include an allowance for animals encountered during seismic operations at night.

Summary and Discussion

During the Shatsky Rise cruise, one or more MMOs were on watch for ~718 h; during this time, there were 27 sightings of a total of 781 cetaceans and four sea turtles. Within the study area, MMOs watched for 357 h and observed five sightings of 13 individuals. The airguns were powered down on one occasion when a group of seven sperm whales was seen near the 180-dB re 1 μPa_{rms} safety radius.

The seismic program included 284 h of "useable" visual observation effort within the study area and 384 h of PAM effort. No acoustic detections were made. Density and behavioral analyses for the Shatsky Rise cruise considered only "useable" survey effort and "useable" sightings in the study area, consisting of 10 cetaceans in four groups. Considering all "useable" survey effort and sightings, ~1.2 marine mammal groups were detected per 1000 km. The sperm whale was the most commonly observed cetacean species during the Shatsky Rise cruise.

Based on direct observations during the Shatsky Rise survey, only one group of seven sperm whales was observed during seismic periods. All seven individuals were estimated to have received sound levels >170 dB re 1 μPa_{rms} (flat-weighted) but <180 dB. The estimated number of exposures to received levels ≥160 dB was slightly lower when based on sightings and effort during non-seismic periods than when based on corresponding data from seismic periods. Cetacean density during seismic periods was higher that that during non-seismic periods. Also, the CPA for sperm whales was greater during non-seismic periods compared with seismic periods. Given the limited sightings in the study area, these differences should be interpreted very cautiously. However, these data contribute to the overall accumulation of similar data across this and other L-DEO seismic surveys. In any case, the estimated total number of cetaceans exposed to strong airgun sounds during L-DEO's Shatsky Rise survey was much lower than that authorized by NMFS.

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Mark Fitzgerald of LGL helped develop and implement procedures to estimate numbers of cetaceans that might have been exposed to seismic sounds, assisted with processing and analyzing data, and produced the maps. We also thank Anne Wright (of LGL) for help with the preparation of this report. Dr. W. John Richardson, LGL's project director for the marine mammal monitoring, assisted at various stages during planning and fieldwork.

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This report is dedicated to our friend and colleague, John Nicolas, and Dr. John Diebold.

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APPENDIX A:[2]
INCIDENTAL HARASSMENT AUTHORIZATION ISSUED TO L-DEO FOR THE SHATSKY RISE SEISMIC STUDY

DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL MARINE FISHERIES SERVICE

Incidental Harassment Authorization

Lamont-Doherty Earth Observatory, Columbia University, P.O. Box 1000, 61 Route 9W, Palisades, New York 10964-8000, is hereby authorized under section 101(a)(5)(D) of the Marine Mammal Protection Act (MMPA) (16 U.S.C. 1371(a)(5)(D)) and 50 CFR 216.107, to harass small numbers of marine mammals incidental to a marine geophysical survey conducted by the R/V *Marcus G.* (*Langseth*) on the Shatsky Rise in the Northwest Pacific Ocean July through September, 2010:

1. This Authorization is valid from July 19, 2010 through September 28, 2010.

2. This Authorization is valid only for the specified activities associated with the R/V *Marcus G. Langseth*'s (*Langseth*) seismic operations in the following specified geographic area:

   (a) The Shatsky Rise area, located at 30 - 37°N, 154 - 161°E in international waters offshore from Japan, as specified in L-DEO's Incidental Harassment Authorization application and Environmental Assessment.

3. Species Authorized and Level of Takes

   (a) The incidental taking of marine mammals, by Level B harassment only, is limited to the following species in the waters around the Shatsky Rise:

      (i) Mysticetes – see Table 2 (attached) for authorized species and take numbers.

      (ii) Odontocetes - see Table 2 (attached) for authorized species and take numbers.

      (iii) Pinnipeds - see Table 2 (attached) for authorized species and take numbers.

      (iv) If any marine mammal species are encountered during seismic activities that are not listed in Table 2 (attached) for authorizing taking and are likely to be exposed to sound pressure levels (SPLs) greater than or equal to 160 dB re 1 μPa (rms), then the Holder of this Authorization must alter speed or course, power-down or shut-down the airguns to avoid take.

[2] This is a verbatim copy (retyped) of the IHA.

(b) The taking by injury (Level A harassment), serious injury, or death of any of the species listed in 3(a) or the taking of any kind of any other species of marine mammal is prohibited and may result in the modification, suspension or revocation of this Authorization.

(c) The methods authorized for taking by Level B harassment is limited to the following acoustic sources without an amendment to this Authorization:

(i) a 36-Bolt airgun array that may range in size from 40 to 360 cubic inches (in^3) with a total volume of approximately 6,600 in^3 as an energy source;

(ii) a multi-beam echosounder;

(iii) a sub-bottom profiler; and

(iv) the acoustic release transponder used to communicate with the Ocean Bottom Seismometers (OBS).

4. The taking of any marine mammal in a manner prohibited under this Authorization must be reported immediately to the Office of Protected Resources, National Marine Fisheries Service (NMFS), at 301-713-2289.

5. The Holder of this Authorization is required to cooperate with NMFS and any other Federal, state or local agency monitoring the impacts of the activity on marine mammals.

6. Mitigation and Monitoring Requirements

The Holder of this Authorization is required to implement the following mitigation and monitoring requirements when conducting the specified activities to achieve the least practicable adverse impact on affected marine mammal species or stocks:

(a) Utilize two , NMFS-qualified, vessel-based Protected Species Visual Observers (PSVOs) (except during meal times and restroom breaks, when at least one PSVO will be on watch) to visually watch for and monitor marine mammals near the seismic source vessel during daytime airgun operations (from civil twilight-dawn to civil twilight-dusk) and before and during start-ups of airguns day or night. The *Langseth*'s vessel crew will also assist in detecting marine mammals, when practicable. PSVOs will have access to reticle binoculars (7x50 Fujinon), big-eye binoculars (25x150), and night vision devices. PSVO shifts will last no longer than 4 hours at a time. PSVOs will also make observations during daytime periods when the seismic system is not operating for comparison of animal abundance and behavior, when feasible.

(b) PSVOs will conduct monitoring while the airgun array and streamers are being deployed or recovered from the water.

(c) Record the following information when a marine mammal is sighted:

(i) 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 airguns or vessel (e.g., none, avoidance, approach, paralleling, etc., and including responses to ramp-up), and behavioral pace; and

(ii) time, location, heading, speed, activity of the vessel (including number of airguns operating and whether in state of ramp-up or power-down), sea state, visibility, cloud cover, and sun glare; and

(iii) the data listed under 6(c)(ii) 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.

(d) Utilize the passive acoustic monitoring (PAM) system, to the maximum extent practicable, to detect and allow some localization of marine mammals around the *Langseth* during all airgun operations and during most periods when airguns are not operating. One PSVO and/or bioacoustician will monitor the PAM at all times in shifts no longer than 6 hours. A bioacoustician shall design and set up the PAM system and be present to operate or oversee PAM, and available when technical issues occur during the survey.

(e) Do and record the following when an animal is detected by the PAM:

(i) notify the PSVO immediately of a vocalizing marine mammal so a power-down or shut-down can be initiated, if required;

(ii) enter the information regarding the vocalization into a database. The data to be entered include an acoustic encounter identification number, whether it was linked with a visual sighting, date, time when first and last heard and whenever any additional information was recorded, position, and water depth when first detected, bearing if determinable, species or species group (e.g., unidentified dolphin, sperm whale), types and nature of sounds heard (e.g., clicks, continuous, sporadic, whistles, creaks, burst pulses, strength of signal, etc.), and any other notable information.

(f) Visually observe the entire extent of the exclusion zone (180 dB for cetaceans; see Table 1 [attached] for distances) using NMFS-qualified PSVOs, for at least 30 minutes prior to starting the airgun (day or night). If the PSVO finds a marine mammal within the exclusion zone, L-DEO must delay the seismic survey until the marine mammal(s) has left the area. If the PSVO sees a marine mammal that surfaces, then dives below the surface, the observer shall wait 30 minutes. If the PSVO sees no marine mammals during that time, they should assume that the animal has moved beyond the exclusion zone. If for any reason the entire radius cannot be seen for the entire 30 minutes (min) (i.e., rough seas, fog, darkness), or if marine mammals are near, approaching, or in the exclusion zone, the airguns may not be started up. If one airgun is already running at a source level of at least 180 dB, L-DEO may start the second gun without observing the entire safety radius for 30 min prior, provided no marine mammals are known to be near the exclusion zone (in accordance with condition 6(h) below).

(g) Establish a 180-dB exclusion zone for marine mammals before the 4-string airgun array (6,600 in^3) is in operation; and a 180-dB exclusion zone before a single airgun (40 in^3) is in operation, respectively. See Table 1 (attached) for distances and safety radii.

(h) Implement a "ramp-up" procedure when starting up at the beginning of seismic operations or anytime after the entire array has been shutdown for more than 8 min, which means start the smallest gun first and add airguns in a sequence such that the source level of the array will increase in steps not exceeding approximately 6 dB per 5-min period. During ramp-up, the PSVOs will monitor the exclusion zone, and if marine mammals are sighted, a course/speed alteration, power-down, or shut-down will be implemented as though the full array were operational. Therefore, initiation of ramp-up procedures from shut-down requires that the PSVOs be able to view the full exclusion zone as described in 6(f) (above).

(i) Alter speed or course during seismic operations if a marine mammal, based on its position and relative motion, appears likely to enter the relevant exclusion zone. If speed or course alteration is not safe or practicable, or if after alteration the marine mammal still appears likely to enter the exclusion zone, further mitigation measures, such as power-down or shut-down, will be taken.

(j) Power-down or shut-down the airgun(s) if a marine mammal is detected within, approaches, or enters the relevant exclusion zone (as defined in Table 1, attached). A shut-down means all operating airguns are shut-down. A power-down means reducing the number of operating airguns to a single 40 in^3 airgun, which reduces the exclusion zone to the degree that the animal(s) is outside of it.

(k) Following a power-down, if the marine mammal approaches the smaller designated exclusion zone, the airguns must then be completely shut-down. Airgun activity will not resume until the PSVO has visually observed the marine mammal(s) exiting the exclusion zone and is not likely to return, or has not been seen within the exclusion zone for 15 min for species with shorter dive durations (small odontocetes) or 30 min for species with longer dive durations (mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, killer, and beaked whales).

(l) Following a power-down or shut-down and subsequent animal departure, airgun operations may resume following ramp-procedures described in 6(h).

(m) Marine geophysical surveys may continue into night and low-light hours if such segment(s) of the survey is initiated when the entire relevant exclusion zones are visible and can be effectively monitored.

(n) No initiation of airgun array operations is permitted from a shut-down position at night or during low-light hours (such as in dense fog or heavy rain) when the entire relevant exclusion zone cannot be effectively monitored by the PSVOs on duty.

(o) If a North Pacific right whale (*Eubalaena japonica*) is visually sighted, the airgun array will be shut-down regardless of the distance of the animal(s) to the sound source. The array will not resume firing until 30 min after the last documented whale visual sighting.

(p) To the maximum extent practicable, schedule seismic operations (i.e., shooting airguns) during daylight hours and OBS operations (i.e., deploy/retrieve) to nighttime hours.

7. Reporting Requirements

The Holder of this Authorization is required to:

(a) Submit a draft report on all activities and monitoring results to the Office of Protected Resources, NMFS, within 90 days of the completion of the *Langseth's* Shatsky Rise cruise. This report must contain and summarize the following information:

(i) Dates, times, locations, heading, speed, weather during, sea conditions (including Beaufort sea state and wind force), and associated activities during all seismic operations and marine mammal sightings;

(ii) Species, number, location, distance from the vessel, and behavior of any marine mammals, as well as associated seismic activity (number of power-downs and shut-downs), observed throughout all monitoring activities.

(iii) An estimate of the number (by species) of marine mammals that: (A) are known to have been exposed to the seismic activity (based on visual observation) at received levels greater than or equal to 160 dB re 1 μPa (rms) and/or 180 dB re 1 μPa (rms) with a discussion of any specific behaviors those individuals exhibited; and (B) may have been exposed (based on modeling results) to the seismic activity at received levels greater than or equal to 160 dB re 1 μPa (rms) and/or 180 dB re 1 μPa (rms) with a discussion of the nature of the probable consequences of that exposure on the individuals that have been exposed.

(iv) A description of the implementation and effectiveness of the: (A) terms and conditions of the Biological Opinion's Incidental Take Statement (ITS) (attached); and (B) mitigation measures of the Incidental Harassment Authorization. For the Biological Opinion, the report will confirm the implementation of each term and condition, as well as any conservation recommendations, and describe their effectiveness, for minimizing the adverse effects of the action on listed marine mammals.

(b) Submit a final report to the Chief, Permits, Conservation, and Education Division, Office of Protected Resources, NMFS, within 30 days after receiving comments from NMFS on the draft report. If NMFS decides that the draft report needs no comments, the draft report will be considered to be the final report.

8. In the unanticipated event that any taking of a marine mammal in a manner. prohibited by this Authorization occurs, such as an injury, serious injury or mortality, and are judged to result from these activities, L-DEO will immediately report the incident to the Chief of the Permits, Conservation, and Education Division, Office of Protected Resources, NMFS, at 301-713-2289. L-DEO will postpone the research activities until NMFS is able to review the circumstances of the take. NMFS will work with L-DEO to determine whether modifications in the activities are appropriate and necessary, and notified the permit holder that they may resume sound source operations.

9. In the event that L-DEO discovers an injured or dead marine mammal that are judged to not have resulted from these activities, L-DEO will contact and report the incident to the Chief of the Permits, Conservation, and Education Division, Office of Protected Resources, NMFS, at 301-713-2289 within 24 hours of the discovery.

10. L-DEO is required to comply with the Terms and Conditions of the Incidental Take Statement (ITS) corresponding to NMFS' Biological Opinion issued to both NSF and NMFS' Office of Protected Resources (attached).

11. A copy of this Authorization and the ITS must be in the possession of all contractors and protected species observers operating under the authority of this Incidental Harassment Authorization.

JUL 16 2010

James H. Lecky
Director
Office of Protected Resources
National Marine Fisheries Service

Date

Attachments

Attachment

Table 1. Exclusion Zone Radii for Triggering Mitigation.

Source and Volume	Tow Depth (m)	Predicted RMS Distances (m)		
		190 dB	180 dB	160 dB
Single Bolt airgun 40 in^3	9-12*	12	40	385
4 strings 36 airguns 6600 in^3	9	400	940	3850
	12	460	1100	4400

*The tow depth has minimal effect on the maximum near-field output and the shape of the frequency spectrum for the single 40-in^3 airgun; thus the predicted safety radii are essentially the same at each tow depth.

Table 2. Authorized Take Numbers for Each Marine Mammal Species in the Shatsky Rise Area.

Species	Authorized Take in the Shatsky Rise Area
Mysticetes	
North Pacific right whale (*Eubalaena japonica*)	1
Humpback whale (*Megaptera novaeangliae*)	10
Minke whale (*Balaenoptera acutorostrata*)	85
Bryde's whale (*Balaenoptera brydei*)	16
Sei whale (*Balaenoptera physalus*)	37
Fin whale (*Balaenoptera borealis*)	16
Blue whale (*Balaenoptera musculus*)	9
Odontocetes	
Sperm whale (*Physeter macrocephalus*)	22
Pygmy sperm whale (*Kogia breviceps*)	100
Dwarf sperm whale (*Kogia sima*)	244
Cuvier's beaked whale (*Ziphius cavirostris*)	212
Baird's beaked whale (*Berardius bairdii*)	27
Longman's beaked whale (*Indopacetus pacificus*)	14
Blainville's beaked whale (*Mesoplodon densirostris*)	40
Mesoplodon spp.	3
Rough-toothed dolphin (*Steno bredanensis*)	97
Bottlenose dolphin (*Tursiops truncatus*)	750
Pantropical spotted dolphin (*Stenella attenuata*)	2,200

Spinner dolphin (*Stenella longirostris*)	26
Striped dolphin (*Stenella coeruleoalba*)	3,721
Fraser's dolphin (*Lagenodelphis hosei*)	143
Short-beaked common dolphin (*Delphinus delphis*)	9,666
Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)	1,137
Northern right whale dolphin (*Lissodelphis borealis*)	13
Risso's dolphin (*Grampus griseus*)	337
Melon-headed whale (*Peponocephala electra*)	41
Pygmy killer whale (*Feresa attenuata*)	0
False killer whale (*Pseudorca crassidens*)	64
Killer whale (*Orcinus orca*)	5
Short-finned pilot whale (*Globicephala macrorhynchus*)	156
Dall's porpoise (*Phocoenoides dalli*)	686
Northern fur seal (*Callorhinus ursinus*)	56

INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and federal regulation pursuant to section 4(d) of the ESA prohibit the "take" of endangered and threatened species, respectively, without special exemption. "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by NMFS as an act which actually kills or injures wildlife, which may include significant habitat modification or degradation which actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of sections 7(b)(4) and 7(o)(2), taking that is incidental and not intended as part of the agency action is not considered to be prohibited taking under the ESA provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement.

The measures described below are nondiscretionary, and must be undertaken by the NSF and the Permits Division so that they become binding conditions for L-DEO for the exemption in Section 7(o)(2) to apply. Section 7(b)(4) of the ESA requires that when a proposed agency action is found to be consistent with Section 7(a)(2) of the ESA and the proposed action may incidentally take individuals of listed species, the NMFS will issue a statement that specifies the impact of any incidental taking of endangered or threatened species. To minimize such impacts, reasonable and prudent measures and term and conditions to implement the measures, must be provided. Only incidental take resulting from the agency actions and any specified reasonable and prudent measures and terms and conditions identified in the incidental take statement are exempt from the taking prohibition of section 9(a), pursuant to Section 7(o) of the ESA.

Section 7(b)(4)(C) of the ESA specifies that in order to provide an incidental take statement for an endangered or threatened species of marine mammal, the taking must be authorized under Section 101(a)(5) of the MMPA. One of the federal actions considered in this Opinion is the Permits Division's proposed authorization of the incidental taking of fin, blue, sei, humpback, North Pacific right, and sperm whales pursuant to Section 101(a)(5)(D) of the MMPA. With this authorization, the incidental take of listed whales is exempt from the taking prohibition of Section 9(a), pursuant to Section 7(o) of the ESA.

Amount or extent of take

NMFS anticipates the proposed seismic survey in the Pacific Ocean over the Shatsky Rise might result in the incidental take of listed species. The proposed action is expected to take 9 blue (10 exposures), 16 fin (17 exposures), 37 sei (40 exposures), 10 humpback (11 exposures), 1 North Pacific right (1 exposure), and 22 sperm whales (24 exposures) by exposing individuals to received seismic sound levels greater than 160 dB re 1 μPa by harassment. These estimates are based on the best available information on whale densities in the area to be ensonified above 160 dB re 1 μPa during the proposed activities. This incidental take would result primarily from exposure to acoustic energy during seismic operations, would be in the form of harassment, and is not expected to result in the death or injury of any individuals that are exposed.

We expect the proposed action will also take individual sea turtles as a result of exposure to acoustic energy during seismic studies, and we expect this take would also be in the form of harassment, with no death or injury expected for individuals exposed. Harassment of sea turtles is expected to occur at received levels above 166 dB re 1 μPa. As we cannot determine the number of individuals to which harassment will occur, we expect the extent of exposures will occur within the 166 dB isopleths of the *Langseth*'s airgun array.

Harassment of blue, fin, humpback, North Pacific right, sei, and sperm whales exposed to seismic studies at levels less than 160 dB re 1 μPa, or of green, hawksbill, leatherback, loggerhead, and olive ridley sea turtles at levels less than 166 dB re 1 µPa, is not expected. If overt adverse reactions (for example, startle responses, dive reactions, or rapid departures from the area) by listed whales or sea turtles are observed outside of the 160 dB or 166 dB re 1 µPa isopleths, respectively, while airguns are operating, incidental take may be exceeded. If such reactions by listed species are observed while airguns, multibeam echosounder, or sub-bottom profiler are in operation, this may constitute take that is not covered in this Incidental Take Statement. The NSF and the Permits Division must contact the Endangered Species Division to determine whether reinitiation of consultation is required because of such operations.

Any incidental take of blue, fin, humpback whales, North Pacific right, sei whales, sperm whales, or green sea turtles, hawksbill sea turtles, leatherback sea turtles, loggerhead sea turtles, and olive ridley sea turtles is restricted to the permitted action as proposed. If the actual incidental take meets or exceeds the predicted level, NSF and Permits Division must reinitiate consultation. All anticipated takes would be "takes by harassment", as described previously, involving temporary changes in behavior.

Reasonable and Prudent Measures

NMFS believes the reasonable and prudent measures described below are necessary and appropriate to minimize the impact of incidental take of listed whales and sea turtles resulting from the proposed action. These measures are non-discretionary and must be binding conditions of the NSF funding of the proposed seismic studies and NMFS' authorization for the exemption in section 7(o)(2) to apply. If NSF or the NMFS fail to ensure compliance with these terms and conditions, the protective coverage of section 7(o)(2) may lapse.

1. For listed sea turtle and marine mammal species these measures include the following: immediate shutdown of all seismic sources in the event a North Pacific right whale is detected; vessel-based visual monitoring by marine mammal and sea turtle observers; real-time passive acoustic monitoring by marine mammal and sea turtle observers; speed or course alteration as practicable; implementation of a marine mammal and sea turtle exclusion zone within the 180 dB re 1 μPa_{rms} isopleth for power-down and shut-down procedures; emergency shutdown procedures in the event of an injury or mortality of a listed marine mammal or sea turtle; and ramp-up procedures when starting up the array. The measures for marine mammals are required to be implemented through the terms of the IHA issued under section 101(a)(5)(D) and 50 CFR 216.107.
2. The implementation and effectiveness of mitigation measures incorporated as part of the Reasonable and Prudent Measure mentioned above and the associated Terms and Conditions must be monitored.

Terms and Conditions

In order to be exempt from the prohibitions of Section 9 of the ESA, the NSF, Permits Division, and

L-DEO must comply with the following terms and conditions, which implement the Reasonable and Prudent Measures described above. These terms and conditions are non-discretionary.

To implement the Reasonable and Prudent Measures, the NSF and the NMFS shall ensure that:

1. L-DEO implements the mitigation, monitoring, and reporting conditions contained in the IHA and this Opinion.
2. The Chief of the Endangered Species Division is immediately informed of any changes or deletions to any portions of the monitoring plan or IHA.
3. L-DEO immediately reports all sightings and locations of injured or dead endangered and threatened species to the Chief of the Permits Division and NSF.
4. The NSF and the Permits Division provide a summary of the implementation and effectiveness of the terms of the IHA to the Chief of the Endangered Species Division. This report shall confirm the implementation of each term and summarize the effectiveness of the terms for minimizing the adverse effects of the project on listed whales and sea turtles.

APPENDIX B:
DEVELOPMENT AND IMPLEMENTATION OF SAFETY RADII

This appendix provides additional background information on the development and implementation of safety radii as relevant to L-DEO seismic studies. The safety radii used for the current survey were based on modeling (single airgun) and empirical data (36-airgun array) from L-DEO's 2007-8 calibration study conducted with the *Langseth*'s airgun array (see Holst and Beland 2008; Tolstoy 2009).

There has been considerable speculation about the potential for strong pulses of low-frequency underwater sound from marine seismic exploration to injure marine mammals (e.g., Richardson et al. 1995), based initially on what was known about hearing impairment to humans and other terrestrial mammals exposed to impulsive low-frequency airborne sounds (e.g., artillery noise). It is not known whether exposure to a sequence of airgun pulses can, under practical field conditions, cause hearing impairment or non-auditory injuries in marine mammals. However, studies on captive odontocetes and pinnipeds suggest that, as a minimum, temporary threshold shift (TTS) is a possibility (Finneran et al. 2002; Kastak et al. 2005; Southall et al. 2007; Lucke et al. 2009). The 180-dB "do not exceed" criterion for cetaceans was established by NMFS (1995) before any data were available on TTS in marine mammals. NMFS (1995, 2000) concluded that there are unlikely to be any physically-injurious effects on cetaceans exposed to received levels of seismic pulses up to 180 dB re 1 μPa_{rms}. The corresponding NMFS "do not exceed" criterion for pinnipeds is 190 dB re 1 μPa (rms). For sea turtles, NMFS specified a criterion of 180 dB re 1 μPa (rms) for most L-DEO surveys (e.g., Smultea et al. 2004, 2005; Holst et al. 2005, Holst and Beland 2008, 2010; Holst and Smultea 2008, Hauser et al. 2008, Holst 2009a,b).

The rms pressure of an airgun pulse is often quoted based on the sound pressure level (SPL) averaged over the pulse duration (see Greene 1997; Greene et al. 1998). The rms level of a seismic pulse is typically about 10 dB less than its peak level (Greene 1997; McCauley et al. 1998, 2000). The sound exposure level (SEL) is a measure of the received energy in the pulse and represents the SPL (or rms) that would be measured if the pulse energy were spread evenly across a 1-s period. Because actual seismic pulses are less than 1 s in duration near the source, and usually are <1 s in duration even at much longer distances, this means that the SEL value for a given pulse is usually lower than the SPL calculated for the actual duration of the pulse. Thus, the rms received levels that are used as impact criteria for marine mammals are not directly comparable to pulse energy (SEL). For receivers about 0.1 to 10 km from an airgun array, the SPL (i.e., rms sound pressure) for a given pulse is typically 10–15 dB higher than the SEL value for the same pulse as measured at the same location (Greene 1997; McCauley et al. 1998, 2000). However, there is considerable variation, and the difference tends to be larger close to the airgun array, and less at long distances (Blackwell et al. 2007; MacGillivray and Hannay 2007a,b).

Finneran et al. (2002) found that the onset of mild TTS in a beluga whale (odontocete) exposed to a single watergun pulse occurred at a received level of 226 dB re 1 μPa pk-pk and a total energy flux density of 186 dB re 1 $\mu Pa^2 \cdot s$ (but see [3], below). The corresponding rms value for TTS onset upon exposure to a single watergun pulse would be intermediate between these values. It is assumed (though data are lacking) that TTS onset would occur at lower received rms levels if the animals received a series of pulses. However, no specific results confirming this are available yet. On the other hand, the levels necessary to cause injury would exceed, by an uncertain degree, the levels eliciting TTS onset.

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

According to Southall et al. (2007), permanent threshold shift (PTS) might occur at SEL levels 15 dB above the TTS onset, or at a SEL of 198 dB re 1 μPa^2·s. Southall et al. (2007) also indicate that PTS onset might occur upon exposure to an instantaneous peak pressure as little as 6 dB above the peak pressure, eliciting onset of TTS; PTS onset might occur at peak pressures ≥230 dB re 1 μPa. Recent data from a harbor porpoise exposed to an operating airgun suggest that its TTS threshold (and thus, by implication, its PTS threshold) was considerably lower than that found by Finneran et al. in the beluga (Lucke et al. 2009).

In pinnipeds, TTS thresholds associated with exposure to brief pulses (single or multiple) of underwater sound have not been measured. Initial evidence from more prolonged (non-pulse) exposures suggested that some pinnipeds (harbor seals in particular) incur TTS at somewhat lower received levels than do small odontocetes exposed for similar durations (Kastak et al. 1999, 2005; Ketten et al. 2001; *cf.* Au et al. 2000). The TTS threshold for pulsed sounds has been indirectly estimated as being an SEL of ~171 dB re 1 μPa^2·s (Southall et al. 2007), equivalent to a single pulse with received level ~181–186 dB re 1 $\mu Pa_{rms,}$ or a series of pulses for which the highest rms values are a few dB lower. Corresponding values for California sea lions and northern elephant seals are likely higher (Kastak et al. 2005).

The advantage of working with SEL is that the SEL measure accounts for the total received energy in the pulse, and biological effects of pulsed sounds probably are most directly dependent on pulse energy (Southall et al. 2007). However, we consider rms pressure because current NMFS criteria are based on that method. NMFS is developing new noise exposure criteria for marine mammals that account for the now-available scientific data on TTS, the expected offset between the TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors.

Received sound levels were predicted by L-DEO, in relation to distance and direction from the airguns, for the 36-airgun array and for a single 1900LL 40-in^3 airgun. Results were recently reported for propagation measurements of pulses from the 36-airgun array in two water depths (~1600 m and 50 m) in the Gulf of Mexico in 2007–2008 (Tolstoy et al. 2009). Results of the propagation measurements showed that radii around the airguns for various received levels varied with water depth. As no measurements were made in intermediate-depth water, values halfway between the deep and shallow-water measurements were used. In addition, propagation varies with array tow depth. The depth at which the source is towed has a major effect on the maximum near-field output and on the shape of its frequency spectrum. If the source is towed at a relatively deep depth, the effective source level for sound propagating in near-horizontal directions is substantially greater than if the array is towed at shallower depths. Thus, if the depth of the array was different in the Gulf of Mexico calibration study (6 m) than the current survey, correction factors were applied to the distances reported by Tolstoy et al. (2009). The correction factors used were the ratios of the 160-, 170-, 180-, and 190-dB distances from the modeled results for the 6600-in^3 airgun array towed at the two different depths.

Measurements were not reported for a single airgun, so model results (Fig. B.1) for the predicted sound field were used. The predicted sound contours are shown as SEL. We assumed that rms pressure levels of received seismic pulses will be 10 dB higher than the SEL values predicted by L-DEO's model (e.g., 170 dB SEL ≈ 180 dB rms).

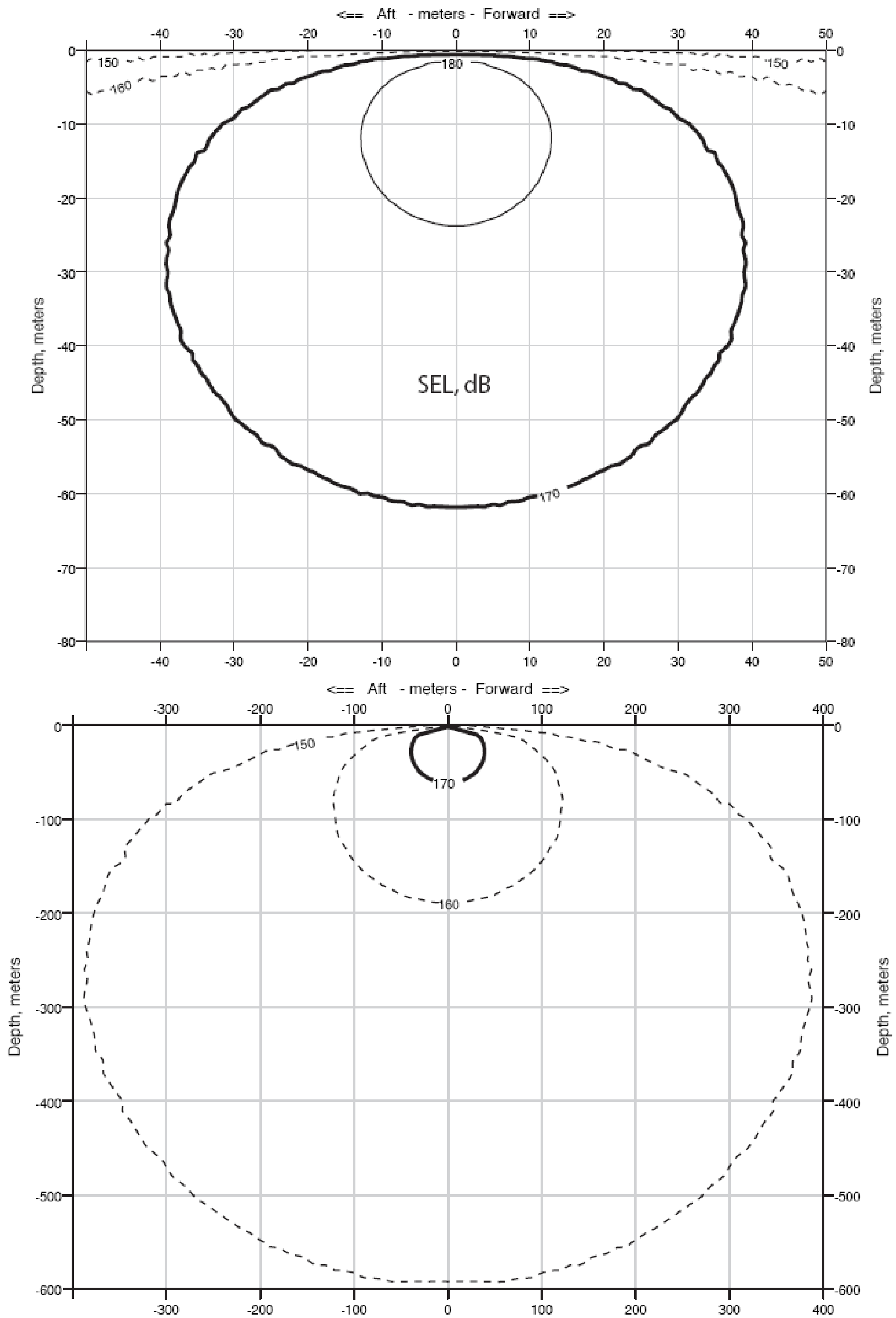

FIGURE B.1. Modeled received sound exposure levels (SELs) from a single 40 in^3 airgun, used during power down operations during the Shatsky Rise survey, 17 July to 13 September 2010. Received rms levels (SPLs) are expected to be ~10 dB higher.

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APPENDIX C: DESCRIPTION OF R/V *MARCUS G. LANGSETH* AND EQUIPMENT USED DURING THE PROJECT

During this seismic survey, L-DEO used the R/V *Marcus G. Langseth* to tow the airgun array (Fig. C.1, C.2), the hydrophone streamer(s), the PAM array, and at times to deploy the OBSs. The *Langseth* is self-contained, with the crew living aboard the vessel. The *Langseth* has a length of 71.5 m, a beam of 17.0 m, and a maximum draft of 5.9 m. The *Langseth* was designed as a seismic research vessel, with a propulsion system designed to be as quiet as possible to avoid interference with the seismic signals. The ship is powered by two Bergen BRG-6 diesel engines, each producing 3550 hp, which drive the two propellers directly. Each propeller has four blades, and the shaft typically rotates at 750 revolutions per minute (rpm). The vessel also has an 800 hp bowthruster, which is not used during seismic acquisition. The operation speed during seismic acquisition is typically 7.4–9.3 km/h. When not towing seismic survey gear, the *Langseth* can cruise at 20–24 km/h. The *Langseth* has a range of 25,000 km.

Other details of the *Langseth* include the following:

Owner:	National Science Foundation
Operator:	Lamont-Doherty Earth Observatory of Columbia University
Flag:	United States of America
Date Built:	1991 (Refit in 2006)
Gross Tonnage:	2925
Accommodation Capacity:	55 including ~35 scientists

The *Langseth* also served as a platform from which vessel-based MMOs watched for marine mammals. The observation tower was the best vantage point and afforded good visibility for the observers (Fig. C.1, C.3).

Multibeam Bathymetric Echosounder and Sub-bottom Profiler

Along with the airgun operations, two additional acoustical data acquisition systems were operated during the *Langseth*'s cruise. The ocean floor was mapped with the 12-kHz Simrad EM120 MBES, and a 3.5-kHz SBP was also operated along with the MBES. These sound sources are operated from the *Langseth* simultaneously with the airgun array.

The Simrad EM120 MBES operates at 11.25–12.6 kHz and is hull-mounted on the *Langseth*. The beamwidth is 1° fore–aft and 150° athwartship. The maximum source level is 242 dB re 1 $\mu Pa_{rms} \cdot m$. For deep-water operation, each "ping" consists of nine successive fan-shaped transmissions, each 15 ms in duration and each ensonifying a sector that extends 1° fore–aft. The nine successive transmissions span an overall cross-track angular extent of about 150°, with 16 ms gaps between the pulses for successive sectors. A receiver in the overlap area between two sectors would receive two 15-ms pulses separated by a 16-ms gap. In shallower water, the pulse duration is reduced to 5 or 2 ms, and the number of transmit beams is also reduced. The ping interval varies with water depth, from ~5 s at 1000 m to 20 s at 4000 m.

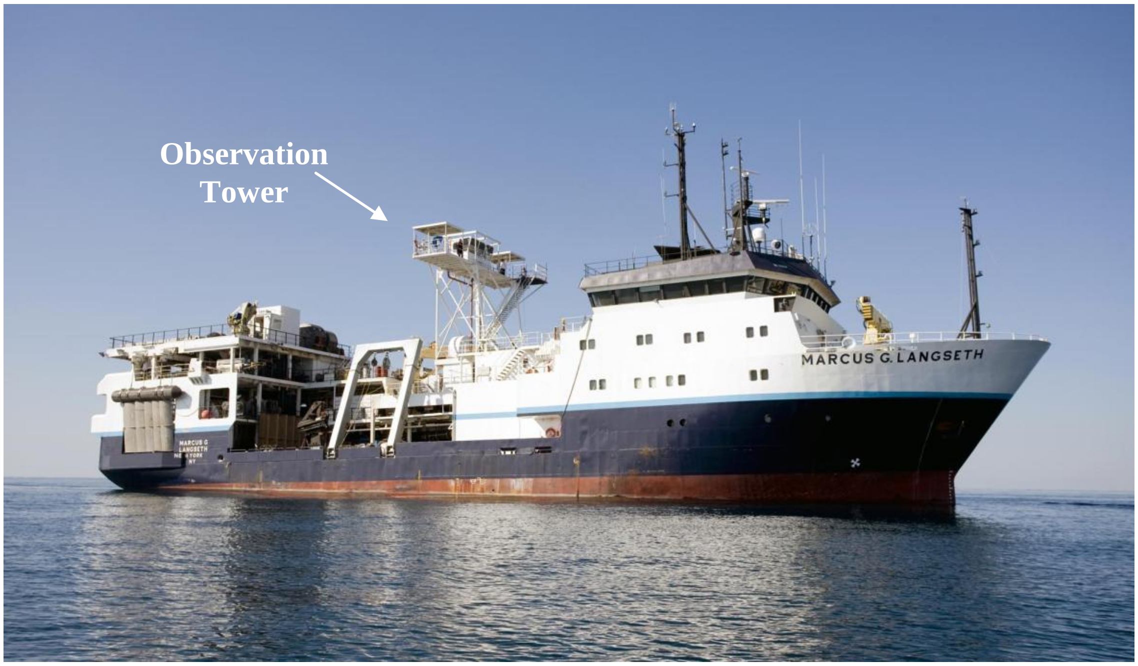

FIGURE C.1. The source vessel, the R/V *Marcus G. Langseth,* showing the location of the observation tower from which visual observations for marine mammals were made.

FIGURE C.2. View off the stern of the R/V *Marcus G. Langseth* when the 4-string airgun array was towed.

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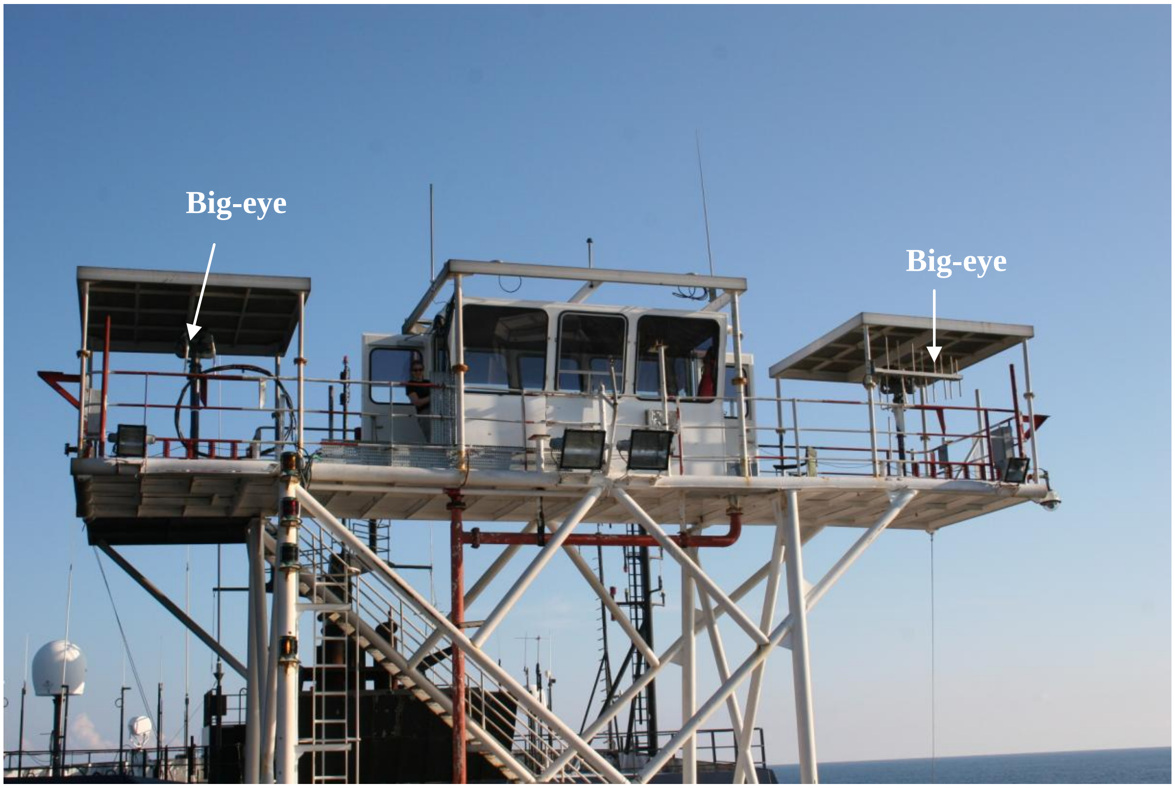

FIGURE C.3. The observation tower on the R/V *Marcus G. Langseth* from which visual observations for marine mammals and sea turtles were made. The locations of two mounted 25x150 "Big-eye" binoculars used during the study is shown. The steel booth in the middle has been replaced by a plastic-coated canvas tent.

The SBP is normally operated to provide information about the sedimentary features and the bottom topography that is being mapped simultaneously by the MBES. The energy from the SBP is directed downward by a 3.5-kHz transducer in the hull of the *Langseth*. The output varies with water depth from 50 watts in shallow water to 800 watts in deep water. The pulse interval is 1 s, but a common mode of operation is to broadcast five pulses at 1-s intervals followed by a 5-s pause.

Langseth Sub-bottom Profiler Specifications

Maximum source output (downward)	204 dB re 1 μPa·m; 800 watts
Normal source output (downward)	200 dB re 1 μPa·m; 500 watts
Dominant frequency components	3.5 kHz
Bandwidth	1.0 kHz with pulse duration 4 ms
	0.5 kHz with pulse duration 2 ms
	0.25 kHz with pulse duration 1 ms
Nominal beam width	30 degrees
Pulse duration	1, 2, or 4 ms

APPENDIX D:
DETAILS OF MONITORING, MITIGATION, AND ANALYSIS METHODS

This appendix provides details on the standard visual and acoustic monitoring methods and data analysis techniques implemented for this project and previous L-DEO seismic studies.

Résumés documenting the qualifications of the MMOs were provided to NMFS prior to commencement of the study. All MMOs participated in a review meeting before the start of the study, designed to familiarize them with the operational procedures and conditions for the cruise, reporting protocols, and IHA stipulations. In addition, implementation of the IHA requirements was explained to the Captain, Science Officer, and the Science Party aboard the vessel. MMO duties included

- watching for and identifying marine mammals and sea turtles and recording their numbers, distances and behavior;
- noting possible reactions of marine mammals and sea turtles to the seismic operations;
- initiating mitigation measures when appropriate;
- passive acoustic monitoring for cetacean calls;
- reporting the results.

Visual Monitoring Methods

Visual watches took place during all daytime airgun activity and at most times during the daytime when the source vessel was underway but the airguns were not firing. This included (1) periods during transit to and from the seismic survey area, (2) a "pre-seismic period" while equipment was being deployed, (3) periods when the seismic source stopped firing while equipment was being repaired, and (4) a "post-seismic" period.

Visual observations were generally made from the *Langseth's* observation tower (Fig. C.1, C.3), which is the highest suitable vantage point on the *Langseth*. When stationed on the observation tower, the eye level is ~21.5 m above sea level (asl), and the observer has a good view around the entire vessel. Other observation platforms aboard the *Langseth* include the helideck or stern (13.7 m asl), the bridge (12.8 m asl), and the catwalk around the bridge (12.3 m asl).

Up to five observers trained in marine mammal identification and observation methods were present on the *Langseth*. Visual watches aboard the *Langseth* were usually conducted in 1–2 h shifts (max. 4 h), alternating with PAM shifts and/or 1–4 h breaks, for a total of ~10 h per day per MMO. Daytime watches were conducted from dawn until dusk. MMO(s) scanned around the vessel, alternating between unaided eyes and 7×50 Fujinon binoculars. Scans were also made using the 25×150 Big-eye binoculars, to detect animals and to identify species or group size during sightings. Both the Fujinon and Big-eye binoculars were equipped with reticles on the ocular lens to measure depression angles relative to the horizon, an indicator of distance. During the day, at least one and (if possible) two MMOs were on duty, especially during the 30 min before and during ramp ups.

When MMO(s) were not on active duty at night, the *Langseth* bridge personnel were asked to watch for marine mammals and turtles during their regular watches. They were provided with a copy of the observer instruction manual and marine mammal identification guides that were kept on the bridge. Bridge crew were given instruction on how, if they sighted marine mammals or sea turtles at night, they were to fill out marine mammal and sea turtle sighting forms in order to collect pertinent information on sightings when MMOs were not on active duty. Bridge personnel would also look for marine mammals and turtles during the day, when MMO(s) were on duty.

While on watch, MMOs kept systematic written records of the vessel's position and activity, and environmental conditions. Codes that were used for this information are shown in Table D.1. Watch data were entered into an Excel database every ~30 min, as activities allowed. Additional data were recorded when marine mammals or sea turtles were observed. For all records, the date and time (in GMT), vessel position (latitude, longitude), water depth, and environmental conditions were recorded. Environmental conditions also were recorded whenever they changed and with each sighting record. Standardized codes were used for the records, and written comments were usually added as well.

For each sighting, the following information was recorded: species, number of individuals seen, direction of movement relative to the vessel, vessel position and activity, sighting cue, behavior when first sighted, behavior after initial sighting, heading (relative to vessel), bearing (relative to vessel), distance, behavioral pace, species identification reliability, and environmental conditions. Codes that were used to record this information during the cruise are shown in Table D.1. Distances to sightings were estimated from where the MMO was stationed (typically the observation tower) rather than from the nominal center of the seismic source (the distance from the sighting to the airguns was calculated during analyses). However, for sightings near or within the safety radius in effect at the time, the distance from the sighting to the nearest airgun was estimated and recorded for the purposes of implementing power downs or shut downs. The bearing from the observation vessel to the nearest member of the group was estimated using positions on a clock face, with the bow of the vessel taken to be 12 o'clock and the stern at 6 o'clock.

Operational activities that were recorded by MMOs included the number of airguns in use, total volume of the airguns in use, and type of vessel/seismic activity. The position of the vessel was automatically logged every minute by the *Langseth's* navigation system and displayed in the observation tower. Those data were used when detailed position information was required. In addition, the following information was recorded, if possible, for other vessels within 5 km at the time of a marine mammal sighting: vessel type, size, heading (relative to study vessel), bearing (relative to study vessel), distance, and activity. Intra-ship phone communication between the observation platform and the ship's science lab was used for several purposes: The MMOs on the observation platform alerted the geophysicists when a power down or shut down was needed. The geophysicists or the MMO conducting PAM (in the ship's science lab) alerted the visual MMOs to any changes in operations and any marine mammals detected acoustically.

All data were entered into a Microsoft Excel® database. The database was constructed to prevent entry of out-of-range values and codes. Data entries were checked manually by comparing listings of the computerized data with the original handwritten datasheets, both in the field and upon later analyses. Data collected by the MMOs were also checked against the navigation and shot logs collected automatically by the vessel's computers.

Passive Acoustic Monitoring Methods

Passive acoustic monitoring was conducted from aboard the *Langseth* to detect calling cetaceans and to alert visual MMOs to the presence of these animals. The Right Waves hydrophone array has been used during recent L-DEO cruises (see Appendix G). The array is deployed from the back deck. The depth at which the hydrophone array is towed can be adjusted by adding or removing weights. Generally, the array is towed at a depth of ~20 m.

The Right Waves array consists of four hydrophones, two of which are monitored simultaneously, and the active section of the array is ~30 m long. The array is attached to the vessel by a 250-m electromechanical lead-in cable and a 50-m long deck lead-in cable. However, not the entire length of lead-in cable is used; thus, the hydrophones are typically located 120 m behind the stern of the ship.

Table D1. Summary of data codes used during the seismic survey.

WS	Watch Start
WE	Watch End

LINE

Enter Line ID or leave blank

SEISMIC ACTIVITY

RU	Ramp-up
LS	Line Shooting
TR	Transiting to study area
MI	Ship milling/stopped
DP	Deploying Equipment
RC	Recovering Equipment
SH	Shooting Between/Off.Lines
ST	Seismic Testing
SD	Mechanical Shut Down
SZ	Safety Zone Shut-Down
PD	Power Down
OT	Other (comment and describe)

 # GUNS

Enter Number of Operating Airguns, or

X	Unknown

ARRAY VOLUME

Enter operating volume, or

X	Unknown

(BEAUFORT) SEA STATE

See Beaufort Scale sheet.

LIGHT OR DARK

L	Light (day)
D	Darkness

GLARE AMOUNT

NO	None
LI	Little
MO	Moderate
SE	Severe

POSITION

Clock Position, or

V	Variable (vessel turning)

WATER DEPTH

In meters

MARINE MAMMAL SPECIES

Baleen Whales

BLW	Blue Whale
BRW	Bryde's Whale
FW	Fin Whale
NPGW	North Pacific Gray Whale
NPRW	North Pacific Right Whale
OW	Omura's Whale
SW	Sei Whale
HW	Humpback Whale
MW	Minke Whale
UMW	Unidentified Mysticete Whale
UW	Unidentified Whale

Large Toothed Whales

DSW	Dwarf Sperm Whale
FKW	False Killer Whale
KW	Killer Whale
LFPW	Long-finned Pilot Whale
MHW	Melon-headed Whale
PKW	Pygmy Killer Whale
PSW	Pygmy Sperm Whale
SPW	Sperm Whale
SFPW	Short-finned Pilot Whale
UTW	Unidentified Tooth Whale

Beaked Whales

BBW	Blainville's Beaked Whale
CBW	Cuvier's Beaked Whale
GBW	Gervais' Beaked Whale
GTBW	Gingko-toothed Beaked Whale
LBW	Longman's Beaked Whale
SBW	Sowerby's Beaked Whale
UBW	Unidentified Beaked Whale

Dolphins

ASD	Atlantic Spotted Dolphin
CBD	Common Bottlenose Dolphin
CD	Clymene Dolphin
FD	Fraser's Dolphin
IPBD	Indo-Pacific Bottlenose Dolphin
IPHD	Indo-Pacific Humpback Dollphin
LCD	Long-beaked Common Dolphin
NRWD	Northern Right Whale Dolphin
PSP	Pantropical Spotted Dolphin
PWD	Pacific White-sided Dolphin
RD	Risso's Dolphin
RTD	Rough-toothed Dolphin
SCD	Short-beaked Common Dolphin
SPD	Spinner Dolphin
STD	Striped Dolphin
UD	Unidentified Dolphin

Porpoises

DP	Dall's Porpoise
HP	Harbor Porpoise
FP	Finless Porpoise

Sirenians

DU	Dugong

TURTLE SPECIES

GR	Green Turtle
HB	Hawksbill Turtle
KR	Kemp's Ridley Turtle
LH	Loggerhead Turtle
LB	Leatherback Turtle
UT	Unidentified Turtle

MOVEMENT

PE	Perpendicular across bow
ST	Swim Toward
SA	Swim Away
FL	Flee
SP	Swim Parallel
MI	Mill
NO	No movement
UN	Unknown

INDIVIDUAL BEHAVIOR

MA	Mating
SI	Sink
FD	Front Dive
TH	Thrash Dive
DI	Dive
LO	Look
LG	Logging
SW	Swim
BR	Breach
LT	Lobtail
SH	Spyhop
FS	Flipper Slap
FE	Feeding
FL	Fluking
BL	Blow
BO	Bow Riding
PO	Porpoising
RA	Rafting
WR	Wake Riding
AG	Approaching Guns
DE	Dead
OT	Other (describe)
NO	None (sign seen only)
UN	Unknown

GROUP BEHAVIOR (BEHAVIORAL STATES)

TR	Travel
SA	Surface Active
ST	Surface Active-Travel
MI	Milling
FG	Feeding
RE	Resting
OT	Other (describe)
UN	Unknown

 # RETICLES or ESTIMATE

(of Initial Distance, etc.; Indicate Big eyes or Fujinons in comments)

0 to 16	Number of reticles
E	Estimate, by eye

SIGHTING CUE

BO	Body
HE	Head
SP	Splash
FL	Flukes
DO	Dorsal Fin
BL	Blow
BI	Birds

IDENTIFICATION RELIABILITY

MA	Maybe
PR	Probably
PO	Positive

BEHAVIOR PACE

SE	Sedate
MO	Moderate
VI	Vigorous

WITH ABOVE RECORD?

Y	Yes
(blank)	not with above record

The deck cable is connected from the array to a computer in the laboratory where signal conditioning and processing takes place. The digitized signal is then sent to the main laboratory, where the acoustic MMO monitors the system.

The array can detect signals at frequencies up to 96 kHz. There are interference effects from ship noise and airgun sounds, although problems from ship noise appeared to be minimal. Hardware is typically used to filter out sounds from airguns as they are fired (to make listening to the received signals more comfortable while using headphones). This filtering procedure filters out all sounds for ~1–2 s so no other sounds are heard during that interval. It is doubtful that any sequences of marine mammal vocalizations are missed as a result of the brief periods of "blanking" during the airgun shots. However, the array has limited ability to detect low frequencies (<100 Hz) such as those that are typically produced by some baleen whales.

The CIBRA software, SeaProUltra, is also used to monitor for vocalizing cetaceans detected via the hydrophone array. The CIBRA system functions include real-time spectrographic display, continuous and event audio recordings, navigation display, semi-automated data logging, and data logging display. A document with detailed explanations of the CIBRA system is available from CIBRA (Pavan 2005).

When a vocalization is detected, information associated with that acoustic encounter is recorded. This includes the acoustic encounter identification number, whether it is linked with a visual sighting, GMT date, GMT time when first and last heard and whenever any additional information is recorded, GPS position and water depth when first detected, species or species group (e.g., unidentified dolphins, sperm whales), types and nature of sounds heard (e.g., clicks, continuous, sporadic, whistles, creaks, burst pulses, strength of signal, etc.), and any other notable information. The data logger, developed by CIBRA, automatically reads some of this information from the ship's navigation data stream (GPS coordinates, time, and water depth) and feeds it directly into a Microsoft Excel® data sheet, which can then be amended and edited with the additional information.

In addition to specific event logging, the acoustic MMO on duty notes the presence or absence of cetacean signals every 15 min. The acoustic MMO also notes the seismic state, vessel activity, and any changes in the number of airguns operating, based on information displayed on a monitor in the acoustic work area. The acoustic MMO notifies the visual MMOs on the observation tower of these changes via telephone or radio.

When the signal-to-noise ratio of vocalizing cetaceans is judged to be adequate (moderately strong and clear vocalizations), the acoustic data are recorded onto the computer hard-drive. The CIBRA system is capable of quick 2-min recordings, or continuous recordings of a user-defined time period.

Mitigation

Ramp-up, power-down, and shut-down procedures are described in detail below. These were the primary forms of mitigation implemented during seismic operations. A ramp up consisted of a gradual increase in the number of operating airguns, not to exceed an increase of 6 dB in source level per 5 min-period, the maximum ramp-up rate authorized by NMFS in the IHA and during past L-DEO seismic cruises (Appendix A). A power down consisted of reducing the number of operating airguns to a single active airgun. A shut down occurred when all the airguns were turned off.

Ramp-up Procedures

A "ramp-up" procedure was followed at the commencement of seismic operations with the airgun array, and anytime after the array was powered down or shut down for a specified duration. Under normal operational conditions (vessel speed 4–5 kt), a ramp up to the full array was conducted after a shut down or power down lasting ~8 min or longer.

The IHA required that, during the daytime, the entire safety radius be visible (i.e., not obscured by fog, etc.), and monitored for 30 min prior to and during ramp up, and that the ramp up could only commence if no marine mammals or sea turtles were detected within the safety radius during this period. Throughout the ramp ups, the safety zone was taken to be that appropriate for the entire airgun array at the time, even though only a subset of the airguns were firing until the ramp up was completed. When no airguns were firing at the start of the ramp up, ramp up of the airgun array began with a single airgun. Airguns were added in a sequence such that the source level of the array would increase in steps not exceeding 6 dB per 5-min period (see Appendix A).

Power-down and Shut-down Procedures

Airgun operations were immediately shut down or powered down to a single operational airgun when one or more marine mammals or sea turtles were detected within, or judged about to enter, the appropriate safety radius.

The power-down procedure was to be accomplished within several seconds (or a "one-shot" period) of the determination that a marine mammal or sea turtle was within or about to enter the safety radius. Airgun operations were not to resume until the animal was seen outside the safety radius, had not been seen for a specified amount of time (15 min for small odontocetes and pinnipeds, 30 min for mysticetes and large odontocetes including sperm, pygmy sperm, dwarf sperm, killer, and beaked whales), or was assumed to have been left behind (and outside the safety radius) by the vessel (e.g., turtles). Once the safety radius was judged to be clear of marine mammals or sea turtles based on those criteria, the MMOs advised the airgun operators and geophysicists, who advised the bridge that seismic surveys could re-commence, and ramp up was initiated.

In contrast to a power down, a shut down refers to the complete cessation of firing by all airguns. If a marine mammal or turtle was seen within the designated safety radius around the one airgun in operation during a power down, a complete shut down was necessary.

The MMOs were stationed on the observation tower, which is located ~35 m ahead of the stern. The closest airgun was located ~215 m behind the *Langseth*'s stern during the Shatsky Rise survey. The decision to initiate a power down was based on the distance from the observers rather than from the airgun array unless the animals were sighted close to the array. This was another precautionary measure, given that most sightings were ahead of the vessel.

Analyses

This section describes the analyses of the marine mammal and sea turtle sightings and survey effort as documented during the cruise. It also describes the methods used to calculate densities of cetaceans and estimate the number of cetaceans potentially exposed to seismic sounds associated with the seismic study. The analysis categories that were used were identified in Chapter 3. The primary analysis categories used to assess potential effects of seismic sounds on marine mammals were the "seismic" (airguns operating with shots at <1.5 min spacing) and "non-seismic" categories (periods before seismic started, and >6 h after airguns are turned off. The analyses for effort and cetaceans excluded the "post-seismic" period 1.5 min to 6 h after the airguns were turned off. The justification for the selection of these criteria is based on the size of the airgun array in use and is provided below. These criteria were discussed in earlier L-DEO cruise reports to NMFS (see Haley and Koski 2004; Smultea et al. 2004, 2005; MacLean and Koski 2005; Holst et al. 2005a,b; Holst and Beland 2008, 2010; Holst and Smultea 2008; Hauser et al. 2008; Holst 2009a,b):

- The period up to 1.5 min after the last seismic shot is typically ~10× the normal shot interval. Mammal distribution and behavior during that short period are assumed to be similar to those while seismic surveying is ongoing.
- It is likely that any marine mammals and turtles near the *Langseth* between 1.5 min and 2 h after the cessation of seismic activities would have been "recently exposed" (i.e., within the past 2 h) to sounds from the seismic survey. During at least a part of that period, the distribution and perhaps behavior of the animals probably would still be influenced by the (previous) sounds.
- For a cruise involving use of a large array of airguns, for some unknown part of the period from 2 to 6 h post-seismic, it is possible that the distribution of marine mammals near the ship, and perhaps the behavior of some of those animals, would still be at least slightly affected by the (previous) seismic sounds. For a cruise using a small array, the period is considered to be up to 2 h.
- By 6 h after the cessation of seismic operations with a large array (or 2 h with a small array), the distribution and behavior of marine mammals would be expected to be indistinguishable from "normal" because of (a) waning of responses to past seismic activity, (b) re-distribution of mobile animals, and (c) movement of the ship and MMOs. Given those considerations, plus the limited observed responses of marine mammals to seismic surveys (e.g., Stone 2003; Gordon et al. 2004; and previous L-DEO projects), it is unlikely that the distribution or behavior of marine mammals near the *Langseth* >6 h post-seismic (for a large array) or >2 h (for a small array) would be appreciably different from "normal" even if they had been exposed to seismic sounds earlier. Therefore, we consider animals seen >6 h after cessation of operations by a large airgun array to be unaffected by the seismic operations.
- It is not expected that the distribution or behavior of turtles would still be affected more than 2 hrs after the airguns are shut off when a large or small array is operating.

Cetacean density was one of the parameters examined to assess differences in the distribution of cetaceans relative to the seismic vessel between seismic and non-seismic periods. Line transect procedures for vessel-based visual surveys were followed. To allow for animals missed during daylight, we corrected our visual observations for missed cetaceans by using approximate correction factors derived from previous studies. (It was not practical to derive study-specific correction factors during a survey of this type and duration.) It is recognized that the most appropriate correction factors will depend on specific observation procedures during different studies, ship speed, and other variables. Thus, use of correction factors derived from other studies is not ideal, but it provides more realistic estimates of numbers present than could be obtained without using data from other studies.

The formulas for calculating densities using this procedure were briefly described in Chapter 3 and are described in more detail below. As is standard for line-transect estimation procedures, densities were corrected for the following two parameters before they were further analyzed:

- $g(0)$, a measure of detection bias. This factor allows for the fact that less than 100% of the animals present along the trackline are detected.
- $f(0)$, the reduced probability of detecting an animal with increasing distance from the trackline.

The $g(0)$ and $f(0)$ factors used in this study for cetaceans were taken from results of previous work, not from observations made during this study. Sighting rates during the present study were either too small or, at most, marginal to provide meaningful data on $f(0)$ based on group size. Further, this type of project cannot provide data on *g*(0). Estimates of these correction factors were derived from Koski et al. (1998). Marine mammal sightings were subjected to species-specific truncation criteria obtained from the above studies.

Number of Marine Mammal Exposures

Estimates of the numbers of potential *exposures* of marine mammals to sound levels ≥160 dB re 1 μPa_{rms} were calculated by multiplying the following two values. These calculations were done separately for times when different numbers of airguns were in use, and the results were summed:

- area assumed to be ensonified to ≥160 dB (depending on the airgun(s) in use at the time; Table 3.1), and
- "corrected" densities of marine mammals estimated by line transect methods as summarized above.

For this calculation, areas ensonified to ≥160 dB on two or more occasions were counted two or more times, as appropriate. This occurred when two survey lines intersected, part or all of a survey line was repeated, or two parallel survey lines were close enough together such that the ≥160 dB zones around those lines overlapped.

Number of Individuals Exposed

The estimated number of individual exposures to levels ≥160 dB obtained by the method described above likely overestimates the number of different *individual* mammals exposed to the airgun sounds at received levels ≥160 dB. This occurs because some exposure incidents may have involved the same individuals previously exposed, given that some seismic lines crossed other lines or were spaced closely together (see Fig. 2.1).

A minimum estimate of the number of different individual marine mammals potentially exposed (one or more times) to ≥160 dB re 1 μPa_{rms} was calculated. That involved multiplying the corrected density of marine mammals by the area exposed to ≥160 dB one or more times during the course of the study. The area was calculated using MapInfo Geographic Information System (GIS) software by creating a "buffer" that extended on both sides of the vessel's trackline to the predicted 160-dB radius. Because the 160-dB radius varied with the number of airguns in use (Table 3.1), the width of the buffer also varied with the number of airguns in use. The buffer includes areas that were exposed to airgun sounds ≥160 dB multiple times (as a result of crossing tracklines or tracklines that were close enough for their 160 dB zones to overlap). The buffer area only counts the repeated-coverage areas once, as opposed to the "exposures" method outlined above. The calculated number of different individual marine mammals exposed to ≥160 dB re 1 μPa_{rms} is considered a minimum estimate because it does not account for the movement of marine mammals during the course of the study.

The buffer process outlined above was repeated for delphinids, assuming that for those animals, the estimated 170 dB-radius (see Table 3.1) was a more realistic estimate of the maximum distance at which significant disturbance would occur. That radius was used to estimate both the number of exposures and the number of individuals exposed to seismic sounds with received levels ≥170 dB re 1 μPa_{rms}.

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APPENDIX E:
BACKGROUND ON MARINE MAMMALS OCCURRING NEAR THE SHATSKY RISE

TABLE E.1. The habitat, abundance, and conservation status of marine mammals that occur in or near the Shatsky Rise in the Northwest Pacific Ocean (taken from the EA/IHA Application; LGL Ltd. 2010a,b).

Species	Habitat	Regional pop. Size [a]	U.S. ESA [b]	IUCN [c]	CITES [d]
Mysticetes					
North Pacific right whale (*Eubalaena japonica*)	Pelagic and coastal	few 100 [e]	EN	EN	I
Humpback whale (*Megaptera novaeangliae*)	Mainly nearshore waters and banks	938–1107 [f]	EN	LC	I
Minke whale (*Balaenoptera acutorostrata*)	Pelagic and coastal	25,000 [g]	NL	LC	I
Bryde's whale (*Balaenoptera edeni* and *B. brydei*)	Pelagic and coastal	20,501 [h]	NL	DD	I
Sei whale (*Balaenoptera borealis*)	Primarily offshore, pelagic	7260-12,620 [i]	EN	EN	I
Fin whale (*Balaenoptera physalus*)	Continental slope, mostly pelagic	13,620–18,680 [j]	EN	EN	I
Blue whale (*Balaenoptera musculus*)	Pelagic and coastal	3500 [k]	EN	EN	I
Odontocetes					
Sperm whale (*Physeter macrocephalus*)	Usually pelagic and deep seas	29,674 [l]	EN	VU	I
Pygmy sperm whale (*Kogia breviceps*)	Deep waters off the shelf	N.A.	NL	DD	II
Dwarf sperm whale (*Kogia sima*)	Deep waters off the shelf	11,200 [m]	NL	DD	II
Cuvier's beaked whale (*Ziphius cavirostris*)	Pelagic	20,000 [m]	NL	LC	II
Baird's beaked whale (*Berardius bairdii*)	Deep water	N.A.	NL	DD	II
Longman's beaked whale (*Indopacetus pacificus*)	Deep water	N.A.	NL	DD	II
Hubb's beaked whale (*Mesoplodon carlhubbsi*)	Deep water	25,300 [n]	NL	DD	II
Ginkgo-toothed beaked whale (*Mesoplodon ginkgodens*)	Pelagic	25,300 [n]	NL	DD	II
Blainville's beaked whale (*Mesoplodon densirostris*)	Pelagic	25,300 [n]	NL	DD	II
Stejneger's beaked whale (*Mesoplodon stejnegeri*)	Deep water	25,300 [n]	NL	DD	II
Rough-toothed dolphin (*Steno bredanensis*)	Deep water	145,900 [m]	NL	LC	II
Common bottlenose dolphin (*Tursiops truncatus*)	Coastal and oceanic, shelf break	168,000 [o]	NL	LC	II
Pantropical spotted dolphin (*Stenella attenuata*)	Coastal and pelagic	438,000 [o]	NL	LC	II
Spinner dolphin (*Stenella longirostris*)	Coastal and pelagic	801,000 [p]	NL	DD	II
Striped dolphin (*Stenella coeruleoalba*)	Off continental shelf	570,000 [o]	NL	LC	II
Fraser's dolphin (*Lagenodelphis hosei*)	Waters >1000 m	289,300 [m]	NL	LC	II

Species	Habitat	Regional pop. Size [a]	U.S. ESA [b]	IUCN [c]	CITES [d]
Short-beaked common dolphin (*Delphinus delphis*)	Shelf and pelagic, seamounts	2,963,000 [q]	NL	LC	II
Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)	Continental slope and pelagic	988,000 [r]	NL	LC	II
Northern right whale dolphin (*Lissodelphis borealis*)	Deep water	307,000 [r]	NL	LC	II
Risso's dolphin (*Grampus griseus*)	Waters >1000 m, seamounts	838,000 [o]	NL	LC	II
Melon-headed whale (*Peponocephala electra*)	Oceanic	45,400 [m]	NL	LC	II
Pygmy killer whale (*Feresa attenuata*)	Deep, pantropical waters	38,900 [m]	NL	DD	II
False killer whale (*Pseudorca crassidens*)	Pelagic	16,000 [o]	NL	DD	II
Killer whale (*Orcinus orca*)	Widely distributed	8500 [m]	NL	DD	II
Short-finned pilot whale (*Globicephala macrorhynchus*)	Mostly pelagic, high-relief topography	53,000 [o]	NL	DD	II
Dall's porpoise (*Phocoenoides dalli*)	Deep water	1,337,224 [s]	NL	LC	II
Pinnipeds Northern fur seal (*Callorhinus ursinus*)	Coastal and pelagic	1.1 million [t]	NL	VU	-

N.A. - Data not available or species status was not assessed.
[a] Region for population size, in order of preference based on available data, is Western North Pacific, North Pacific, or Eastern Tropical Pacific; see footnotes below.
[b] U.S. Endangered Species Act; EN = Endangered, NL = Not listed.
[c] Codes for IUCN (2009) classifications; EN = Endangered; VU = Vulnerable; LC = Least Concern; DD = Data Deficient.
[d] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2009): Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled.
[e] North Pacific (Jefferson et al. 2008).
[f] Western North Pacific (Calambokidis et al. 2008).
[g] Northwest Pacific and Okhotsk Sea (Buckland et al. 1992; IWC 2009).
[h] Western North Pacific (Kitakado et al. 2008; IWC 2009).
[i] North Pacific (Tillman 1977).
[j] North Pacific (Ohsumi and Wada 1974).
[k] North Pacific (NMFS 1998).
[l] Western North Pacific (Whitehead 2002b).
[m] Eastern Tropical Pacific (ETP) (Wade and Gerrodette 1993).
[n] ETP; all *Mesoplodon* spp. (Wade and Gerrodette 1993).
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[p] Whitebelly spinner dolphin in the ETP in 2000 (Gerrodette et al. 2005 *in* Hammond et al 2008a).
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APPENDIX F:
VISUAL EFFORT AND SIGHTINGS

TABLE F.1. All and useable[a] visual observation effort from the *Langseth* during the Shatsky Rise cruise, 17 July to 13 September 2010, in **(A)** kilometers and **(B)** hours, subdivided by location, Beaufort Wind Force (Bf), and airgun status. No effort occurred in Bf = 0.

Airgun Status	1	2	3	4	5	6*	Total
(A) Effort in km							
Seismic Survey							
Total Airguns On (Seismic)	**69.6 (53.8)**	**365.9 (350.4)**	**579.0 (553.6)**	**436.2 (427.2)**	**250.6 (239.2)**	**111.4 (0)**	**1812.7 (1624.2)**
Ramp up	0	21.8 (21.8)	4.7 (4.7)	9.0 (9.0)	0	13.5 (0)	**49 (35.5)**
1-90 s after shut down	0	0	0.2 (0.2)	0.3 (0.3)	0	0.3 (0)	**0.8 (0.5)**
1 airgun	0	0	2.1 (2.1)	0	0	0	**2.1 (2.1)**
18 airguns	0	57.4 (46.4)	41.5 (41.5)	14.9 (14.9)	4.5 (4.5)	0	**118.3 (107.2)**
27 airguns	0	1.6 (1.6)	0	2.1 (2.1)	0	0	**3.7 (3.7)**
36 airguns	69.6 (53.8)	285.0 (280.6)	530.5 (505.1)	409.0 (400.9)	246.1 (234.7)	97.7 (0)	**1638.8 (1475.1)**
Total Airguns Off	**0**	**267.9 (263.9)**	**835.5 (733.6)**	**536.8 (435.6)**	**341.6 (283.5)**	**158.9 (0)**	**2140.5 (1716.6)**
Non-seismic[b]	**0**	**267.9 (263.9)**	**768.7 (733.6)**	**476.9 (435.6)**	**326.6 (283.5)**	**158.3 (0)**	**2016.4 (1716.6)**
Recently-exposed[c]	0	0	19.7 (0)	15.8 (0)	0	0.6 (0)	**36.0 (0)**
Potentially exposed[d]	0	0	29.1 (0)	44.0 (0)	15.0 (0)	0	**88.1**
Total Effort (Airguns On&Off)	**69.6 (53.8)**	**633.7 (614.3)**	**1414.5 (1217.2)**	**972.9 (862.8)**	**592.1 (422.7)**	**270.3 (0)**	**3953.2 (3340.8)**
Transit to and from Hawaii[e]	**0**	**275.4 (275.4)**	**1343.7 (1328.0)**	**1877.9 (1839.3)**	**703.0 (670.6)**	**50.7 (0)**	**4250.7 (4113.2)**
Transit to and from Japan[e]	**4.2 (4.2)**	**543.9 (540.6)**	**1230.4 (1230.4)**	**870.6 (869.9)**	**95.4 (95.4)**	**114.1 (0)**	**2858.6 (2740.5)**
(B) Effort in hr							
Seismic Survey							
Total Airguns On (Seismic)	**7.4 (5.7)**	**41.1 (39.2)**	**67.3 (64.4)**	**50.9 (49.9)**	**29.2 (27.9)**	**13.1 (0)**	**209.1 (187.2)**
Ramp up	0	2.7 (2.7)	0.6 (0.6)	1.2 (1.2)	0	1.9 (0)	6.3 (4.4)
1-90 s after shut down	0	0	0.03 (0.03)	0.04 (0.04)	0	0.03 (0)	0.1 (0.07)
1 airgun	0	0	0.2 (0.2)	0	0	0	0.2 (0.2)
18 airguns	0	6.1 (6.1)	5.6 (5.6)	1.9 (1.9)	0.5 (0.5)	0	14.0 (14.0)
27 airguns	0	0.2 (0.2)	0.0	0.2 (0.2)	0	0	0.4 (0.4)
36 airguns	7.4 (5.7)	30.7 (30.2)	61.0 (58.1)	47.6 (46.6)	28.7 (27.4)	11.2 (0)	186.5 (168.0)
Total Airguns Off	**0**	**17.6 (16.4)**	**51.4 (39.8)**	**38.5 (24.4)**	**29.6 (16.1)**	**10.4 (0)**	**147.5 (96.8)**
Non-seismic[b]	0	16.4 (16.4)	39.8 (39.8)	24.4 (24.4)	16.1 (16.1)	0	96.8 (96.8)
Recently-exposed[c]	0	0	3.2 (0)	2.1 (0)	0	0.1 (0)	5.4 (0)
Potentially exposed[d]	0	0	4.0 (0)	3.2 (0)	0.8 (0)	0	8.0 (0)
Total Effort (Airguns On&Off)	**7.4 (5.7)**	**58.7 (55.6)**	**118.7 (104.3)**	**89.4 (74.3)**	**58.8 (44.0)**	**23.6 (0)**	**356.6 (284.0)**
Transit to and from Hawaii[e]	**0**	**13.5 (13.2)**	**67.7 (66.9)**	**95.8 (93.8)**	**37.7 (36.1)**	**2.5 (0)**	**217.2 (210.2)**
Transit to and from Japan[e]	**0.2 (0.2)**	**26.9 (26.8)**	**61.5 (61.5)**	**45.4 (45.2)**	**4.6 (4.6)**	**5.1 (0)**	**143.8 (138.3)**

[a] See "useable" definition in *Acronyms and Abbreviations.*

[b] >6 h since seismic

[c] 90 s - 2 hr after seismic

[d] 2 - 6 hr after seismic

[e] No airguns were used during this phase.

*Effort in these categories is not considered "useable".

TABLE F.2. Sightings of marine mammals and turtles made during all visual effort during the Shatsky Rise cruise, 17 July to 13 September 2010.

Species	Useable ?[a]	Group size	Date & Time (GMT)	Latitude	Longitude	Initial Sighting Dstance (m)	CPA (m)[b]	Move-ment[c]	Initial Behavior[d]	Wind Force[e]
Shatsky Rise										
Unidentified Turtle	Y	1	27/07/2010 19:06:17	33.241 °N	158.887 °E	100	350	NO	OT[f]	3
Unidentified Dolphin	N	3	08/08/2010 01:21:49	33.275 °N	157.590 °E	1200	1422	ST	ST	6
Sperm Whale[g]	Y	7	26/08/2010 05:05:33	32.290 °N	158.322 °E	3375	1031	SP	SW	3
Unidentified Whale	Y	1	03/09/2010 20:56:11	31.722 °N	158.169 °E	3000	3132	UN	UN	3
Sperm Whale	Y	1	03/09/2010 23:32:17	31.766 °N	158.703 °E	700	950	UN	BL	3
Sperm Whale	Y	1	28/07/2010 07:34:35	32.388 °N	158.294 °E	2917	3050	NO	LG	4
Unidentified Turtle	Y	1	28/07/2010 23:14:45	33.622 °N	156.607 °E	200	320	SP	SW	4
Japan										
Unidentified Whale	Y	2	06/08/2010 02:25:16	34.171 °N	147.697 °E	343	516	SP	BL	4
Sperm Whale	Y	1	06/08/2010 19:50:04	33.841 °N	151.468 °E	2917	3167	PE	LG	2
Unidentified Dolphin	N	150	06/08/2010 22:03:00	33.803 °N	151.939 °E	8178	8395	MI	SA	2
Unidentified Toothed Whale	Y	1	06/08/2010 22:07:54	33.801 °N	151.956 °E	2352	2486	NO	RE	2
Unidentified Dolphin	Y	25	06/08/2010 23:56:17	33.766 °N	152.349 °E	2352	2486	SP	TR	2
False Killer Whale	Y	4	07/08/2010 02:13:10	33.713 °N	152.856 °E	660	885	ST	TR	2
Unidentified Mysticet Whale	Y	1	07/08/2010 05:02:53	33.629 °N	153.532 °E	2917	3136	SP	SW	3
Pantropical Spotted Dolphin	Y	3	07/08/2010 05:18:13	33.623 °N	153.594 °E	40	290	ST	SW	3
Minke Whale	N	1	07/08/2010 05:27:00	33.619 °N	153.630 °E	3375	3507	PE	BR	3
Sperm Whale	Y	10	07/08/2010 05:27:00	33.619 °N	153.630 °E	4345	4352	SP	SW	3
Unidentified Dolphin	N	150	07/08/2010 05:55:16	33.609 °N	153.747 °E	4345	4226	SP	SW	3
Unidentified Dolphin	Y	50	18/08/2010 00:15:16	32.789 °N	147.785 °E	2352	2486	SP	SW	2
Sperm Whale	Y	1	18/08/2010 06:57:00	33.157 °N	146.319 °E	660	885	SP	SW	3
Risso's Dolphin	Y	1	18/08/2010 07:27:00	33.190 °N	146.198 °E	954	1101	SP	SW	3
Sperm Whale	Y	6	18/08/2010 20:41:30	33.875 °N	143.395 °E	954	1204	SP	TR	2
Sperm Whale	N	3	22/08/2010 03:52:39	32.013 °N	151.312 °E	6222	6351	SA	SW	3
Unidentified Turtle	N	1	03/08/2010 22:54:02	34.783 °N	139.909 °E	20	251	SP	SW	4
Unidentified Turtle	N	1	04/08/2010 01:37:08	35.050 °N	139.714 °E	30	266	SP	SA	2
Short-finned Pilote Whale	Y	3	05/08/2010 00:13:15	34.576 °N	142.028 °E	400	568	SP	SW	3
Unidentified Mysticet Whale	Y	2	05/08/2010 08:22:25	34.429 °N	143.864 °E	1228	1370	SP	SW	3
Sperm Whale	Y	1	06/08/2010 01:21:27	34.190 °N	147.471 °E	1435	1575	SA	SW	4
Hawaii										
Pantropical Spotted Dolphin	Y	3	19/07/2010 02:23:00	21.903 °N	162.488 °W	400	350	ST	PO	3
Unidentified Dolphin	N	300	06/09/2010 05:11:59	29.335 °N	169.642 °E	5099	4979	SP	PO	2
Unidentified Dolphin	N	50	07/09/2010 01:52:14	28.229 °N	173.630 °E	6222	6227	SP	PO	2

[a] Useable sighting? Y = Yes. N = No. "No" if sighting was made during periods 90 s to 6 h after airguns were turned off (post-seismic), or during nighttime observations, poor visibility conditions (visibility <3.5 km), or periods with Beaufort Wind Force >5 (>2 for cryptic species). Also excluded were periods when the *Langseth*'s speed was <3.7 km/h (2 kt) or with >60º of severe glare between 90º left and 90º right of the bow. Note, only "useable" sightings *within* the study area were used for analyses in Chapter 4.

[b] CPA is the distance at the closest observed point of approach to the nearest airgun. This is not necessarily the distance at which the individual or group was initially seen nor the closest it was observed to the vessel. * indicates that the airguns were not firing at the time of the sighting.
[c] The initial movement of the individual or group relative to the vessel. PE = swimming perpendicular to ship or across ship track; SP = swimming parallel; ST = swimming toward the vessel; SA = swimming away from vessel; UN = movement unknown; NO = no movement relative to vessel.
[d] The initial behavior observed. BR = breaching; PO = porpoising; SW = swimming; SA = surface active; TR = traveling; ST = surface active/traveling; BL = blowing; LG = logging; RE = resting; OT = other; UN = behavior unknown.
[e] Beaufort Wind Force Scale.
[f] Live turtle trapped in fishing gear.
[g]Mitigation (power down) implemented as whales were seen near safety radius during seismic operations with the full 36-airgun array.

APPENDIX G:
SHATSKY RISE SURVEY, 17 JULY – 13 SEPTEMBER 2010, PAM REPORT

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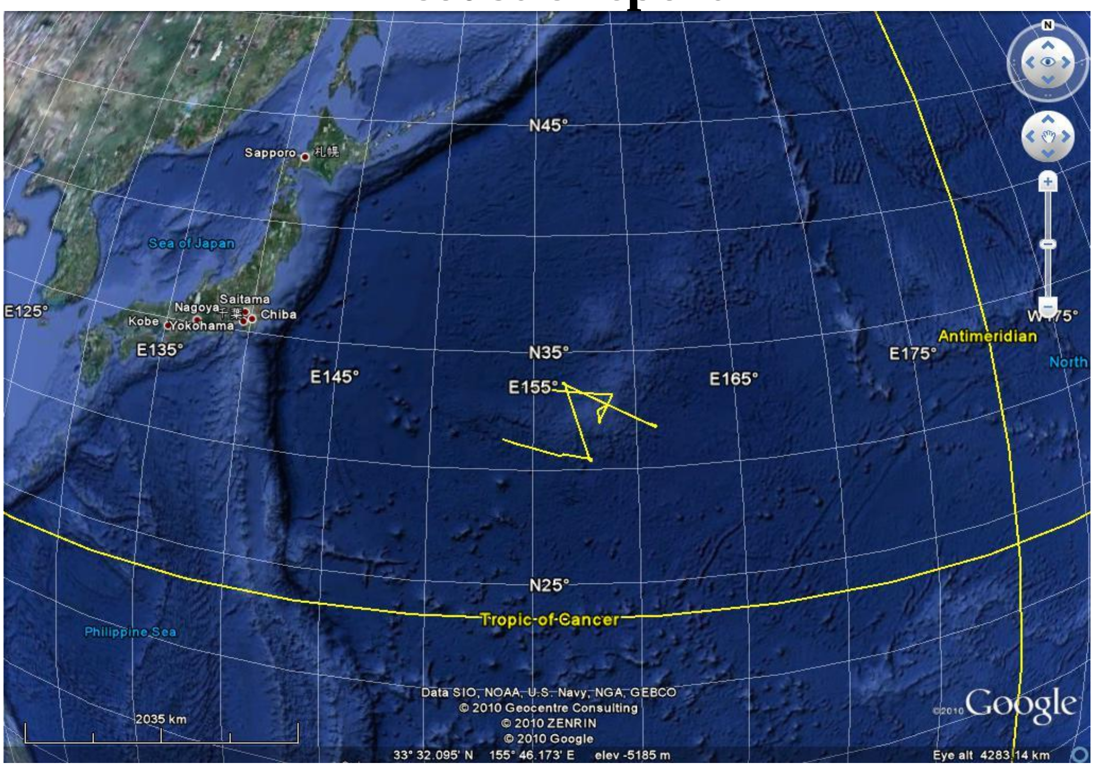
MGL1004 SHATZKY RISE

July 17 – September 14 2010

Acoustic report



Prepared by Claudio Fossati, RIGHT WAVES – CIBRA

Note: PAM effort in the acoustic report does not add up to the total PAM effort as given in the main body of the report, because data were collected by two different methods.

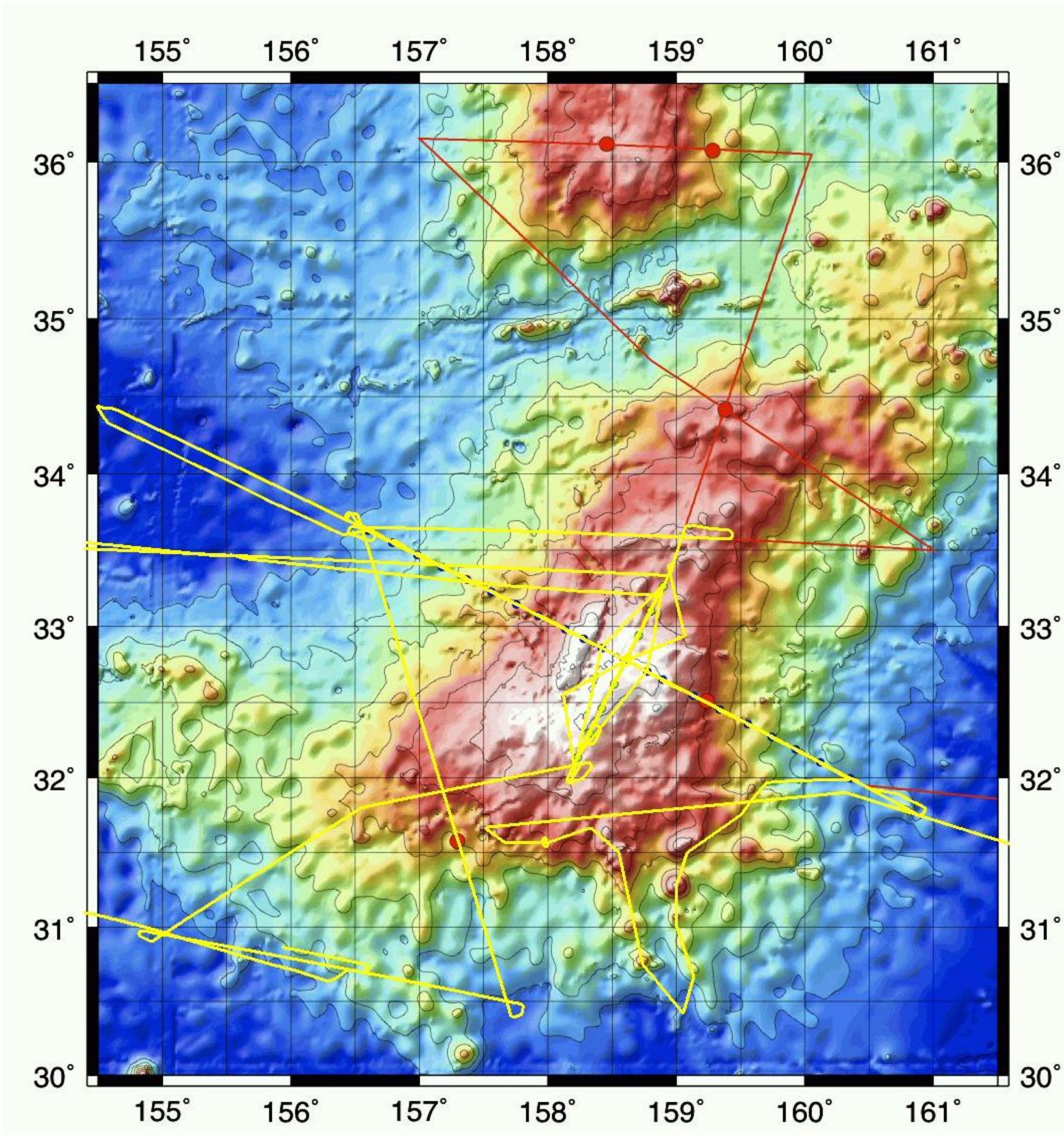


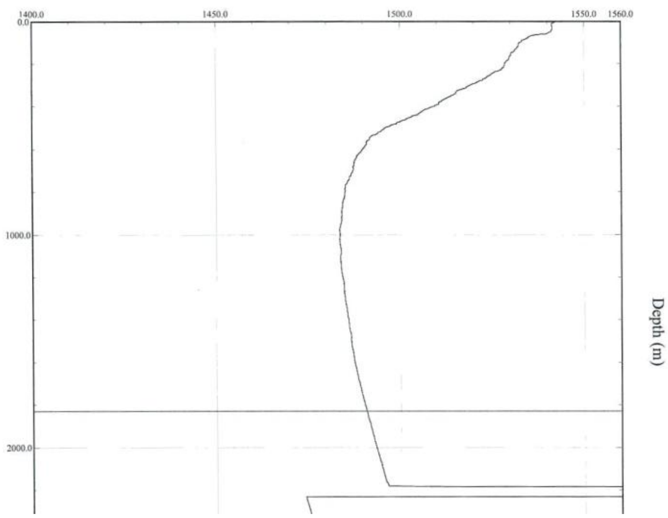
Fig. 1 The study area with the track. Shooting lines were limited to the core area on the map.

The Area

The study area was located at 30°-37°N, 154°-161°E, on a submarine formation known as the Shatzky Rise. Seismic operations were conducted in deep water only, with depths ranging between 2400 and 6000 m. Due to a series of unfortunate circumstances, seismic had to be interrupted twice for portcalls to Japan, each of them taking at least 8 days of transit time. Seismic was thus limited to a total of 17 non-consecutive days.

Sound propagation conditions

Daily XBTs were launched during the survey. They reflected the typical water column layers of tropical areas. Sound speed dropped quickly in the first 30 to 60 m, making this surface layer poor for detections of sound sources off the vertical axis off the array (see picture below). With the actual deployment system the PAM array is never deeper than 15-18 m, and is thus affected by these adverse sound propagation conditions. During the transits to and from Japan, we crossed an area characterized by mixing currents, and the relative XBT profile revealed this. This current mixing resulted in a very productive area, and the marine mammals sightings (10 in a single day) confirmed that. Unfortunately, the acoustic array was not in the water, since seismic operations were not underway and the actual array is not suited for towing at 10 knots (transit speed). Such favorable conditions for marine life never occurred in the study area, where there were just 3 sightings, two of which during OBS deployment.



Sound speed profile in the study area.

PAM system

Other than the usual acoustic equipment (one wideband digital array + one analog backup), RW provided an extra one, with new sensors and housing, to test it. It was deployed during the first days of seismic activity, from July 29 to July 30 (58h28min). Sensitivity and self noise were very good, resulting in a higher SRN (Signal to Noise Ratio, see Fig.1). It was tested also without the 1 kHz high pass filter used to cut the vibrations induced by the small depressor actually in use. Although some low-frequency noise was present, the overall signal was acceptable, confirming the stability of this new array. Being more stable and heavy, it sank to about 15 m (75-m leader deployed and depressor wing). It is the same array type successfully used for Beaked whale acoustic tracking during other research cruises (MED09 and Sirena 2010).

During the rest of the cruise, the backup array was used. This was because the actual towing system does not allow for safe operations during rough seas, and the weather forecast was poor. It was deployed with the usual wing to guarantee an acceptable depth considering the small length of leader paid out. Operational depth was about 12 m. Fig. 2 compares the different sensitivities of the arrays with similar configuration. Note the weaker signature of the airguns and the higher white noise due to shallower depth. During last deployment (Aug. 22), the PAM backup got briefly entangled with the seismic array. This resulted in new damage to the leader, which was already broken and then repaired during last 2009 cruise. A new on-the-fly repair was arranged to keep it working, but just few tens of meters of leader could be deployed. Array depth was then even shallower (8-10 m), and the proximity of propellers induced a lot of broadband noise, due to cavitation (Fig.3).

We recommend that a dedicated, safe deployment system should be designed, tested and consolidated, in order to guarantee the proper conditions to operate the PAM array with proficient results. Depth, stability and positioning of the sensors (along with their quality) are critical points in effectiveness of mitigation measures.

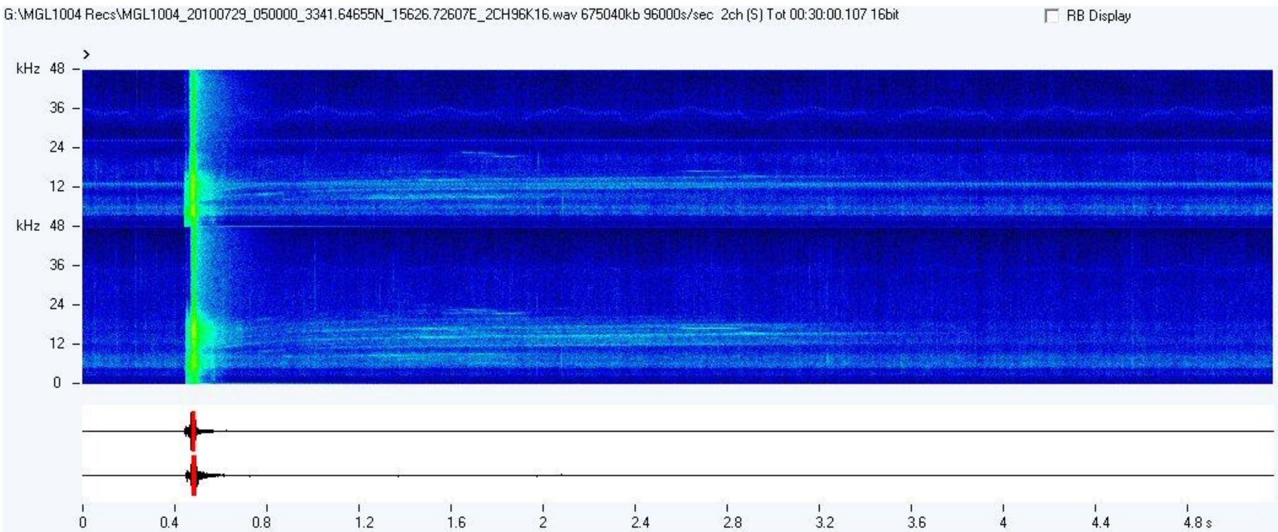


Fig.1 RW test array, 80 m from the stern, 15 m deep

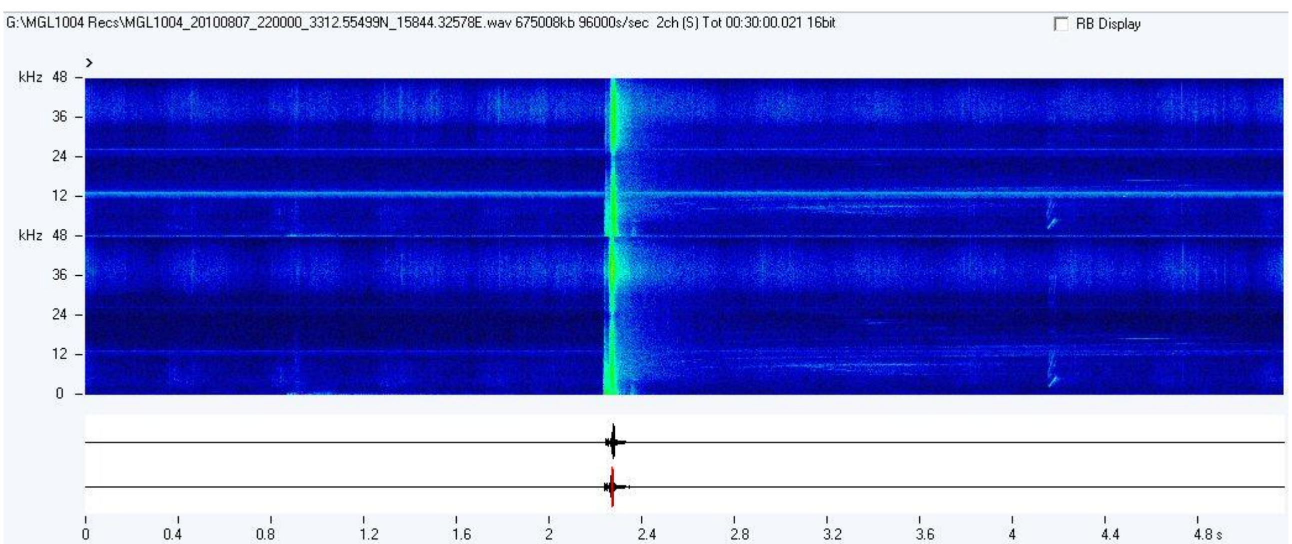


Fig.2 backup array, 80 m from the stern, 12 m deep

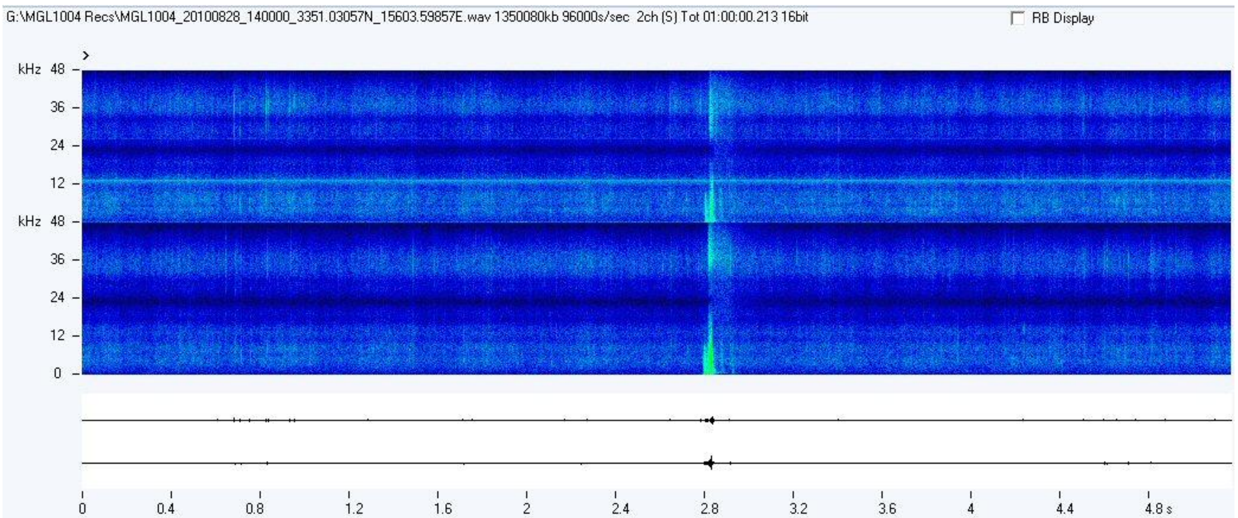


Fig.3 backup array, 25m off the stern, 9 m deep

Acoustic contacts
During the MGL 1004 **no (0) acoustic contacts** occurred.

Period (local time)	Total Effort		Ac. Cont.	No Seismic		Ac. Cont.
	Hours	*Min.*		*Hours*	*Min.*	
July 28-30	58	28	0	0	31	0
Aug 7-10	63	04	0	0	29	0
Aug 10-15	114	50	0	0	05	0
Aug 22-29	157	28	0	0	37	0
TOT.	***393***	***50***	***0***	***1***	***50***	***0***

Table 1 ***PAM effort and acoustic contacts during MGL1004.***

Post cruise analysis
About 520 GB of 48 kHz stereo recordings were collected during the cruise. As usual, recordings were analyzed in our acoustic lab for any missed acoustic contacts. Particular attention was paid to the hours before and after the only visual contact (7 sperm whales, surface active, as close as 800 m from the *Langseth*), but no vocalizations were present. Other than the consideration that animals may have been silent, there were a series of limiting factors: poor surface propagation, the sound source and receiver were both near the surface, and the receiver was close to the props due to the damage described above. Again we stress the fact that PAM deployment and towing system should be improved to achieve an acceptable level of performance.