Marine Mammal and Sea Turtle Monitoring During Lamont-Doherty Earth Observatory's Marine Seismic Program In the Southwest Pacific Ocean, January – March 2009

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and

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MARINE MAMMAL AND SEA TURTLE MONITORING DURING LAMONT-DOHERTY EARTH OBSERVATORY'S MARINE SEISMIC PROGRAM IN THE SOUTHWEST PACIFIC OCEAN, JANUARY – MARCH 2009

by

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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
CRE	Center for Regulatory Effectiveness
CV	Coefficient of Variation
cu. in.	cubic inches
dB	decibels
EA	Environmental Assessment
EEZ	Exclusive Economic Zone
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
IUCN	International Union for the Conservation of Nature
kHz	kilohertz
km	kilometer
km^2	square kilometers
km/h	kilometers per hour
kW	kilowatt
kt	knots
L-DEO	Lamont-Doherty Earth Observatory (of Columbia University)
µPa	microPascal
m	meters
MBES	Multibeam Bathymetric Echosounder
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
NMFS	(U.S.) National Marine Fisheries Service

No.	number
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
SPWRC	South Pacific Whale Research Consortium
SWPO	Southwest Pacific Ocean
SZ	Shut Down of all the airguns because of a marine mammal/turtle 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) by the National Marine Fisheries Service (NMFS) on 13 January 2009. 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* in the Southwest Pacific Ocean (SWPO), January–March 2009. 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 is not known 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 survey in the Lau Basin of the SWPO as part of the Lau Integrated Studies Site (Lau ISS) initiative of the National Science Foundation's (NSF) RIDGE 2000 program. The seismic survey took place within the Exclusive Economic Zone (EEZ) of Tonga, in water depths >1000 m. A bathymetric survey also took place between Tonga and Fiji in water depths >620 m. The purpose of study was to obtain data integral to advancing scientific understanding of the Eastern Lau Spreading Center (ELSC) magma storage and thermal system. The study area was located between 19°30'–22°S, 175°–178°30'W in the SWPO. The ELSC cruise took place from 24 January to 8 March 2009.

During the ELSC seismic survey, a full 36-airgun array with a total discharge volume of 6600 in^3 was towed at a depth of 9 m. The acoustic receiving system consisted of Ocean Bottom Seismometers (OBSs) deployed by the *Langseth*; a hydrophone streamer was not used during the survey. A 12-kHz multibeam bathymetric echosounder (MBES) and a lower energy 3.5 kHz sub-bottom profiler (SBP) were operated from the *Langseth* throughout most of the study; these two sound sources were also used for the bathymetric survey. 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

Five 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, but most often two MMOs, watched for marine mammals and sea turtles at all times while airguns operated during daylight periods, during night-time ramp ups, and whenever the vessel was underway but the airguns were not firing. The visual MMOs used 7 x 50 binoculars, 25 x 150 Big-eye binoculars, and/or the naked eye to scan the surface of the water around the vessel for marine mammals and sea turtles. Reticle markings on the binoculars were used to estimate the distance from the observer to a sighting. If a marine mammal or turtle had been detected within or approaching the safety radius, the MMO was to call for a power down or shut down of the airguns. MMOs also conducted PAM during daytime and nighttime seismic operations, and during some non-seismic periods. The primary purpose of the acoustic monitoring was to aid visual observers by detecting vocalizing cetaceans. The acoustic MMO listened with headphones or speakers 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 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. Pinnipeds were not expected nor encountered in the study area.

Monitoring Results

The *Langseth* traveled a total of 10,166 km (1033 h) during the ELSC study. The distance traveled within the seismic study area (including transit from Tonga to the study area) was 6913 km (855 h). During the bathymetric survey, the vessel traveled 2847 km (154 h), and the transit to Fiji totaled 406 km (24 h) (Table ES.1). A total of 4783 km and 2130 km of seismic and non-seismic operations took place within the seismic survey area, respectively (Table ES.1). In total, 520 h of visual observations took place during the ELSC study (Table ES.1). Nearly all (~99%) visual effort within the study area occurred during daylight periods. MMOs were on visual watch during all daylight seismic operations, including ramp ups. MMOs were also on watch for 1.1 h during periods of darkness (Table ES.1). In addition, 533 h of PAM occurred during seismic periods, and 6 h occurred during non-seismic periods, but no acoustic detections of marine mammals were made (Table ES.1).

Within the seismic survey area, “useable” survey conditions represented ~85% of the total visual effort in km (Table ES.1). “Useable” effort excluded periods 90 s to 6 h after airguns were turned off (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. For L-DEO surveys, analyses of marine mammal and sea turtle data typically focus on “useable” sightings and survey effort in the seismic survey area.

During the ELSC survey, no sightings of cetaceans or sea turtles were made within the seismic study area. During the bathymetric survey, two sightings of single, unidentified sea turtles were made (Table ES.1); one turtle was likely a green turtle. A single group of 10 short-finned pilot whales was seen during the ELSC survey; the sighting was made during the transit to Fiji (Table ES.1). Since no sightings were made during seismic operations, no power downs or shut downs for cetaceans or sea turtles were required during the ELSC study (Table ES.1).

TABLE ES.1. Summary of *Langseth* operations, visual and passive acoustic monitoring (PAM) effort, and marine mammal sightings during the ELSC survey, 24 January to 8 March 2009.

	Seismic Survey Area									
	Non-seismic				Seismic					
		Post-Seismic[b]								
	Useable[a]	Recently Exposed	Potentially Exposed	Other Non-Useable	Useable[a]	Non-Useable	Total Useable[a]	Bathymetric Study Area[c]	Transit to Fiji	Overall Total
Operations effort in h										
Langseth Darkness	-	3.9	2.1	103.3	-	260.8	-	66.3	10.0	446.3
Langseth Daylight	43.2	2.1	9.9	108.7	299.0	22.2	342.2	87.8	14.4	587.2
***Langseth* Total**	**43.2**	**6.0**	**12.0**	**211.9**	**299.0**	**283.0**	**342.2**	**154.1**	**24.4**	**1033.5**
Observer Darkness	-	0	0	0	-	1.1	-	0	0	1.1
Observer Daylight	43.2	2.0	6.6	59.5	299.0	22.2	342.3	76.1	9.8	518.4
Observer Total	**43.2**	**2.0**	**6.6**	**59.5**	**299.0**	**23.3**	**342.3**	**76.1**	**9.8**	**519.5**
PAM Total[c]		**6.1**			**533.1**			**0**	**0**	**539.2**
Operations effort in km										
Langseth Darkness	-	26.6	7.5	776.7	-	2145.2	-	1224.3	176.5	4356.8
Langseth Daylight	546.3	12.4	67.0	693.4	2463.5	174.8	3009.8	1622.6	229.2	5809.2
***Langseth* Total**	**546.3**	**39.0**	**74.5**	**1470.2**	**2463.5**	**2320.0**	**3009.8**	**2846.9**	**405.7**	**10165.9**
Observer Darkness	-	0	0	0	-	6.6	-	0	0	6.6
Observer Daylight	546.3	12.0	49.0	298.1	2463.5	174.8	3009.8	1407.4	181.3	5132.3
Observer Total	**546.3**	**12.0**	**49.0**	**298.1**	**2463.5**	**181.4**	**3009.8**	**1407.4**	**181.3**	**5139.0**
No. Cetacean Sightings (Individuals)	0	0	0	0	0	0	0	0	1 (10)	1 (10)
No. Cetacean Acoustic Detections		0			0			0	0	0
No. Turtle Sightings (Individuals)	0	0	0	0	0	0	0	2 (2)	0	2 (2)
No. Power/Shut Downs for Cetaceans & Turtles										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."
[c]Effort during useable and non-useable non-seismic periods.
[c]Effort during all non-seismic categories was combined, as was effort during all seismic activity.

Number of Marine Mammals Present and Potentially Affected

During the ELSC study, the "safety radii" for cetaceans and sea turtles were the best estimates of the 180-dB re 1 μPa_{rms} radius for the 36-airgun array. The airguns did not need to be powered down or shut down for the single cetacean sighting or the two sea turtles encountered during the survey (Table ES.1).

Any large cetaceans that might have been exposed to received sound levels ≥160 dB re 1 μPa_{rms}, and delphinids exposed to received levels ≥170 dB re 1 μPa_{rms}, were assumed to have been potentially disturbed during the seismic survey. However, no cetaceans were seen during seismic or non-seismic periods of the ELSC survey. Thus, it seems unlikely that any cetaceans were exposed to received levels ≥160 dB re 1 μPa_{rms}.

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. However, it cannot be assumed that cetaceans were not encountered during seismic periods of the survey because of avoidance, as cetaceans were not seen during seismic or non-seismic periods. If some marine mammals and sea turtles did go undetected and were exposed to seismic sounds, any effects were likely localized and transient, without significant impact on either individuals or their populations.

1. INTRODUCTION

Lamont-Doherty Earth Observatory (L-DEO) conducted a marine seismic program in the Southwest Pacific Ocean (SWPO), between Fiji and Tonga, from 24 January to 8 March 2009. The survey took place in the Lau Basin as part of the Lau Integrated Studies Site (Lau ISS) initiative of the National Science Foundation's (NSF) RIDGE 2000 program. The project was conducted aboard the R/V *Marcus G. Langseth*, which is owned by NSF and operated by L-DEO. The goal of the study was to obtain data integral to advancing scientific understanding of the Eastern Lau Spreading Center (ELSC) magma storage and thermal system. The ELSC survey used a 36-airgun array as an energy source, with a discharge volume of 6600 in^3. The geophysical investigation was under the direction Dr. Doug Wiens (Washington University), Dr. Robert Dunn (University of Hawaii), Dr. Donna Blackman (Scripps Institution of Oceanography), and Dr. Spahr Webb (L-DEO). Dr. Dunn was the Chief Scientist aboard the *Langseth* during the study.

Marine seismic surveys emit strong sounds into the water (Greene and Richardson 1988; Tolstoy et al. 2004a,b; 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; 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 waters of the SWPO, including several that are listed as endangered under the ESA, including the sperm, humpback, sei, fin, and blue whales. Other listed species known to inhabit the SWPO include the endangered leatherback and hawksbill turtles, and the threatened green, olive ridley, and loggerhead turtles.

On 18 August 2008, L-DEO requested that the National Marine Fisheries Service (NMFS) issue an Incidental Harassment Authorization (IHA) to authorize non-lethal "takes" of marine mammals incidental to the airgun operations in the SWPO (LGL Ltd. 2008a). The IHA was requested pursuant to Section 101(a)(5)(D) of the MMPA. An Environmental Assessment (EA) was also prepared to evaluate the potential impacts of the ELSC survey (LGL Ltd. 2008b). That EA was adopted by NSF, the federal agency sponsoring this seismic study. The IHA was issued by NMFS on 13 January (Appendix A).

The IHA authorized "potential take by harassment" of marine mammals during the seismic program described in this report. The *Langseth* departed from Nuku'alofa, Tonga, on 24 January 2009, for a 6-hr transit to the Lau Basin study area. After the program was completed, the vessel transited to Suva, Fiji, for arrival on 8 March 2009.

This document serves to meet reporting requirements specified in the IHA. The primary purposes of this report are to describe the seismic program in the SWPO, 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 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), and general vessel operations. No serious injuries or deaths of marine mammals (or sea turtles) were anticipated from the seismic (or bathymetric) survey, given the nature of the operations and the mitigation measures that were implemented, and no injuries or deaths were attributed to the seismic (or bathymetric) operations insofar as this could be determined. Nonetheless, the seismic survey operations described in Chapter 2 had the potential to "take" marine mammals by harassment. Behavioral disturbance to marine mammals is considered to be "take by harassment" under the provisions of the 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 current 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) distance 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). Dolphins, Dall's 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. 2008a,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 any substantial manner.

A notice regarding the proposed issuance of an IHA for the seismic study in the SWPO was published by NMFS in the *Federal Register* on 25 November 2008, and public comments were invited (NMFS 2008). The Marine Mammal Commission (MMC), the Center for Regulatory Effectiveness (CRE), and the South Pacific Whale Research Consortium (SPWRC) submitted comments.

On 13 January 2009, L-DEO received the IHA that had been requested for the seismic study, and on 9 February 2009, NMFS published a second notice in the *Federal Register* to announce the issuance of the IHA (NMFS 2009). The second notice responded to the received comments and provided additional

[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.

information concerning the IHA and any changes from the originally proposed IHA. A copy of the issued IHA is 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 and EA (LGL Ltd. 2008a,b) 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 2008, 2009).

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 airguns was to be delayed or ramp up discontinued until the safety radius was 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 ELSC survey that took place in the SWPO from 24 January to 8 March 2009, including the associated monitoring and mitigation program, and to present results as required by the IHA (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 "taken" by harassment.

Those chapters are followed by Acknowledgements and Literature Cited sections.

In addition, there are six 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 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. a passive acoustic monitoring report for the ELSC cruise.

2. SEISMIC PROGRAM DESCRIBED

The ELSC study took place in the Lau Basin of the SWPO (Fig. 2.1). The study consisted of three phases: the seismic survey in the EEZ of Tonga, a bathymetric survey (using the MBES and SBP only) between Tonga and Fiji, and the transit to Fiji. 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 Ocean Bottom Seismometers (OBSs) were used to record the returning acoustic signals. The bathymetric survey used a 12-kHz MBES and a lower energy 3.5 kHz SBP to map the bathymetry and sub-bottom conditions. These two acoustical systems were also operated during the seismic survey. At times (and during all seismic operations), the *Langseth* towed a hydrophone array to detect calling cetaceans by PAM methods (see Chapter 3).

The following sections briefly describe the 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 encompassed the area 19°30' to 22°S and 175° to 178°30'W. The seismic survey took place in the EEZ of Tonga, between 175°30'–176°32'W, in water depths >1000 m. The bathymetric survey was located in the EEZs of Fiji and Tonga in water depths >620 m between 173°32'–178°20'W, and the transit occurred in the area west of 178°20'W (Fig. 2.1). The ship departed Nuku'alofa, Tonga, on 24 January 2009, for the 6-hr transit to the study area (Table 2.1). After ~3 days of OBS deployment, seismic operations commenced on 27 January, but were discontinued after ~8.5 hrs due to poor weather (Table 2.1). Seismic operations recommenced the morning of 29 January. Seismic operations are shown as gray-shaded lines ("Ship Track Exposed") in Figure 2.1. On 10 February, seismic operations stopped again, and OBSs were retrieved and redeployed. The airgun array was ramped up again on 13 February, and seismic operations continued until 25 February. The vessel retrieved all of the OBS, and the bathymetric portion of the study took place from 1-6 March. The vessel commenced the transit to Suva, Fiji, on 7 March and arrived 8 March. Airgun operations occurred during the day and at night. A summary of the total distances traveled by the *Langseth* during the ELSC study, 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.

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 ELSC survey. The array consisted of 36 Bolt 1500LL and Bolt 1900LLX airguns with volumes ranging from 40 to 360 in^3. 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.

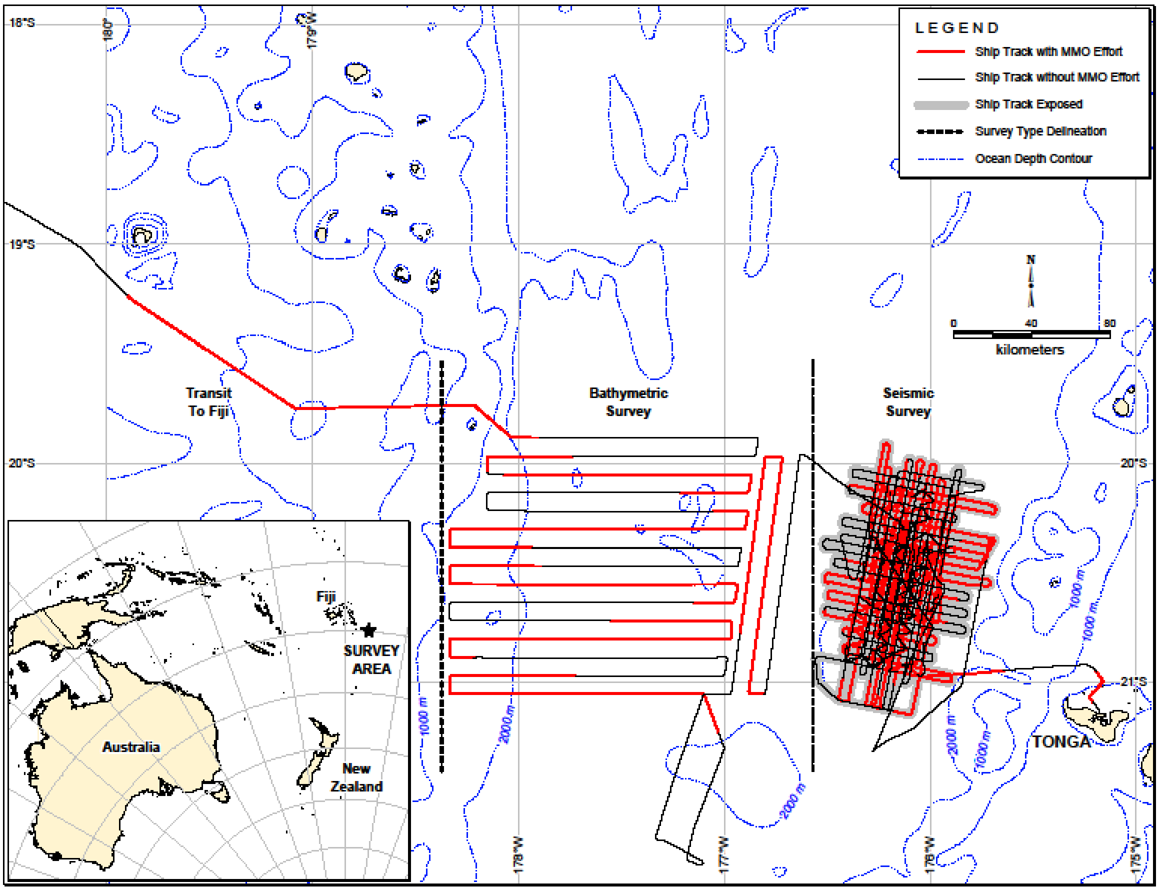

FIGURE 2.1. Map of the study area showing ship tracks with and without observer effort, the bathymetric and seismic survey areas, plus acquired seismic lines ("Ship Track Exposed") during the ELSC survey, 24 January to 8 March 2009.

The airguns were configured as four identical linear arrays or "strings" (Fig. 2.2). Each string had ten 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 ~150 m behind the vessel. The airguns were suspended in the water from air-filled floats (see Appendix C). The airguns were towed at a depth of 9 m for the ELSC survey and at an average speed of ~4.4 kt. The shot spacing was ~440 m (190 s).

The nominal source level for downward propagation of low-frequency energy from the 36-airgun array is shown in Table 2.2. 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 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 sound from the airgun array. The source level 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 2.2, but source levels of airguns are not normally determined on an rms basis by airgun manufacturers or geophysicists.

TABLE 2.1. Timeline for the ELSC study in the SWPO, 24 January to 8 March 2009.

Date (local) 2009	Time (local)	Activity
24 January	08:00	Left Nuku'alofa, Tonga, for study area
24 January	08:52	Commenced marine mammal observations
24 January	14:55	Arrived in study area; deployed first OBS
27 January	~12:00	Finished deploying OBSs
27 January	17:31	Seismic operations and PAM commenced
28 January	01:54	Seismic operation, marine mammal observations, and PAM suspended due to poor weather
29 January	08:05	Marine mammal observations resumed
29 January	08:53	Seismic operations and PAM resumed
10 February	10:53	Seismic operations and PAM ceased
10 February	12:15	OBS recovery and redeployment commenced
13 February	08:34	Seismic operations and PAM resumed
25 February	04:05	Seismic operations and PAM completed; OBS recovery began
1 March	~07:05	Bathymetric survey commenced using MBES and SBP
7 March	~06:00	Bathymetric survey ended; transit to Suva
7 March	18:36	End of marine mammal observations
8 March	~08:00	Arrived in Suva

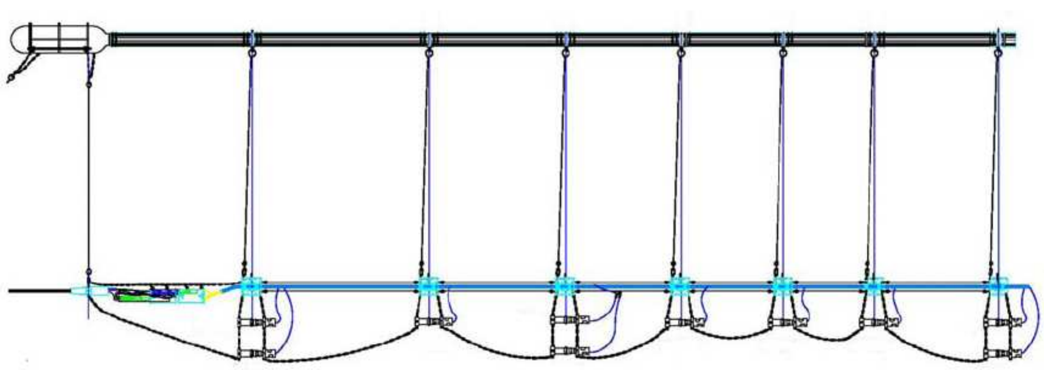

FIGURE 2.2. One of the four linear airgun arrays or strings with ten airguns. Nine airguns per string were active during seismic operations.

TABLE 2.2. Specification of the 36-airgun array used during L-DEO's ELSC survey, 24 January to 8 March 2009.

Energy source	Thirty-six 2000 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.

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 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 study. 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 MBES and SBP were also used during the bathymetric study. The echosounders are described in Appendix C.

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 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 program were to ensure that the provisions of the IHA 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 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 current 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} 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 (dolphins, Dall's porpoise, 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. The radii depend on water depth (see Tolstoy et al. 2004a,b) as well as tow depth of the airgun array; a tow depth of ~9 m in deep water was assumed when estimating the safety radii during the ELSC study. The 9-m tow depth was actually used during the survey, and the water depth in the study area was >1000 m. 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. Distances are estimated for the 36-airgun array and for a single airgun, as used during the ELSC seismic survey. Predicted radii were based on L-DEO's model (see Appendix B).[a]

Source and Volume	Tow Depth (m)	Predicted RMS Radii (m)			
		190 dB	180 dB	170 dB	160 dB
Single Bolt airgun 40 in^3	9	12	40	120	385
36 airguns 6600 in^3	9	300	950	2900	6000

[a] Empirical data for the specific airgun configurations operated from the *Langseth* were acquired recently in the Gulf of Mexico (see Holst and Beland 2008 for project description), but the acoustic measurements are not yet available.

Mitigation Measures as Implemented

Ramp up was the primary mitigation measure implemented during the present seismic survey; power downs and shut downs of the airguns were not necessary as no sightings were made during seismic periods. Ramp ups, power downs, and shut downs are the three standard mitigation procedures employed during L-DEO seismic cruises and are described in detail in Appendix D. Mitigation also included those measures specifically identified in the IHA (Appendix A).

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 seismic study were based on acoustic modeling specific to the *Langseth*'s airgun configurations (see Appendix B),
3. Power-down or shut-down procedures were to be implemented when a marine mammal or 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, power downs or shut downs were deemed to be the preferred and most practical mitigation measures.
5. Ramp-up procedures were implemented whenever the 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 or turtles 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.

7. PAM was conducted during all seismic operations.

In addition, the IHA specified that concentrations of beaked, humpback, blue, sei, fin, and sperm whales should be avoided by moving the survey elsewhere if groups of these whales were encountered. No concentrations of marine mammals were seen during the ELSC study.

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 marine mammals and sea turtles to airgun sounds with received levels >180 dB re 1 μPa_{rms}. ***(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 very 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), and Hauser and Holst (2009). The standard visual observation methods are described in Appendix D.

In summary, during the present seismic study, at least one but at most times (89% of visual observations) two or more MMOs maintained a visual watch for marine mammals during all daylight hours from dawn to dusk. Visual observations were most often conducted from the *Langseth*'s observation tower; during poor weather conditions, observations took place from the bridge. 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 made up <1% of observation effort within the study area. 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 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 monitoring 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* often detects 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 previous L-DEO seismic cruises.

The Right Waves 4-channel hydrophone array was used during the ELSC study (see Appendices D & G for a description of this system). Acoustic monitoring software developed by CIBRA (University of Pavia, Italy) can be used to 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 1–4 h.

During PAM as implemented from the *Langseth*, when a cetacean call is heard, the visual observer (if on duty) is immediately notified of the presence of calling marine mammals. Each acoustic "encounter" is 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; Holst and Smultea 2008; Hauser et al. 2008; Hauser and Holst 2009). These categories are defined briefly below, with more details in Appendix D.

In general, data were categorized as "seismic" or "non-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" category was not included in either the "seismic" or "non-seismic" categories, but the "potentially exposed" category was included under "non-seismic" for sea turtles. 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 cruises that used moderate-sized or large (10–36 airgun) arrays (e.g., Smultea et al. 2004, 2005; Holst et al. 2005b; Holst and Beland 2008; Holst and Smultea 2008; Hauser et al. 2008; Hauser and Holst 2009). A shorter (i.e., 2-h) post-seismic cut off was used during other recent 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 marine mammals 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.

Line Transect Estimation of Densities

For L-DEO surveys, sightings during the "seismic" and "non-seismic" periods are used to calculate sighting rates (#/1000 km). Sighting rates are then used to calculate the corresponding densities (#/km^2) of marine mammals near the survey ship during seismic and non-seismic periods. Density calculations are 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 are included in density calculations. Effort and sightings are 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 include 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 outside of the study area (i.e., during transit) and outside of the truncation distance (used for density calculations) are considered non-useable. Although “non-useable” sightings (and associated survey effort) are not considered when calculating densities of marine mammals, such sightings are 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 of the low number of sightings of any individual species during the present study, and the inability to assess trackline sighting probability, during a study of this type. Densities that allow for these factors are listed here as “corrected” densities.

Densities during non-seismic periods are used to estimate the numbers of animals that presumably would have been present in the absence of seismic activities. Densities during seismic periods are generally 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. As no marine mammal sightings were made during the ELSC study, densities for seismic and non-seismic periods were zero. Further details on the line transect methodology 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 is applied (Table 3.1).

Two approaches are applied to estimate the numbers of marine mammals that may have been exposed to sound levels ≥160 dB re 1 μPa_{rms}:

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”) is obtained by multiplying the area assumed to be ensonified to ≥160 dB and “corrected” densities of marine mammals estimated by line transect methods. The second approach (“individuals”) involves multiplying the 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 this method, areas ensonified to ≥160 dB on more than one occasion, e.g., when seismic lines crossed or were repeated, are counted only once.

The two approaches can be interpreted as providing minimum and maximum estimates of the number of marine mammals exposed to sound levels ≥160 dB re 1 μPa_{rms}. The actual number exposed 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), and has recently 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; Holst and Smultea 2008; Hauser et al. 2008; Hauser and Holst 2009). The methodology is described in detail in these past reports and in Appendix D. Densities of marine mammals during the current ELSC survey were zero; thus, it is assumed that no marine mammals were potentially affected.

4. MONITORING RESULTS

Introduction

There have been limited surveys for marine mammals in Lau Basin. What information exists is summarized by Reeves et al. (1999) for the area served by the South Pacific Regional Environment Programme (SPREP). The SPREP region covers a vast area of the Pacific Ocean between the Tropic of Capricorn and the Equator from Papua New Guinea (140°E) to Pitcairn Island (130°W).

Thirty species of cetacean, including 21 odontocete (dolphins and small- and large-toothed whales) species and nine mysticete (baleen whales) species may occur in the ELSC study area in the SWPO. Several of those species are listed under the ESA as endangered: the sperm, humpback, fin, sei, and blue whales. In addition to those five species, the southern bottlenose, pygmy right, Antarctic minke, minke, and Bryde's whales are listed in Appendix I (i.e., threatened with extinction) of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Additional information on the occurrence, distribution, population size, and conservation status for the 30 marine mammal species that may occur in the ELSC study area is presented in Appendix E.

In addition, six species of sea turtle occur within the SPREP region: the leatherback (*Dermochelys coriacea*), green (*Chelonia mydas*), loggerhead (*Caretta caretta*), hawksbill (*Eretmochelys imbricata*), olive ridley (*Lepidochelys olivacea*), and flat back turtles (*Natator depressus*) (SPREP 2007). However, only five of these species may occur in the study area; the flat back turtle occurs only in Australia and Papua New Guinea, although unconfirmed sighting data exist for Vanuatu (SPREP 2007). The hawksbill and green turtles are the most widespread species in the SPREP region, and also nest in most countries and territories of this region (SPREP 2007).

Visual Monitoring Effort and Sightings

This section summarizes the visual monitoring effort and sightings from the *Langseth* during the ELSC survey, 24 January to 8 March 2009. Summaries of the monitoring results are presented here, including visual survey effort subdivided by seismic activity and Beaufort wind force. A general summary of effort and sightings is shown in Table ES.1.

Visual Survey Effort

The *Langseth* traveled a total of ~10,166 km (1033 h) during the ELSC study (Table ES.1). The distance traveled within the seismic study area (including transit from Tonga to the study area) was 6913 km (855 h). During the bathymetric survey, the vessel traveled 2847 km (154 h), and the transit to Fiji totaled 406 km (24 h) (Table ES.1). A total of 4783 km and 2130 km of seismic and non-seismic operations took place within the seismic survey area, respectively (Table ES.1).

Visual observations were obtained for ~5139 km (520 h) during the ELSC study. A total of 3550 km (434 h) of observations occurred within the seismic survey area, 1407 km (76 h) during the bathymetric survey, and 181 km (10 h) during the transit to Fiji (Table ES.1). Observers were on watch during all daytime airgun operations and during most daytime periods when the vessel was underway but not firing the airguns. A total of ~6.6 km (1.1 h) of visual observation effort occurred during nighttime seismic operations. The number of hours of observation per day varied according to the schedule of operations.

Most (74%) of the visual effort (322 of 434 h) within the seismic survey area took place during seismic operations (Fig. 4.1). Survey conditions were considered "useable" during ~85% of total visual effort in the seismic survey area (Table ES.1). During the seismic survey, 2070 km of a total of 2464 "useable" seismic km were surveyed with the 36-airgun array (Table 4.1). The remaining "useable"

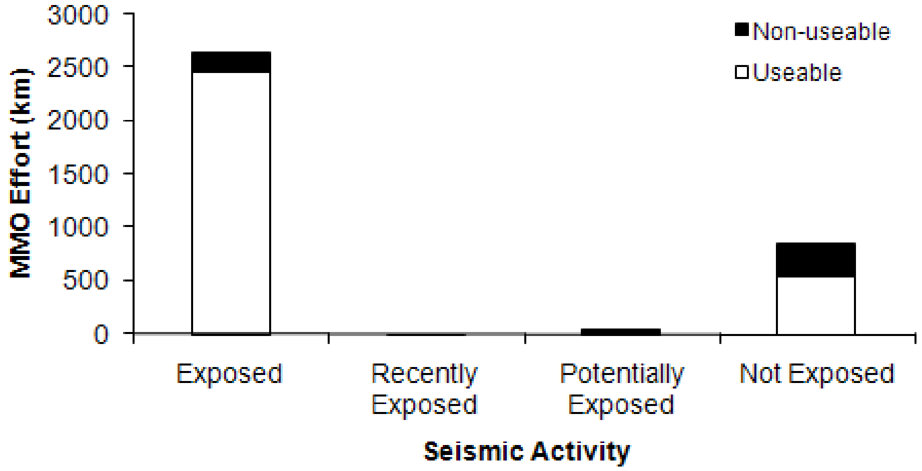

FIGURE 4.1. Total observer effort, categorized by seismic activity, in the seismic survey area during the ELSC study, 24 January to 8 March 2009. Recently Exposed includes periods 90 s to 2 h after airguns were turned off. Potentially Exposed includes periods 2–6 h after airguns were turned off.

operations (394 km) occurred during ramp up, power down, or seismic testing with fewer airguns. "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 for most marine mammal species and Bf >2 for cryptic species, 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". Beaufort wind force during observations aboard the *Langseth* ranged from zero to six (Fig. 4.2; Table 4.1).

Sightings of Marine Mammals and Sea Turtles

No sightings of marine mammals or sea turtles were made within the seismic survey area. However, two individual unidentified turtles (one probable green turtle) were seen during the bathymetric survey, and one group of 10 short-finned pilot whales was seen during the transit to Fiji (Fig. 4.3).

The probable green turtle was sighted on 3 March 2009, 13:33 local time, at 177.186ºW and 20.901ºS. It was seen in water 2158 m deep during Beaufort wind force 5. The turtle was spotted 5 m ahead of the bow, dove, and was seen swimming away from the vessel. An unidentified turtle was seen 6 March, 8:50 local time, at 176.928ºW and 20.050ºS. The turtle sighting occurred in water 2737 m deep, during a Beaufort wind force of 3. The turtle was seen 30 m from the bow and was swimming parallel to the vessel.

The group of 10 short-finned pilot whales was first seen 6 March, 10:03 local time, at 178.558ºW and 19.740ºS. The water depth at the time of the sighting was ~970 m, and the Beaufort wind force was 2. The group was first seen 727 m ahead of the bow. The animals appeared to be swimming towards the vessel, as the *Langseth* approached the group. The animals dove just ahead of the bow. Several minutes later, the group of pilot whales was spotted ~700 m behind the vessel. Several fishing vessels were seen during the ELSC study. However, none were seen during the cetacean or turtle sightings.

TABLE 4.1. All and useable[a] (shown in parentheses) visual observation effort from the *Langseth* during the ELSC study, 24 January to 8 March 2009, in **(A)** kilometers and **(B)** hours, subdivided by Beaufort wind force (Bf) and airgun status.

	Beaufort Wind Force							
Airgun Status	0	1	2	3	4	5	6*	Total
(A) Effort in km								
Seismic Survey								
Total Airguns On (Seismic)	**21.6 (21.6)**	**178.1 (173.1)**	**695.7 (658.1)**	**771.7 (742.5)**	**519.4 (508.1)**	**435.2 (360.1)**	**23.0 (0)**	**2644.7 (2463.5)**
Ramp up	0	0	0	14.4 (12.4)	0	1.0 (1.0)	15.5 (0)	**30.9 (13.4)**
1-90 s after shut down	0	0	0.3 (0.3)	0	0	0	0	**0.3 (0.3)**
9 airguns	0	0	0	0	17.2 (17.2)	0	0	**17.2 (17.2)**
16-18 airguns	7.6 (7.6)	0	25.2 (25.2)	9.2 (9.2)	12.0 (12.0)	0	7.5 (0)	**61.5 (54.1)**
20-27 airguns	0	0	31.8 (31.8)	23.5 (23.5)	35.8 (35.8)	32.9 (14.6)	0	**123.9 (105.7)**
30-35 airguns	0	16.0 (16.0)	151.7 (144.6)	29.9 (29.9)	12.3 (12.3)	0	0	**209.9 (202.7)**
36 airguns	14.0 (14.0)	162.1 (157.1)	486.7 (456.2)	694.8 (667.5)	442.1 (430.8)	401.3 (344.5)	0	**2201 (2070.1)**
Total Airguns Off	**0**	**0**	**112.2 (76.5)**	**336.3 (170.9)**	**262.9 (176.3)**	**138.4 (122.6)**	**55.5 (0)**	**905.3 (546.3)**
Non-seismic[b]	0	0	107.9 (76.5)	299.2 (170.9)	243.4 (176.3)	138.4 (122.6)	55.5 (0)	**844.4 (546.3)**
Recently-exposed[c]	0	0	4.3 (0)	7.6 (0)	0	0	0	**11.9 (0)**
Potentially exposed[d]	0	0	0	29.5 (0)	19.5 (0)	0	0	**49.0 (0)**
Total Effort (Airguns On&Off)	**21.6 (21.6)**	**178.1 (173.1)**	**807.9 (734.6)**	**1108.0 (913.3)**	**782.3 (684.4)**	**573.6 (482.7)**	**78.5 (0)**	**3550.0 (3009.8)**
Bathymetric Survey[e]	**0**	**0**	**61.5 (61.5)**	**405.6 (390.2)**	**429.1 (398.1)**	**511.2 (477.6)**	**0**	**1407.4 (1327.4)**
Transit[e]	**122.1 (122.1)**	**59.2 (59.2)**	**0**	**0**	**0**	**0**	**0**	**181.3 (181.3)**
(B) Effort in hr								
Seismic Survey								
Total Airguns On (Seismic)	**3.0 (3.0)**	**21.5 (20.9)**	**83.8 (79.3)**	**93.7 (90.2)**	**62.8 (61.4)**	**54.8 (44.4)**	**2.7 (0)**	**322.2 (299.0)**
Ramp up	0	0	0	2.1 (1.9)	0	0.2 (0.2)	2.7 (0)	5.0 (2.1)
1-90 s after shut down	0	0	0	0	0	0	0	0
9 airguns	0	0	0	0	2.2 (2.2)	0	0	2.2 (2.2)
16-18 airguns	1.2 (1.2)	0	3.0 (3.0)	1.4 (1.4)	1.5 (1.5)	1.2 (0)	0	8.3 (7.1)
20-27 airguns	0	0	3.8 (3.8)	3.1 (3.1)	4.4 (4.4)	4.6 (2.3)	0	15.9 (13.7)
30-35 airguns	0	1.9 (1.9)	18.3 (17.4)	3.6 (3.6)	1.7 (1.7)	0	0	25.5 (24.6)
36 airguns	1.7 (1.7)	19.6 (19.0)	58.7 (55.0)	83.5 (80.2)	53 (51.6)	48.8 (41.8)	0	265.3 (249.3)
Total Airguns Off	**0**	**0**	**11.7 (6.8)**	**47.6 (13.7)**	**30.9 (14.4)**	**14.2 (8.3)**	**6.8 (0)**	**111.3 (43.2)**
Non-seismic[b]	0	0	11.1 (6.8)	42.3 (13.7)	28.3 (14.4)	14.2 (8.3)	6.8 (0)	102.7 (43.2)
Recently-exposed[c]	0	0	0.6 (0)	1.4 (0)	0	0	0	2.0 (0)
Potentially exposed[d]	0	0	0	4.0 (0)	2.6 (0)	0	0	6.6 (0)
Total Effort (Airguns On&Off)	**3.0 (3.0)**	**21.5 (20.9)**	**95.6 (86.1)**	**141.3 (103.9)**	**93.7 (75.8)**	**67.9 (52.6)**	**10.7 (0)**	**433.6 (342.3)**
Bathymetric Survey[e]	**0**	**0**	**3.3 (3.3)**	**22.0 (21.1)**	**23.2 (21.5)**	**27.6 (25.8)**	**0.0**	**76.1 (71.7)**
Transit[e]	**0**	**6.6 (6.6)**	**3.2 (3.2)**	**0**	**0**	**0**	**0**	**9.8 (9.8)**

[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".

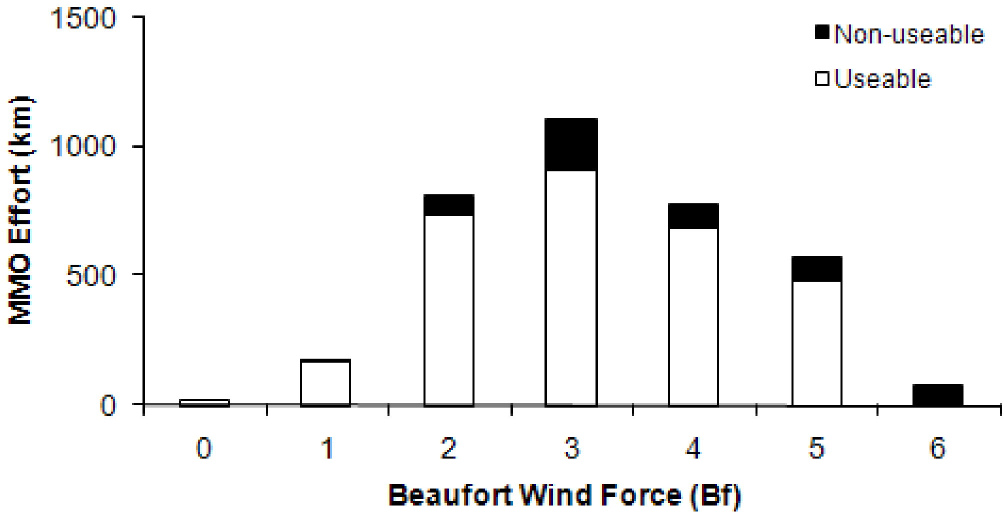

FIGURE 4.2. Total observer effort, categorized by Beaufort wind force, in the seismic survey area of the ELSC study, 24 January to 8 March 2009.

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).

The data collected during visual observations normally provide information about behavioral responses of marine mammals and sea turtles 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. During this study, there were no sightings during the seismic survey. Thus, no behavioral comparisons between seismic and non-seismic periods could by made.

Acoustic Monitoring Effort and Detections

PAM only took place during the seismic survey of the ELSC study. During the bathymetric survey and transit, the vessel traveled too fast for PAM deployment. Within the seismic survey area, PAM took place during all seismic operations. In total, 533 h of PAM occurred during seismic periods, and 6 h occurred during non-seismic periods (Table ES.1). No acoustic detections of marine mammals were made during the survey. A more detailed PAM summary is presented in Appendix F.

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

The only mitigation measure employed during the ELSC survey was the ramp-up procedure. As no marine mammals or sea turtles were seen during seismic operations, power downs and shut downs of the airgun array were not required. Ramp ups were conducted during daylight whenever the airguns were started up after a prolonged period of inactivity (7 min) or during the day or night when there was a requirement to increase the number of operating airguns by a factor exceeding 2× (e.g., from 1 to 36 airguns).

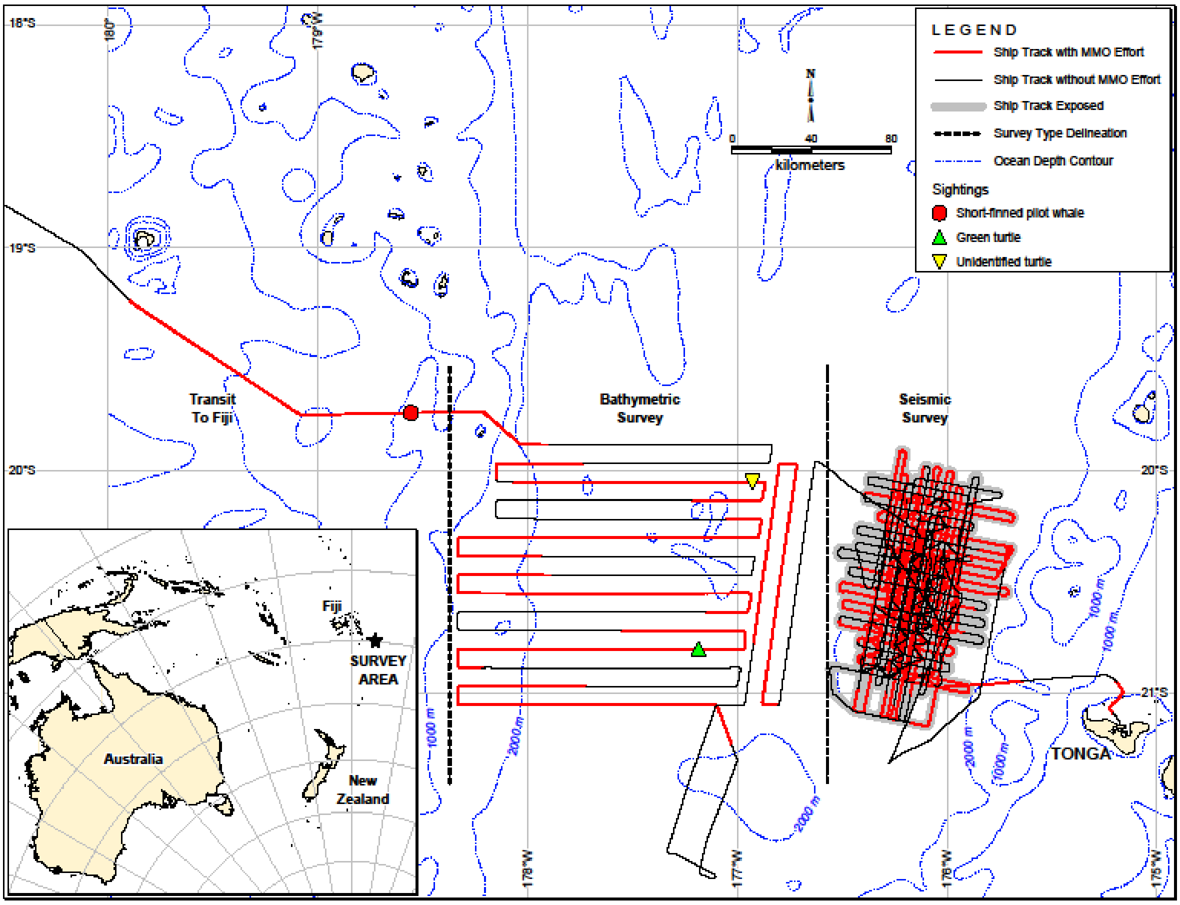

FIGURE 4.3. The ELSC survey showing the ship track, the bathymetric and seismic survey areas, seismic lines, and sightings of cetaceans and sea turtles, 24 January to 8 March 2009. Airguns operated along the shaded lines ("Ship track exposed").

In order to minimize the incidental 'taking' of ESA-listed marine mammals, L-DEO implemented the ramp-up procedure for marine mammals. Neither sperm, humpback, blue, fin, or sei whales, nor sea turtles were encountered during the ELSC seismic survey; thus, no power downs or shut downs were necessary. As no ESA-listed species were encountered during seismic operations, it is unlikely that any individuals were affected by the seismic survey.

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). ***(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).

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) is 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 appropriate 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). Probable exposure to rms received levels ≥170 dB is used as an alternative criterion in estimating potential disturbance of 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 used as an alternative criterion in 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, no sightings were made during seismic operations; thus, no power downs or shut downs were required. Thus, it is unlikely that any marine mammal was exposed to received levels ≥180 dB re 1 μPa_{rms}.

Two methods are typically used 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. The actual numbers of individual marine mammals exposed to, and potentially affected by, seismic survey sounds likely are between the minimum and maximum estimates.

Estimates from Direct Observations

No marine mammals were sighting during 3550 km (434 h) of observations in the seismic survey area (of which 905 km or 111 h were daylight surveys when airguns were not operating). Also, no marine mammals were sighted during 1407 km (76 h) of observations (with no airguns operating) in the bathymetric survey area. These results suggest that marine mammal densities in Lau Basin during the southern summer were very low. That, in turn, suggests that very few (if any) marine mammals were exposed to strong airgun sounds during the ELSC study.

However, it is possible that some animals moved away before coming within visual range of MMOs, and it is possible that MMOs were unable 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 ~6 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, a very limited amount (~1 h) of marine mammal survey effort occurred at night during the ELSC study.

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 ≥160–170 dB radii around the source (i.e., up to 6 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.

Estimates Extrapolated from Marine Mammal Density

As an alternative, we considered using previously reported marine mammal densities to estimate the number of marine mammals exposed to airgun sound levels strong enough that they might have caused disturbance or other effects. This approach could be more realistic given that some marine mammals present within the 160 dB (or 170 dB) radii around the *Langseth*'s airgun array might not have been visible to vessel-based observers, even during daylight. In addition, some animals that were originally close to the trackline may have moved away or otherwise altered their behavior to avoid the approaching vessel, and hence might not have been seen by observers on board the source vessel. However, no previous survey data were available for Lau Basin. In the absence of more appropriate data, the IHA application and EA for the ELSC cruise (LGL Ltd. 2008a,b) used data collected during surveys in the Eastern Tropical Pacific (Ferguson and Barlow 2001) to estimate the numbers of marine mammals that may potentially be affected by the ELSC seismic survey; data collected during surveys in Hawaii (ManTech-SRS Technologies 2007) were also considered but not used. As these surveys occurred in different areas from the study area, they do not appear to be representative of Lau Basin. Therefore, the systematic survey data collected during the ELSC cruise, and especially those collected when the airguns were not operating, provide a better basis for estimating numbers potentially affected. Given the lack of sightings during the present study, the best estimate of the number of marine mammals exposed to sound levels ≥160 dB re 1 µPa (or any higher level) was zero.

Summary and Discussion

The seismic program included 342 h of "useable" visual observation effort and 539 h of PAM effort. Two sea turtles were sighted during the bathymetric survey, and one sighting of 10 short-finned pilot whales was made during transit to Fiji. As no previous marine mammal survey data were available for this area, it was unknown how many cetaceans would be encountered. However, it was unexpected that only a single sighting would be made in the area. The lack of sightings could be seasonal; perhaps more animals use the area during other seasons. During September to December 1994, fin whale calls were detected via the LABATTS OBS experiment spanning the Lau Basin at roughly 18.5ºS with a few stations scattered further north (Dr. James Conder, Southern Illinois University, pers. comm., 4 March 2009). Many fin whale calls were recorded throughout that experiment, with thousands of individual calls. The calls are short duration 'chirps', usually occurring in pairs or higher multiples which continue for hours and sometimes days at a particular OBS site both in the shallower basin west of Tonga (depths <2500 m) and in the deeper ocean east of Tonga (depths >4000 m). However, no whale calls were detected via OBSs during the ELSC study (Dr. Robert Dunn, University of Hawaii, 4 March 2009). As no marine mammals were seen during seismic operations or within the seismic survey area during the ELSC study, it is unlikely that any animals were exposed to received sounds ≥180 dB re 1 μPa_{rms}.

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6. LITERATURE CITED

Bain, D.E. and R. Williams. 2006. Long-range effects of airgun noise on marine mammals: responses as a function of received sound level and distance. Working Pap. SC/58/E35. Int. Whal. Comm., Cambridge, U.K. 13 p.

Barlow, J. 1999. Trackline detection probability for long-diving whales. p. 209-221 *In:* G.W. Garner, S.C. Amstrup, J.L. Laake, B.F.J. Manly, L.L. McDonald and D.G. Robertson (eds.), Marine mammal survey and assessment methods. A.A. Balkema, Rotterdam. 287 p.

Breitzke, M., O. Boebel, S.E. Naggar, W. Jokat and B. Werner. 2008. Broad-band calibration of marine seismic sources used by R/V *Polarstern* for academic research in polar regions. **Geophys. J. Intern.** 174(2):505-524.

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers and L. Thomas. 2001. Introduction to distance sampling/Estimating abundance of biological populations. Oxford Univ. Press, Oxford, U.K. 432 p.

Burgess, W.C. and C.R. Greene, Jr. 1999. Physical acoustics measurements. p. 3-1 to 3-63 *In*: W.J. Richardson (ed.), Marine mammal and acoustical monitoring of Western Geophysical's open-water seismic program in the Alaskan Beaufort Sea, 1998. LGL Rep. TA2230-3. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for Western Geophysical, Houston, TX, and U.S. Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 390 p.

Caldwell, J. and W. Dragoset. 2000. A brief overview of seismic air-gun arrays. **The Leading Edge** 2000(8, Aug.): 898-902.

Ferguson, M.C. and J. Barlow. 2001. Spatial distribution and density of cetaceans in the Eastern Tropical Pacific Ocean based on summer/fall research vessel surveys in 1986-96. Admin. Rep. LJ-01-04, SWFSC, NMFS, La Jolla, CA. 61 p.

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

Greene, C.R. 1997. An autonomous acoustic recorder for shallow arctic waters. **J. Acoust. Soc. Am.** 102(5, Pt. 2):3197.

Greene, C.R., Jr. and W.J. Richardson. 1988. Characteristics of marine seismic survey sounds in the Beaufort Sea. **J. Acoust. Soc. Am.** 83(6):2246-2254.

Greene, C.R., Jr., R. Norman and J.S. Hanna. 1998. Physical acoustics measurements. p. 3-1 to 3-64 *In:* W.J. Richardson (ed.), Marine mammal and acoustical monitoring of BP Exploration (Alaska)'s open-water seismic program in the Alaskan Beaufort Sea, 1997. LGL Rep. TA2150-3. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Explor. (Alaska) Inc., Anchorage, AK, and U.S. Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 318 p.

Haley, B. and W.R. Koski. 2004. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic program in the Northwest Atlantic Ocean, July–August 2004. LGL Rep. TA2822-27. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 80 p.

Harris, R.E., G.W. Miller and W.J. Richardson. 2001. Seal responses to airgun sounds during summer seismic surveys in the Alaskan Beaufort Sea. **Mar. Mamm. Sci.** 17(4):795-812.

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

Hauser, D.D.W. and M. Holst. 2009. Marine mammal monitoring during Lamont-Doherty Earth Observatory's marine seismic program in the Gulf of Alaska, September-October 2008. LGL Rep. TA4412-3. Rep. from LGL Ltd., King City, Ont. and St. John's, Nfld, for Lamont-Doherty Earth Observatory, Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 78 p.

Holst, M. 2004. Marine mammal monitoring during Lamont-Doherty Earth Observatory's TAG seismic study in the mid-Atlantic Ocean, October-November 2003. LGL Rep. TA2822-21. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory, Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 42 p.

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

Holst, M. and M.A. Smultea. 2008. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program off Central America, February – April 2008. LGL Rep. TA4342-3. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 133 p.

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

Holst, M., M.A. Smultea, W.R. Koski and B. Haley. 2005b. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program off the Northern Yucatán Peninsula in the Southern Gulf of Mexico, January–February 2005. LGL Rep. TA2822-31. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 96 p.

Koski, W.R., D.H. Thomson and W.J. Richardson. 1998. Descriptions of Marine Mammal Populations. p. 1-182 plus Appendices *In:* Point Mugu Sea Range Marine Mammal Technical Report. Rep. from LGL Ltd., King City, Ont., for Naval Air Warfare Center, Weapons Div., Point Mugu, CA, and Southwest Div. Naval Facilities Engin. Command, San Diego, CA. 322 p.

LGL Ltd. 2008a. Request by Lamont-Doherty Earth Observatory for an Incidental Harassment Authorization to allow the incidental take of marine mammals during a marine geophysical surveys by the R/V *Marcus G. Langseth* in the Southwest Pacific Ocean, January-February 2009. LGL Rep. TA4686-2. Rep. from LGL Ltd, King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 79 p.

LGL Ltd. 2008b. Environmental assessment of a marine geophysical survey by the R/V *Marcus G. Langseth* in the Southwest Pacific Ocean, January-February 2009. LGL Rep. TA4686-1. Rep. from LGL Ltd, King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Sci. Found., Arlington, VA. 188 p.

MacLean, S.A. and B. Haley. 2004. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic study in the Støregga Slide area of the Norwegian Sea, August - September 2003. LGL Rep. TA2822-20. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory, Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 59 p.

MacLean, S.A. and W.R. Koski. 2005. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic program in the Gulf of Alaska, August–September 2004. LGL Rep. TA2822-28. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 102 p.

Manghi, M., C. Fossati, M. Priano, G. Pavan, J.F. Borsani and C. Bergamasco. 1999. Acoustic and visual methods in the odontocetes survey: a comparison in the Central Mediterranean Sea. p. 251-253 *In:* P.G.H. Evans and E.C.M. Parson (eds.), European Cetaceans 12. Proc. 12th Annu. Conf. Europ. Cetac. Soc., Monte Carlo, Monaco. European Cetac. Soc., Valencia, Spain.

ManTech-SRS Technologies. 2007. Marine mammal and sea turtle density estimates for the Pacific northwest study area. Final draft. Solana Beach, California. 43 p.

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

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

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

NMFS. 2008. Incidental takes of marine mammals during specified activities; marine seismic surveys in the Southwest Pacific Ocean, January–February, 2009/Notice of proposed incidental take authorization. **Fed. Regist.** 73(228, 25 Nov.):71606-71620.

NMFS. 2009. Incidental takes of marine mammals during specified activities; marine geophysical survey in the Southwest Pacific Ocean, January–February, 2009/Notice of issuance of an incidental take authorization. **Fed. Regist.** 74(25, 9 Feb.):6387-6395.

Reeves, R.R., S. Leatherwood, G.S. Stone, and L. G. Eldredge. 1999. Marine mammals in the area served by the South Pacific Regional Environment Programme (SPREP). SPREP, Apia, Samoa. 55 p.

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

Richardson, W.J., G.W. Miller and C.R. Greene Jr. 1999. Displacement of migrating bowhead whales by sounds from seismic surveys in shallow waters of the Beaufort Sea. **J. Acoust. Soc. Am.** 106(4, Pt. 2):2281.

Smultea, M.A. and M. Holst. 2003. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic study in the Hess Deep area of the Eastern Equatorial Tropical Pacific, July 2003. LGL Rep. TA2822-16. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory, Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 68 p.

Smultea, M.A., W.R. Koski and T.J. Norris. 2005. Marine mammal monitoring during Lamont-Doherty Earth Observatory's marine seismic study of the Blanco Fracture Zone in the Northeastern Pacific Ocean, October-November 2004. LGL Rep. TA2822-29. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 89 p.

Smultea, M.A., M. Holst, et al. 2003. Marine mammal monitoring during Lamont-Doherty Earth Observatory's acoustic calibration study in the northern Gulf of Mexico, 2003. LGL Rep. TA2822-12. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 76 p.

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

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

SPREP (Secretariat of the Pacific Regional Environment Programme). 2007. Pacific Islands Regional marine species program 2008–2012. SPREP, Apia, Samoa. 48 p.

Stone, C.J. 2003. The effects of seismic activity on marine mammals in UK waters 1998-2000. JNCC Report 323. Joint Nature Conservation Committee, Aberdeen, Scotland. 43 p.

Stone, C.J. and M.L. Tasker. 2006. The effects of seismic airguns on cetaceans in UK waters. **J. Cetac. Res. Manage.** 8(3):255-263.

Tolstoy, M., J. Diebold, S. Webb, D. Bohnenstiehl and E. Chapp. 2004a. Acoustic calibration measurements. Chapter 3 *In:* W.J. Richardson (ed.), Marine mammal and acoustic monitoring during Lamont-Doherty Earth Observatory's acoustic calibration study in the northern Gulf of Mexico, 2003. Revised ed. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD.

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

Weir, C.R. 2008. Overt responses of humpback whales (*Megaptera novaeangliae*), sperm whales (*Physeter macrocephalus*), and Atlantic spotted dolphins (*Stenella frontalis*) to seismic exploration off Angola. **Aquat. Mamm.** 34(1):71-83.

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

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

Incidental Harassment Authorization

Amended on February 9, 2009

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 (16 U.S.C. 1371(a)(5)(D)) and 50 CFR 216.107, to harass small numbers of marine mammals incidental to a marine seismic survey conducted by the R/V *Marcus G. Langseth* in the southwest Pacific Ocean, January −March, 2009:

1. This Authorization is valid from January 14 through March 15, 2009.

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

   (a) The Eastern Lau Spreading Center (ELSC) in the southwest Pacific Ocean west of the island of Tonga. The overall area for the marine geophysical survey is between 19°40'-21°30'S, 175°30'-176°50'W which is in the Exclusive Economic Zone of Tonga. Water depths in the survey area range from 1000 meters (m) (3280 feet (ft)) to 2600 m (8530 ft), and the survey will not approach land closer than 42 kilometers.

3. Species Impacted and Level of Takes

   (a) The incidental taking of marine mammals, by Level B harassment only, is limited to the species listed under condition 3(b)(i-ii) of this Authorization.

   (b) The species authorized for takings by incidental harassment are:

      (i) Mysticetes — blue whale *(Balaenoptera musculus)*, Bryde's whale *(Balenoptera edeni)*, dwarf minke whale *(Balaenoptera acutorostrata)*, fin whale *(Balaenoptera physalus)*, humpback whale *(Megaptera novaeangliae)*, minke whale *(Balaenoptera acutorostrata)*, pygmy right whale *(Caperea marginata)*, and sei whale *(Balaenoptera borealis)*.

      (ii) Odontocetes — Blainville's beaked whale *(Mesoplodon densirostris)*, Cuvier's beaked whale *(Ziphius cavirostris)*, dwarf sperm whale *(Kogia sima)*, ginkgo- toothed beaked

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

whale *(Mesoplodon ginkgodens)*, Longman's beaked whale *(Indopacetus pacificus)*, pygmy sperm whale *(Kogia breviceps)*, southern bottlenose *(Hyperoodon planifrons)*, sperm whale *(Physeter macrocephalus)*, bottlenose dolphin *(Tursiops truncates)*, short-beaked common dolphin *(Delphinus delphis)*, Fraser's dolphin *(Lagenodelphis hosei)*, Pantropical spotted dolphin *(Stenella attenuata)*, Risso's dolphin *(Grampus griseus)*, Rough-toothed dolphin *(Steno bredanensis)*, Spinner dolphin *(Stenella longirostris)*, Striped dolphin *(Stenella coeruleoalba)*, false killer whale *(Pseudorca crassidens)*, killer whale *(Orcinus orca)*, melon-headed whale *(Peponocephala electra)*, pygmy killer whale *(Feresa attenuata)*, and short-finned pilot whale *(Globicephala macrorhynchus)*.

(iii) See Table 1 for authorized take numbers.

(c) The taking by Level A harassment, serious injury, or death of any of the species listed in 3(b)(i and ii) 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.

(d) The authorization 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) 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 within 48 hours (hr) to the Director, Office of Protected Resources, 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. NMFS encourages NSF and L-DEO to coordinate with Tongan government regarding the proposed seismic activity.

7. <u>Mitigation Requirements</u>

L-DEO must suspend the seismic survey if a dead or injured marine mammal is found in the vicinity of the project area and the serious injury or mortality, and are judged to result from these activities.

L-DEO must schedule seismic operations and ocean bottom seismometer (OBS) operations in deep waters during daylight hours, whenever possible.

In addition, the holder of this Authorization must follow the conditions listed below when conducting the seismic survey:

(a) Safety Zones

(i) L-DEO will establish a 180-dB, 1,120 m (3,674 ft) radius safety zone for marine mammals before the 4-string airgun array (6,600 in^3) is in operation; and a 180-dB 40 m (131 ft) radius safety zone before a single air gun (40 in^3) is in operation, respectively. See Table 2 for distances and safety radii.

(ii) NMFS-qualified marine mammal visual observers (MMVO) will visually observe the entire extent of the safety radius (180 dB for cetaceans) for at least one hour prior to starting the airgun (day or night) to ensure that no marine mammals are seen within the safety zone before a seismic survey commences.

(iii) If the MMVO finds a marine mammal within the safety zone, L-DEO must delay the seismic survey until the marine mammal has left the area. If the MMO sees a marine mammal that surfaces, then dives below the surface, the observer shall wait 30 minutes. If the MMVO sees no marine mammals during that time, they should assume that the animal has moved beyond the safety zone.

(iv) If for any reason the MMVO cannot see the entire radius for the entire 30 minutes (i.e., rough seas, fog, darkness), or if marine mammals are near, approaching, or in the safety radius, L-DEO may not start up the airguns. 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 minutes prior, provided that no marine mammals are known to be near the safety radius.

(b) Direction, Speed, and Course Alteration:

(i) To the maximum extent possible, L-DEO will conduct inshore seismic surveys starting from upstream (inshore) and proceeding towards the sea (offshore) in order to avoid trapping marine mammals in shallow water.

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

(iii) If concentrations of beaked whales are observed (by MMVOs or passive acoustic detection) at a continental slope site just prior to or during the airgun operations, L-DEO will move those operations to another location along the slope based on recommendations by the on-duty MMVO aboard the *Langseth.*

(iv) If concentrations of blue, humpback, fin, Sei or sperm whales are observed (by MMVOs or passive acoustic detection) prior to or during the airgun operations, L-DEO will power-down/shut down and/or move the operations to another location based on recommendations by the on-duty MMVO aboard the *Langseth.*

(c) Power-down and Shut-down Procedures:

(i) Shutdown or power-down the airguns if a marine mammal is detected within, approaches, or enters the relevant safety radius (as defined in Table 2, attached).

A shutdown means all operating airguns are shut down. A power- down means shutting down one or more airguns and reducing the safety radius to the degree that the animal is outside of it.

(ii) Following a power-down, if the marine mammal approaches the smaller designated safety radius, L-DEO must completely shut down the airguns. L-DEO will not resume the airgun activity until the marine mammal has cleared the safety radius. That is: the MMVO visually observed the marine mammal exiting the safety radius or the MMVO sees no marine mammals within the radius for 15 minutes (small odontocetes) or one hour (mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, killer, and beaked whales).

(iii) Following a power-down or shut-down and subsequent animal departure, L-DEO may resume airgun operations following ramp-up procedures described below in 6(d).

(c) Ramp-up Procedures:

(i) 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 7 minutes, which means start the smallest gun in the array first and add airguns in a sequence such that the source level of the array (40 in^3) will increase in steps not exceeding approximately 6 dB per a 5-minute period.

(ii) During ramp-up, the MMVO will monitor the safety radius. If a MMVO sights a marine mammal, he/she will implement decisions about course/speed alteration, power-down, or shutdown as though the full array were operational. Therefore, initiation of ramp-up procedures from shutdown requires that the MMVO can view full safety zone as described in 6(a)(iv).

(d) Night-time and Low-light Hour Operations

(i) L-DEO may continue marine geophysical surveys into night and low-light hours if such segment of the survey is initiated when the entire relevant safety zones are visible and can be monitored.

(ii) No initiation of airgun array operation is permitted from a shut-down position at night or during low-light hours (such as in dense fog) when the full safety zone cannot be monitored by the MMOs.

(iii) If L-DEO wishes to conduct marine geophysical surveys at night or during low light hours, a small airgun with the source level of at least 180 dB re 1 microPa (rms) shall be initiated during the day-time with good visibility when no marine mammal is in the safety zone, and be kept on and monitored before ramping up for the survey.

8. Monitoring Requirements

(a) Vessel-Based Monitoring

The Holder of this Authorization is required to:

(i) Utilize at least one, and two (when practical), NMFS-qualified, vessel-based MMVOs to watch for and monitor marine mammals near the seismic source vessel during daytime airgun operations and before and during start-ups of airguns day or night. Observers will have access to reticle binoculars (7 X 50 Fujinon), big-eye binoculars (25 X 150), and night vision devices to scan the area around the vessel. MMVO shifts will last no longer than 4 hr at a time. MMVOs will also make observations during daytime periods when the seismic system is not operating for comparison of animal abundance and behavior, when feasible.

(ii) The *Langseth's* vessel crew will also assist in detecting marine mammals, when practical.

(iii) MMVOs will also conduct monitoring onboard the *Langseth* while the seismic array is being deployed or being pulled from the water.

(iv) L-DEO and the MMVOs will record the following information when a marine mammal is sighted:

1. species, group size, age/size/sex categories (if determinable), behavior when first sighted and after initial sighting, heading (if consistent), bearing and distance from seismic vessel, sighting cue, apparent reaction to the airguns or vessel (e.g., none, avoidance, approach, paralleling, etc., and including responses to ramp-up), and behavioral pace; and

2. 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

3. the data listed under 7(a)(iii)(2) 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.

(b) <u>Passive Acoustic Monitoring (PAM)</u>

(i) L-DEO will 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.

(ii) One NMFS-qualified MMVO and/or bioacoustician will monitor the PAM at all times in shifts of 1-6 hr. 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.

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

1. notify the MMVO immediately of a vocalizing marine mammal so a power-down or shutdown can be initiated, if required;

2. 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.

9. Reporting

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 after the expiration of the IHA. This report must contain and summarize the following information:

(i) Dates, times, locations, heading, speed, weather, 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 shutdowns), observed throughout all monitoring activities.

(iii) An estimate of the number (by species) of marine mammals that: (i) are known to have been exposed to the seismic activity (visual observation) at received levels greater than or equal to 160 dB re 1 microPa (rms) and/or 180 dB re 1 microPa (rms) with a discussion of any specific behaviors those individuals exhibited and (ii) may have been exposed (modeling results) to the seismic activity at received levels greater than or equal to 160 dB re 1 microPa (rms) and/or 180 dB re 1 microPa (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 (attached), and (b) mitigation measures of the IHA. 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, Headquarters, 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.

10. 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 is judged to result from these activities, L-DEO will immediately cease operating all authorized sound sources and 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 notify L-DEO that they may resume the seismic survey operations.

11. In the event that L-DEO discovers an injured, or dead marine mammal that is judged to not result 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.

12. L-DEO is required to comply with the Terms and Conditions of the. Biological Opinion's Incidental Take Statement issued to both the National Science Foundation and NMFS' Office of Protected Resources (attached).

13. A copy of this Authorization and the Incidental Take Statement must be in the possession of all contractors and marine mammal monitors operating under the authority of this Incidental Harassment Authorization.

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

JAN 1 3 2009
Date

Attachments

Attachment

Table 1. Authorized Take Numbers for Each Species in the Southwest Pacific Ocean.

Mysticetes	
Pygmy right whale	3
Humpback whale	1
Minke whale	3
Dwarf Minke whale	3
Bryde's whale	14
Sei whale	1
Fin whale	1
Blue whale	1
Odontocetes	
Sperm whale	50
Pygmy sperm whale	353
Dwarf sperm whale	353
Cuvier's beaked whale	40
Southern bottlenose whale	0
Longman's beaked whale	16
Blainville's beaked whale	40
Gingko-toothed beaked whale	16
Rough-toothed dolphin	1649
Bottlenose dolphin	330
Pantropical spotted dolphin	1649
Spinner dolphin	3298
Striped dolphin	330
Fraser's dolphin	989
Short-Beaked Common dolphin	330
Risso's dolphin	330
Melon-headed whale	152
Pygmy killer whale	30
False killer whale	91
Killer whale	61
Short-finned pilot whale	61

Table 2. Safety 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	300	950	6000
	12	340	1120	6850

Table 2. Predicted distances to which sound levels $\geq$190, 180, and 160 dB re 1 μPa might be received in deep (>1000 m; 3280 ft) water from the 36-airgun array during the seismic survey, January – **March**, 2009.

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. Additional information on L-DEO's 2003 calibration study conducted with various configurations of the *Ewing*'s airgun arrays is also provided. Further information on these topics can be found in Smultea et al. (2003) and Tolstoy (2004a,b).

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). 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 other L-DEO surveys from 2003–2005 (e.g., Smultea et al. 2004, 2005; Holst et al. 2005) and in 2008 (Holst and Beland 2008; Holst and Smultea 2008).

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.

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 depend mainly 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.

Radii within which received levels around the *Langseth's* airgun arrays were expected to diminish to various values relevant to NMFS' current criteria were determined via acoustic modeling by L-DEO. During previous L-DEO surveys in various water depths, acoustic modeling was combined with empirical measurements. Empirical data were obtained by Tolstoy et al. (2004a,b) for sounds from two 105 in^3 GI (generator injector) guns, a 20-airgun array (the largest array deployed from the *Ewing*), and various intermediate-sized airgun arrays. The empirical data were collected in the northern Gulf of Mexico from 27 May to 3 June 2003, with separate measurements in deep and shallow water (Tolstoy et al. 2004a,b).

Figure B.1 shows the predicted sound fields for the 4-string array used during L-DEO's seismic survey, and Figure B.2 shows the sound fields for a single airgun used during power downs. 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). A maximum relevant depth of 2000 m was applied when predicting safety radii.

The modeled sound fields shown below pertain primarily to deep water, and the model itself does not allow for bottom interactions. The 2003 calibration study showed that sounds from L-DEO's larger airgun sources (i.e., 6–20 airguns) operating in deep water tended to have lower received levels than estimated by the model. In other words, the model tends to overestimate actual distances at which various sound levels are received in deep water (Tolstoy et al. 2004a,b). Conversely, in shallow water, the model substantially underestimates the actual measured radii for various source configurations ranging from 2 to 20 airguns. More specifically, the primary conclusions of L-DEO's calibration study in 2003 are summarized below:

- The empirical data indicated that, for ***deep water*** (>1000 m), the L-DEO model tends to overestimate the received sound levels at a given distance (Tolstoy et al. 2004a,b). The estimated radii during airgun operations in deep water during all recent L-DEO cruises were predicted by L-DEO's model, and thus are likely to somewhat overestimate the actual radii for corresponding received sound levels.

- Empirical measurements were not conducted for ***intermediate depths*** (100–1000 m). On the expectation that results would be intermediate between those from shallow and deep water, 1.1×

to 1.5× correction factors have been applied to the estimates provided by the model for deep water situations. The 1.5× factor was applied to model estimates during L-DEO cruises in 2003, and 1.1× to 1.5× factors were applied to estimates for intermediate-depth water during all subsequent cruises.

- For ***shallow*** water (<100 m deep), the radii are based on the empirical data of Tolstoy et al. (2004a,b) for 160, 170 and 180 dB, and are extrapolated to estimate the radii for 190 dB. The safety radii were typically based on measured values in shallow water, and ranged from 3× to 15× higher than the modeled values depending on the sound level measured (Tolstoy et al. 2004b).

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.

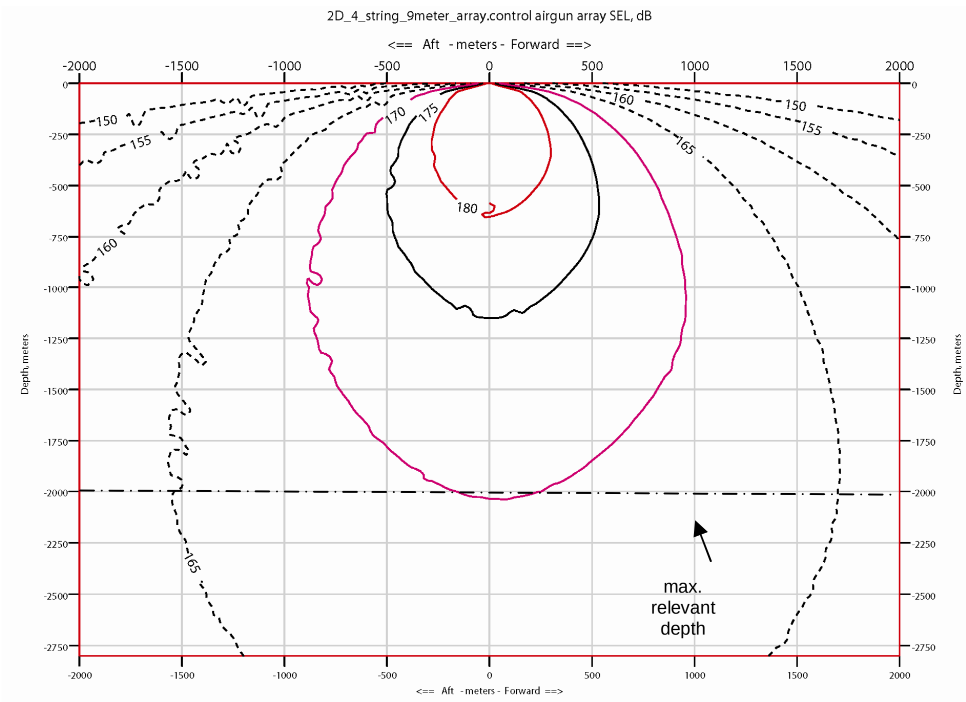

FIGURE B.1. Modeled received sound levels (SELs) from the 36-airgun array operating in deep water at a 9-m tow depth, during the ELSC survey, 24 January–8 March 2009. Received rms levels (SPLs) are expected to be ~10 dB higher. Maximum relevant depth is applicable to marine mammals.

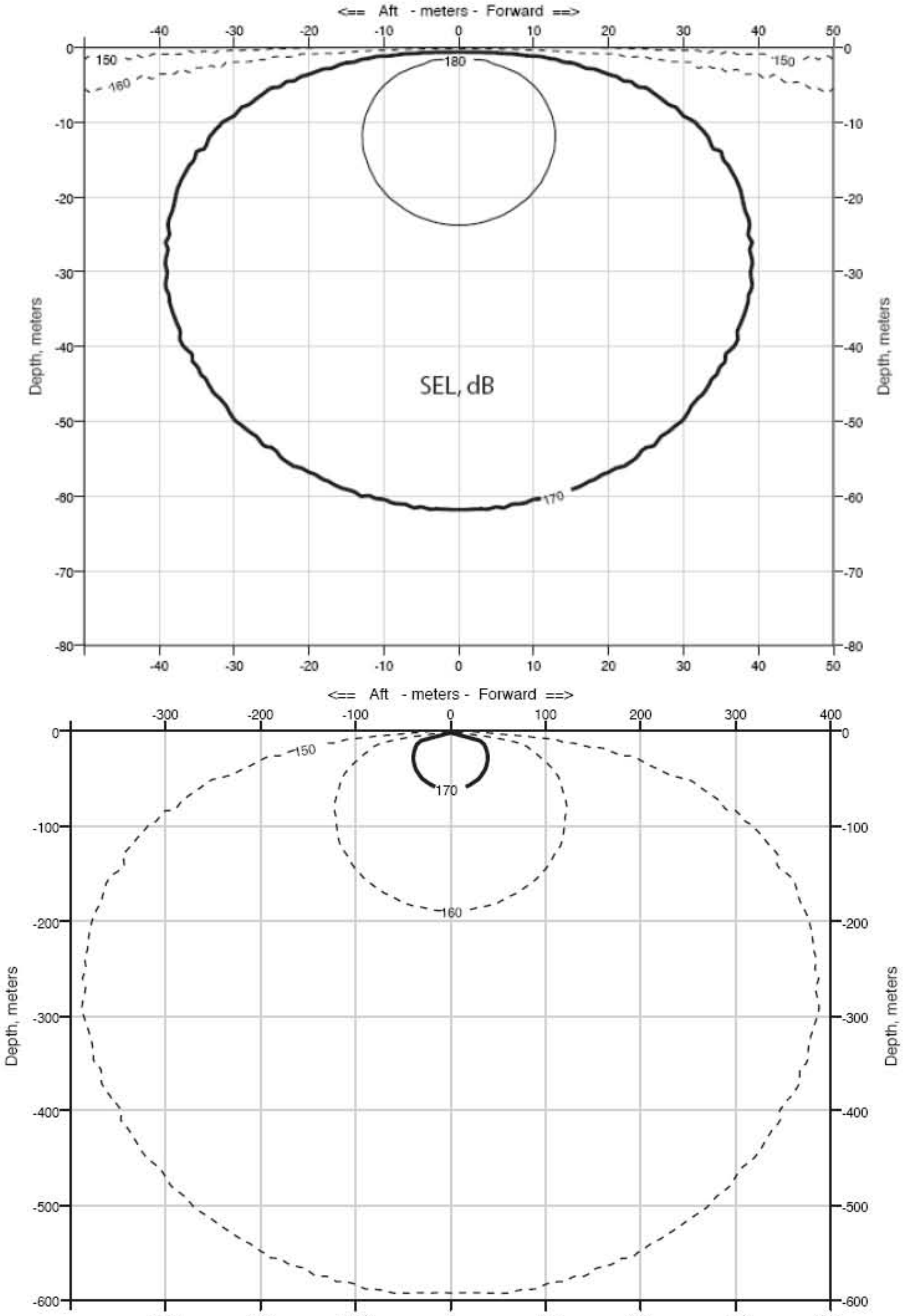

FIGURE B.2. Modeled received sound exposure levels (SELs) from a single 40 in^3 airgun, at a tow depth of ~9 m, used during power down operations during the ELSC survey, 24 January to 8 March 2009. Otherwise same as above.

References

Au, W.W.L., A.N. Popper and R.R. Fay. 2000. Hearing by Whales and Dolphins. Springer-Verlag, New York, NY. 458 p.

Blackwell, S.B., R.G. Norman, C.R. Greene Jr. and W.J. Richardson. 2007. Acoustic measurements. p. 4-1 to 4-52 *In:* Marine mammal monitoring and mitigation during open water seismic exploration by Shell Offshore Inc. in the Chukchi and Beaufort Seas, July-September 2006: 90-day report. LGL Rep. P891-1. Rep. from LGL Alaska Res. Assoc. Inc., Anchorage, AK, and Greeneridge Sciences Inc., Santa Barbara, CA, for Shell Offshore Inc., Houston, TX, Nat. Mar. Fish. Serv., Silver Spring, MD, and U.S. Fish & Wildl. Serv., Anchorage, AK. 199 p.

Finneran, J.J., C.E. Schlundt, R. Dear, D.A. Carder and S.H. Ridgway. 2002. Temporary shift in masked hearing thresholds in odontocetes after exposure to single underwater impulses from a seismic watergun. **J. Acoust. Soc. Am.** 111(6):2929-2940.

Greene, C.R., Jr., with J.S. Hanna and R.W. Blaylock. 1997. Physical acoustics measurements. p. 3-1 to 3-63 *In*: W.J. Richardson (ed.), Northstar marine mammal monitoring program, 1996: marine mammal and acoustical monitoring of a seismic program in the Alaskan Beaufort Sea. LGL Rep. TA2121-2. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Explor. (Alaska) Inc., Anchorage, AK, and Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 245 p.

Greene, C.R., Jr., R. Norman and J.S. Hanna. 1998. Physical acoustics measurements. p. 3-1 to 3-64 *In:* W.J. Richardson (ed.), Marine mammal and acoustical monitoring of BP Exploration (Alaska)'s open-water seismic program in the Alaskan Beaufort Sea, 1997. LGL Rep. TA2150-3. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Explor. (Alaska) Inc., Anchorage, AK, and U.S. Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 318 p.

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

Holst, M. and M.A. Smultea. 2008. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program off Central America, February – April 2008. LGL Rep. TA4342-3. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 133 p.

Holst, M., M.A. Smultea, W.R. Koski and B. Haley. 2005. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program off the Northern Yucatán Peninsula in the Southern Gulf of Mexico, January–February 2005. LGL Rep. TA2822-31. Rep. by LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 96 p.

Kastak, D., R.L. Schusterman, B.L. Southall and C.J. Reichmuth. 1999. Underwater temporary threshold shift induced by octave-band noise in three species of pinnipeds. **J. Acoust. Soc. Am.** 106(2):1142-1148.

Kastak, D., B.L. Southall, R.J. Schusterman and C. Reichmuth Kastak. 2005. Underwater temporary threshold shift in pinnipeds: effects of noise level and duration. **J. Acoust. Soc. Am.** 118(5):3154-3163.

Ketten, D.R., J. O'Malley, P.W.B. Moore, S. Ridgway and C. Merigo. 2001. Aging, injury, disease, and noise in marine mammal ears. **J. Acoust. Soc. Am.** 110(5, Pt. 2):2721.

MacGillivray, A.O. and D. Hannay. 2007a. Summary of noise assessment. p. 3-1 to 3-21 *In:* Marine mammal monitoring and mitigation during open water seismic exploration by ConocoPhillips Alaska, Inc., in the Chukchi Sea, July-October 2006. LGL Rep. P903-2 (Jan. 2007). Rep. from LGL Alaska Res. Assoc. Inc., Anchorage, AK, and JASCO Res. Ltd., Victoria, B.C., for ConocoPhillips Alaska Inc., Anchorage, AK, and Nat. Mar. Fish. Serv., Silver Spring, MD. 116 p.

MacGillivray, A. and D. Hannay. 2007b. Field measurements of airgun array sound levels. p. 4-1 to 4-19 *In:* Marine mammal monitoring and mitigation during open water seismic exploration by GX Technology in the Chukchi Sea, October-November 2006: 90-day report. LGL Rep. P891-1 (Feb. 2007). Rep. from LGL Alaska Res. Assoc. Inc., Anchorage, AK, and JASCO Res. Ltd., Victoria, B.C., for GX Technology, Houston, TX, and Nat. Mar. Fish. Serv., Silver Spring, MD. 118 p.

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

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch and K. McCabe. 2000. Marine seismic surveys: Analysis of airgun signals; and effects of air gun exposure on humpback whales, sea turtles, fishes and squid. Report by Centre for Marine Science and Technology, Curtain University, Australia for Australian Petroleum Producers Association, Australia. 188 p.

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

Smultea, M.A., M. Holst, et al. 2003. Marine mammal monitoring during Lamont-Doherty Earth Observatory's acoustic calibration study in the northern Gulf of Mexico, 2003. LGL Rep. TA2822-12. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory, Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD.

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

Smultea, M.A., W.R. Koski and T.J. Norris. 2005. Marine mammal monitoring during Lamont-Doherty Earth Observatory’s marine seismic study of the Blanco Fracture Zone in the Northeastern Pacific Ocean, October-November 2004. LGL Rep. TA2822-29. Rep. From LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 89 p.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L Gentry, C.R. Greene, Jr., D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J. Richardson, J.A. Thomas and P.L. Tyack. 2007. Marine mammal noise exposure criteria: initial scientific recommendations. **Aquat. Mamm.** 33:1-521.

Tolstoy, M., J. Diebold, S. Webb, D. Bohnenstiehl and E. Chapp. 2004a. Acoustic calibration measurements. Chapter 3 *In:* W.J. Richardson (ed.), Marine mammal and acoustic monitoring during Lamont-Doherty Earth Observatory's acoustic calibration study in the northern Gulf of Mexico, 2003. Revised ed. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. (Advance copy).

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

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

L-DEO used the R/V *Marcus G. Langseth* for the seismic study. The *Langseth* is used to tow the airgun array (Fig. C.1, C.2), the hydrophone streamer(s), 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
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* simultaneous 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 μPa_{rms}. 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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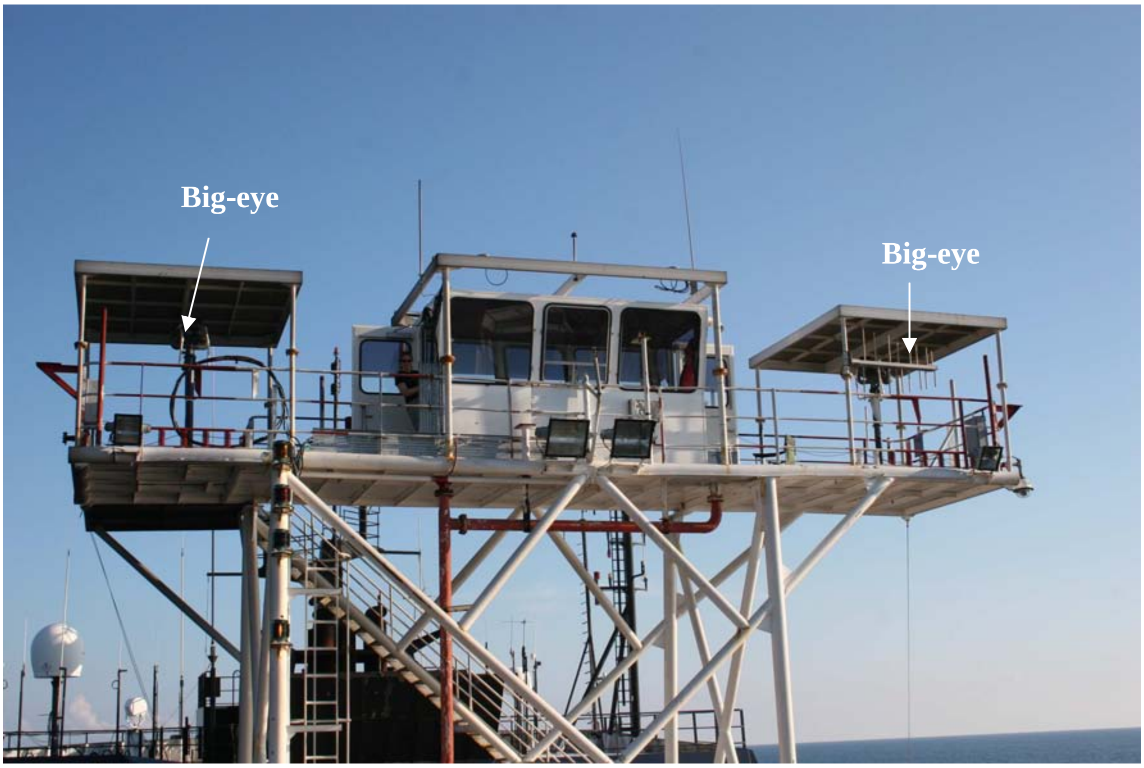

FIGURE C.3. The observation tower and booth on the R/V *Marcus G. Langseth* from which visual observations for marine mammals and sea turtles were made. The locations of two mounted 25x150 "Big-eye" binoculars used during the study is shown.

The 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; and
- 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 ~18.9 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).

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. If bridge crew sighted marine mammals or sea turtles at night, they were given instructions on how to fill out specific 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, vessel position (latitude, longitude), 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 is used during L-DEO cruises (see Appendix G).

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
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
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
SBW Sowerby's Beaked Whale
UBW Unidentified Beaked Whale

Dolphins
ASD Atlantic Spotted Dolphin
BD Bottlenose Dolphin
CD Clymene Dolphin
FD Fraser's Dolphin
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

Mustelids
SO Sea Otter

Pinnipeds
HS Harbor Seal
NFS Northern Fur Seal
SSL Steller Sea Lion

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

Right Waves Hydrophone Array and SeaProUltra

The Right Waves array consists of hardware (i.e., the hydrophone) and a software program. The "wet end" of the system consists of a towed hydrophone array that is connected to the vessel by a "hairy" faired cable. The array is deployed from the back deck. A deck cable is connected from the winch to the main computer lab where the signal conditioning and processing system are located.

The Right Waves array consists of four hydrophones; however, only two hydrophones are monitored simultaneously. The active section of the array is ~50 m long. The array is attached to a cable, which is typically 50 to 100 m long. Thus, the hydrophones are typically 150 m behind the stern of the ship. The depth at which the hydrophone array is towed can be adjusted by adding or removing weights; it is generally towed at a depth of ~30 m.

The array can detect signals at frequencies up to 48 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 numbers 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 ~7 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 ~150 m behind the *Langseth's* stern during the survey. The decision to initiate a power down was based on the distance from the observers rather than from the 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 L-DEO cruises. It also describes the methods used to calculate densities of cetaceans and turtles 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 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; Holst and Smultea 2008; Hauser et al. 2008; Hauser and Holst 2009):

- 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 some marine mammals to seismic surveys (e.g., Stone 2003; Stone and Tasker 2006; 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 is 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 are followed. To allow for animals missed during daylight, we correct 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 are 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 track-line.

The $g(0)$ and $f(0)$ factors used are 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} are calculated by multiplying the following two values. These calculations are done separately for times when different numbers of airguns are in use, and the results are summed:

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

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 if the seismic lines cross other lines or are spaced closely together.

A minimum estimate of the number of different individual marine mammals potentially exposed (one or more times) to ≥160 dB re 1 μPa_{rms} can also be calculated. That involves 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 is calculated using MapInfo Geographic Information System (GIS) software by creating a "buffer" that extends on both sides of the vessel's trackline to the predicted 160-dB radius. Because the 160-dB radius varies with the number of airguns in use (Table 3.1), the width of the buffer also varies 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 is repeated for delphinids, assuming that for those animals, the estimated 170 dB-radius (see Table 3.1) is a more realistic estimate of the maximum distance at which significant disturbance would occur. That radius is 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}.

References

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

Haley, B. and W.R. Koski. 2004. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic program in the Northwest Atlantic Ocean, July–August 2004. LGL Rep. TA2822-27. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 80 p.

Hauser, D.D.W. and M. Holst. 2009. Marine mammal monitoring during Lamont-Doherty Earth Observatory's marine seismic program in the Gulf of Alaska, September-October 2008. LGL Rep. TA4412-3. Rep. from LGL Ltd., King City, Ont. and St. John's, Nfld, for Lamont-Doherty Earth Observatory, Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 78 p.

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

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

Holst, M. and M.A. Smultea. 2008. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program off Central America, February – April 2008. LGL Rep. TA4342-3. Rep. From LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 133 p.

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

Holst, M., M.A. Smultea, W.R. Koski and B. Haley. 2005b. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program off the Northern Yucatán Peninsula in the Southern Gulf of Mexico, January–February 2005. LGL Rep. TA2822-31. Rep. by LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 96 p.

Koski, W.R., D.H. Thomson and W.J. Richardson. 1998. Descriptions of Marine Mammal Populations. p. 1-182 plus Appendices *In:* Point Mugu Sea Range Marine Mammal Technical Report. Rep. from LGL Ltd., King City, Ont., for Naval Air Warfare Center, Weapons Div., Point Mugu, CA, and Southwest Div. Naval Facilities Engin. Command, San Diego, CA. 322 p.

MacLean, S.A. and W.R. Koski. 2005. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic program in the Gulf of Alaska, August–September 2004. LGL Rep. TA2822-28. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 102 p.

Pavan, G. 2005. Cruise RV *Langseth* EW0412 LDEO / Columbia Univ., results, comments and recommendations. Rep. from Univ. degli Studi di Pavia, Centro Interdisciplinare di Bioacustica e Ricerche Ambientali. Pavia, Italy, March 15, 2005.

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

Smultea, M.A., W.R. Koski and T.J. Norris. 2005. Marine mammal monitoring during Lamont-Doherty Earth Observatory's marine seismic study of the Blanco Fracture Zone in the Northeastern Pacific Ocean, October-November 2004. LGL Rep. TA2822-29. Rep. From LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 89 p.

Stone, C.J. 2003. The effects of seismic activity on marine mammals in UK waters 1998-2000. JNCC Report 323. Joint Nature Conservancy, Aberdeen , Scotland. 43 p.

Stone, C.J. and M.L. Tasker. 2006. The effects of seismic airguns on cetaceans in UK waters. **J. Cetac. Res. Manage.** 8(3):255-263.

APPENDIX E: BACKGROUND ON MARINE MAMMALS IN THE SOUTHWEST PACIFIC OCEAN

TABLE E.1. The habitat, occurrence, regional population sizes, and conservation status of marine mammals that may occur in or near Lau Basin, Southwest Pacific Ocean (taken from the EA/IHA Application; LGL Ltd. 2008a,b).

Species	Habitat	Occurrence in the South Pacific Ocean	Regional population size	U.S. ESA[1]	IUCN[2]	CITES[3]
Mysticetes						
Humpback whale (*Megaptera novaeangliae*)	Mainly nearshore waters and banks	Rare in Jan–Feb	~6200[4]	EN	VU	I
Pygmy right whale (*Caperea marginata*)	Coastal and oceanic	Common	N.A.	-	N.A.	I
Antarctic minke whale (*Balaenoptera bonaerensis*)	Coastal and oceanic	Rare in Jan–Feb	140,000–155,000[5]	-	LR-cd	I
Minke whale (*Balaenoptera acutorostrata*)	Pelagic and coastal	Rare in Jan–Feb	140,000–155,000[5]	-	LR-nt	I
Bryde's whale (*Balaenoptera edeni*)	Pelagic and coastal	Common	20,000-30,000[6]	-	DD	I
Sei whale (*Balaenoptera borealis*)	Primarily offshore, pelagic	Common	12,000[7]	EN	EN	I
Fin whale (*Balaenoptera physalus*)	Continental slope, mostly pelagic	Uncommon in Jan–Feb	3031[8]	EN	EN	I
Blue whale (*Balaenoptera musculus*)	Pelagic and coastal	Uncommon in Jan–Feb	756[9]	EN	EN	I
Odontocetes						
Sperm whale (*Physeter macrocephalus*)	Usually pelagic and deep seas	Common	22,700[10]	EN	VU	I
Pygmy sperm whale (*Kogia breviceps*)	Deep waters off the shelf	Common	N.A.	-	N.A.	II
Dwarf sperm whale (*Kogia sima*)	Deep waters off the shelf	Uncommon?	11,200[10]	-	N.A.	II
Cuvier's beaked whale (*Ziphius cavirostris*)	Pelagic	Common	20,000[10]	-	DD	II
Southern bottlenose whale (*Hyperoodon planifrons*)	Pelagic	Rare	N.A.	-	LR-cd	I
Longman's beaked whale (*Indopacetus pacificus*)	Pelagic	Uncommon	NA	-	DD	II
Blainville's beaked whale (*Mesoplodon densirostris*)	Pelagic	Common	25,300[10*]	-	DD	II
Ginkgo-toothed beaked whale (*Mesoplodon ginkgodens*)	Pelagic	Rare	25,300[10*]	-	DD	II
Rough-toothed dolphin (*Steno bredanensis*)	Deep water	Uncommon	145,900[10]	-	DD	II
Bottlenose dolphin (*Tursiops truncatus*)	Coastal and oceanic, shelf break	Common	243,500[10]	-	DD	II
Pantropical spotted dolphin (*Stenella attenuata*)	Coastal and pelagic	Uncommon	1,298,400[10]	-	LR-cd	II
Spinner dolphin (*Stenella longirostris*)	Coastal and pelagic	Rare south of 15ºS	1,019,300[10]	-	LR-cd	II
Striped dolphin (*Stenella coeruleoalba*)	Off continental shelf	Rare	1,918,000[10]	-	LR-cd	II
Fraser's dolphin (*Lagenodelphis hosei*)	Waters >1000 m	Rare south of 30°S	289,300 [10]	-	DD	II
Short-beaked common dolphin (*Delphinus delphis*)	Shelf and pelagic, seamounts	Common	2,210,900[10]	-	N.A.	II
Risso's dolphin (*Grampus griseus*)	Waters >1000 m, seamounts	Common	175,800[10]	-	DD	II
Melon-headed whale (*Peponocephala electra*)	Oceanic	Uncommon south of 20ºS	45,400[10]	-	N.A.	II
Pygmy killer whale (*Feresa attenuata*)	Deep, pantropical waters	Uncommon	38,900[10]	-	DD	II
False killer whale (*Pseudorca crassidens*)	Pelagic	Uncommon	39,800[10]	-	N.A.	II
Killer whale (*Orcinus orca*)	Widely distributed	Common	8,500[10]	-	LR-cd	II
Short-finned pilot whale (*Globicephala macrorhynchus*)	Mostly pelagic, high-relief topography	Common north of 40°S	160,200[10†]	-	LR-cd	II

N.A. - Data not available or species status was not assessed.
[1] EN = Endangered, - = Not listed
[2] EN = Endangered; VU = Vulnerable; LR = Lower Risk (-cd = Conservation Dependent; -nt = Near Threatened); DD = Data Deficient (IUCN 2007).
[3] UNEP-WCMC 2008.
[4] Humpback Group E, 2004 (Johnston and Butterworth 2005).
[5] Antarctic Area V, 1991/1992-2003/2004 (Branch 2006).
[6] Western South Pacific (IWC 1981 *in* Reeves et al. 1999).
[7] Antarctic Area V, 1973 (Horwood 1987:295).
[8] Antarctic Area V, 2003 (Murase et al. 2005).
[9] Antartctic Area V, 2001/2002-2003/2004 (Branch 2007)
[10] Eastern Tropical Pacific (Wade and Gerrodette 1993).
* Estimate is for all *Mesoplodon* species combined.
[†] Estimate includes long- and short-finned pilot whales.

References

Branch, T.A. 2006. Abundance estimates for Antarctic minke whales from three completed circumpolar sets of surveys, 1978/79 to 2003/04. Paper SC58/IA18 presented to the IWC Scientific Committee, June 2006 (unpublished). 28 p. Available from the IWC Secretariat: secretariat@iwcoffice.org.

Branch, T.A. 2007. Abundance of Antarctic blue whales south of 60 degrees S from three complete circumpolar sets of surveys. **J. Cetac. Res. Manage.** 9(3):253-262.

Horwood, J. 1987. The sei whale: population biology, ecology, and management. Croom Helm, Beckenham, Kent, U.K. 375 p.

IUCN (The World Conservation Union). 2007. 2007 IUCN Red List of Threatened Species. http://www.iucnredlist.org.

Johnston, S.J. and D.S. Butterworth. 2005. A Bayesian assessment of the west and east Australian breeding populations (Stocks D and E) of southern hemisphere humpback whales. Paper SC/57/SH15 presented to the IWC Scientific Committee, June 2006 (unpublished). 25 p. Paper available from the IWC Secretariat: secretariat@iwcoffice.org.

Murase, H. T. Tamura, K. Matsuoka, T. Hakamada, and K. Konishi. 2005. First attempt of estimation of feeding impact on krill standing stock by three baleen whale species (Antarctic minke, humpback and fin whales) in Areas IV and V using JARPA data. Paper JA/J05/JR12 presented to the Japan-sponsored meeting to review data and results from the Japanese Whale Research Program under special permit in the Antarctic (JARPA) (Pre-JARPA review meeting, January 2005. 7 p.

Reeves, R.R., S. Leatherwood, G.S. Stone, and L. G. Eldredge. 1999. Marine mammals in the area served by the South Pacific Regional Environment Programme (SPREP). SPREP, Apia, Samoa. 55 p.

UNEP-WCMC. 2008. UNEP-WCMC Species Database: CITES-Listed Species. http://www.cites.org.

Wade, P.R. and T. Gerrodette. 1993. Estimates of cetacean abundance and distribution in the Eastern Tropical Pacific. **Rep. Int. Whal. Comm.** 43:477-493.

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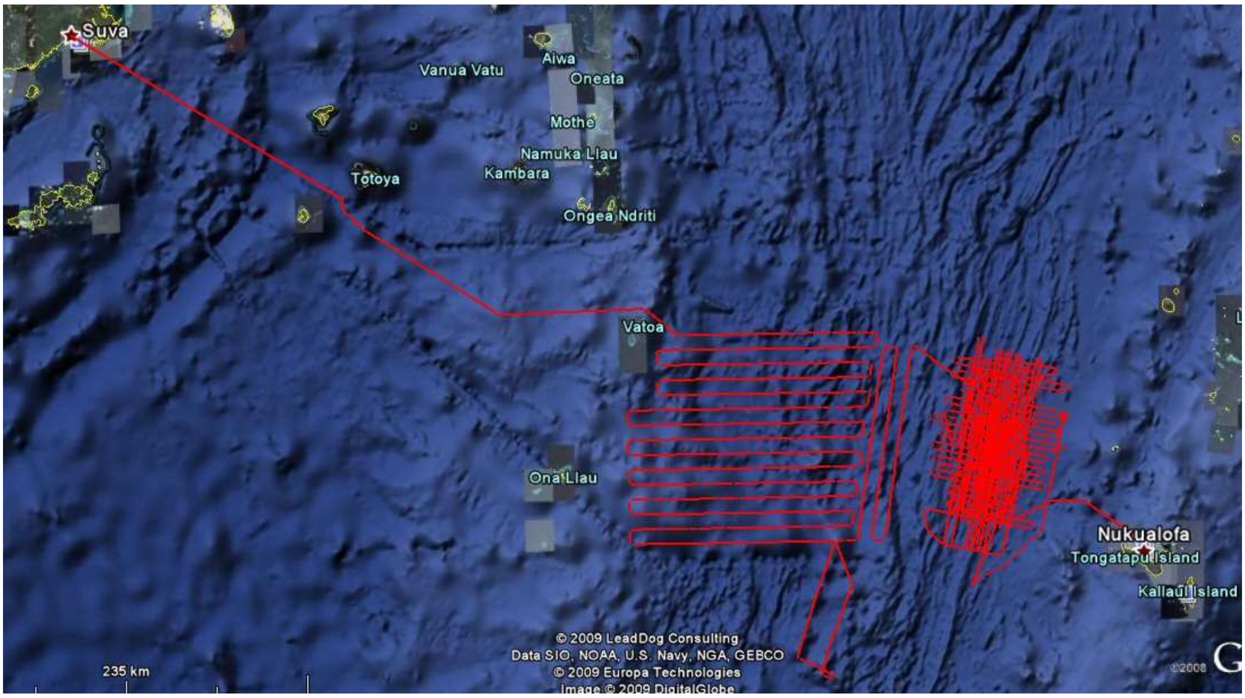
APPENDIX F: ELSC SURVEY, LAU BASIN, 24 JANUARY – 8 MARCH 2009 PAM REPORT

Prepared by Claudio Fossati, RIGHT WAVES - CIBRA



PAM hardware and software

During the 2008 cruises, all the "wet" hardware has been irreparably damaged due to towing difficulties. The seismic gear operated by the Langseth virtually takes all the available space behind its stern (Fig. 1).

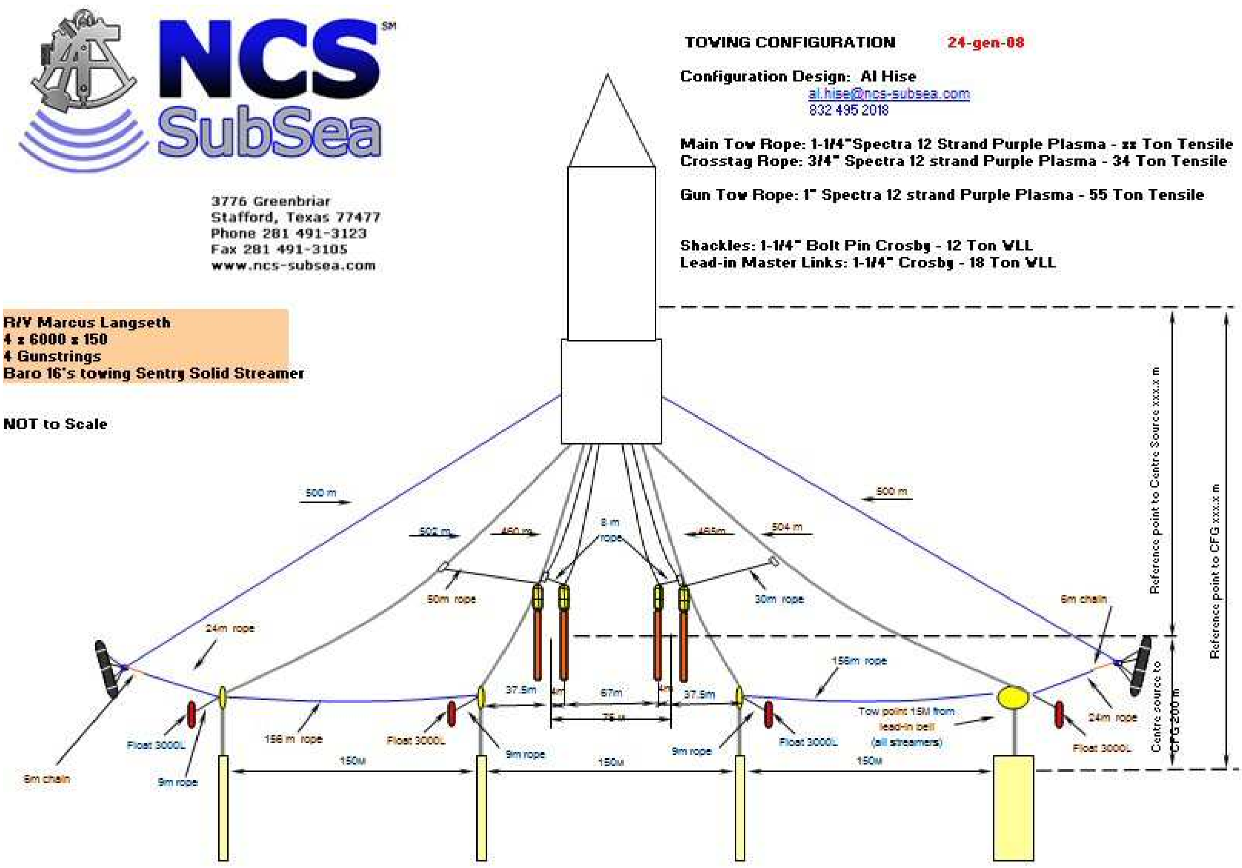


Fig. 1

All the approaches attempted last year to deploy and tow PAM streamers were unsuccessful. Difficulties experienced in 2008 are described in the previous reports.
At the end of the year, RW had a meeting at Lamont to set a "transition" strategy for 2009. The vessel needs some major work/modifications to operate PAM safely (both for personnel and instruments) and proficiently.

RW provided 2 new streamers with improved characteristics. The main streamer consists of a Towed Digital Array, 4 channels, digital (optical and electrical) and analog output up to 96kHZ bandwidth, adjustable gain and filters (via USB), pressure gauge, 250mt lead-in coax electromechanical cable, 50mt pigtail, 42mt hose (15mt VIM Vibration Insulation Module + 30mt active section), OD 3cm (Fig. 2). The signal is received and redistributed by a separate control unit that interfaces with a PC via USB 2.0 to access all the array controls.

Fig 2.

Fig 2A.

Fig 2B.

The second one, intended as a backup, is tough Towed Analog Array, 2 channels, differential output up to 96 kHz bandwidth, OD 3.5cm, 15mt long active section, with 200 m of electro-mechanical lead-in cable, pressure gauge and 50 m pigtail (Fig. 3).

Audio signal is captured and digitized by high quality A/D converters and fed to a dedicated laptop PC located in a convenient place on the vessel. Recordings (wav format) are stored in two 1TB each external HDD. All the converters, power supply, laptop PC are housed in a watertight Pelicase (Fig 3) equipped with watertight connectors for streamer signal, AC power and Net link. A/D converters have been renewed to increase the sample frequency up to 192 kHz.

Fig 3.

The new acquisition system, although has been designed for open deck operations, has been placed in the bird lab, that is a more user friendly environment. It gets the signal from the streamer (orange cable), digitizes it, send it to the laptop PC, which broadcast the audio on the Langseth intranet.

The software is an evolution of the CIBRA – RIGHT WAVES software suite, which has been updated to improve performance, reliability and compatibility with the new MS Windows OS releases.

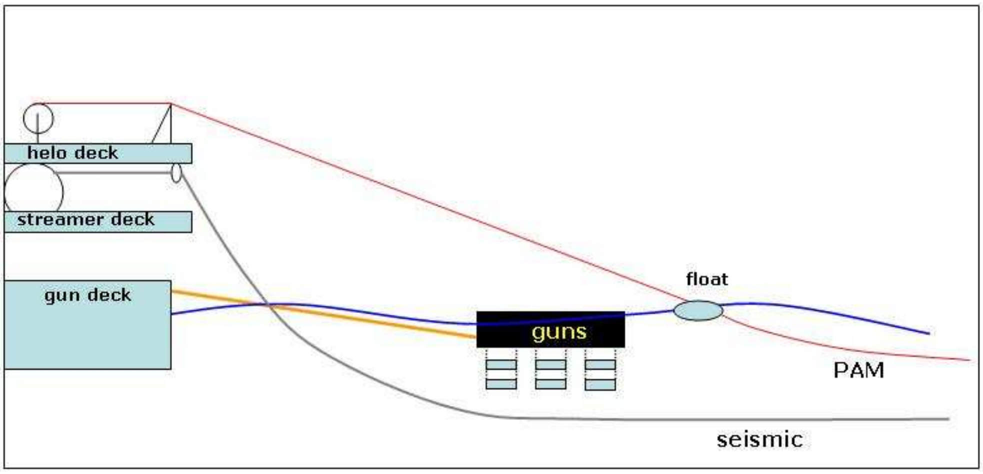
Fig 4.

This is the actual PAM station in the main lab (Fig 4). The laptop on the right receives and manages the audio stream from the network (Audiogem software). It also runs the SeaPro sound analysis software (upper screen). Stereo audio signal is monitored and continuously recorded at 48kHz bandwidth on a 1TB external HDD. The central laptop runs the Cnav nmea manager that grabs nav data from the udp, filters the appropriate GPS string (GPRMC) and broadcast it as udp back to the network and other software. It also runs the PAMLogger that assist the PAM operator in logging the info relative to the current operations/sounds. On the upper screen there is a real time digital map (OziExplorer) that shows map of the area along with the track, the sightings and acoustic contacts.

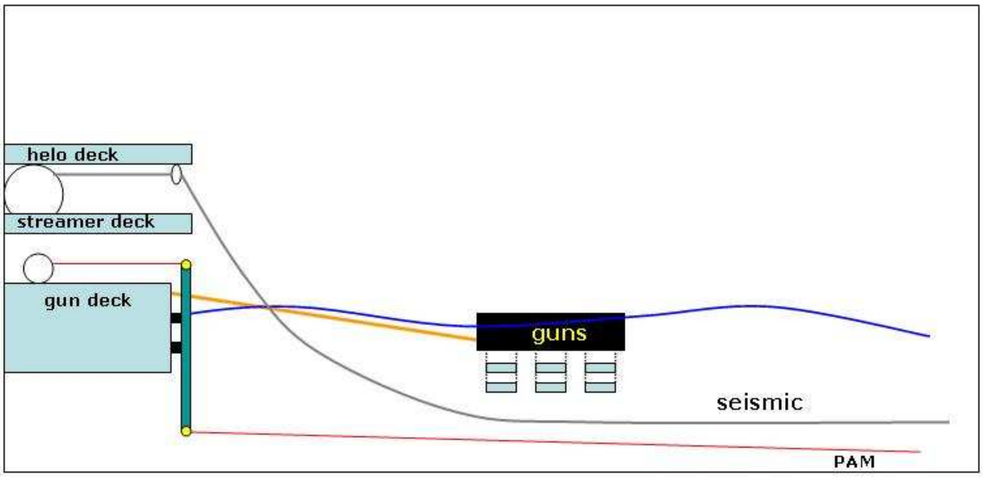
Cnav manager is also feeding a laptop on the MMO tower. Another copy of PAMLogger and OziExplorer (courtesy of RW/CIBRA) are running on that laptop and are assisting MMOs to get nav data for the LGL's XLS spreadsheet data entry.

Towing system and hardware setup

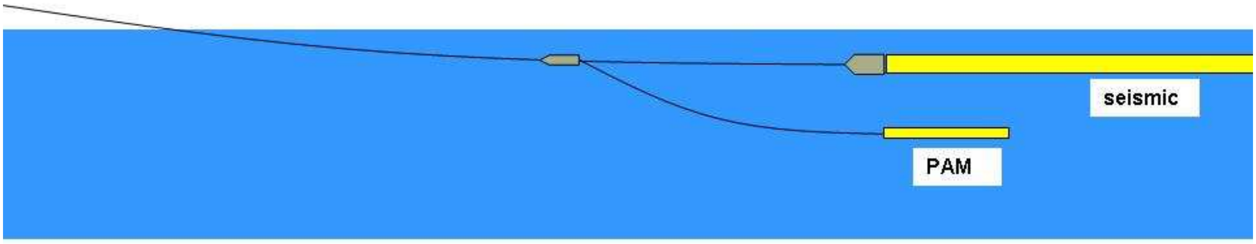
After the Steep cruise (Gulf of Alaska) in 2008, a series of different techniques in deploying and towing PAM streamers on seismic vessels was reviewed and presented to Lamont by RW. None of the solutions found seemed to be practical in the short term, since they all require major modification or dry dock ops (see drawings below).
Deployment and tow above the gunstrings. Requires new winch and structures on the helo deck + float and sea anchor.



Deployment and tow under the gunstrings through a dedicated telescopic pipe system. Requires a new winch on the back deck + design and installation of the pipe system.

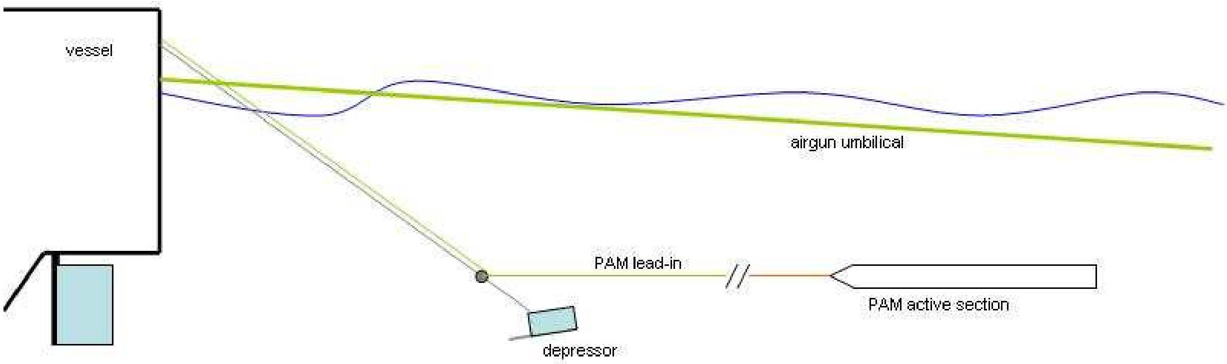


Other options considered were to integrate PAM tow leader in the Seismic array tow leader (Fig. x), but this solutions has more bad then good sides (e.g. the cost to modify the seismic tow leaders and cruises without the streamers, like the present one).



A final hypothesis to put cetacean dedicated sensors in the seismic streamer is not feasible due to suppression of fundamental part of the spectrum related to physical size of the streamer itself.

We therefore decided to try a simple solution to bridge these difficulties. We bought an off the shelf depressor used for fishery. The idea is to get the PAM streamer tow leader and therefore the active section as deep as possible right off the stern. Unfortunately, detailed measures of the depressor performance vs. tow line length and vessel's speed couldn't be done properly. But the set arranged (see following drawing) based on our experience did the job.



The depressor is deployed and towed by a Spectra line. There are 3 towing points on the depressor with increasing working angle (> angle = > depth). We set it at the maximum angle. The PAM tow leader is attached to the Spectra line by a cable grip. During the first leg, we deployed 15mt of spectra line and 55mt of tow cable after the depressor. The pressure gauge indicated 10-12mt operating depth (PG is located in the head of the active section). During the second deployment, we augmented the distance between the depressor and the vessel up to 30 mt. This resulted in a deeper level of the active section (14-16mt).

Respect to the previous year situation, this represents a better configuration mostly for 2 reasons. The PAM streamer tow leader doesn’t interact with the airguns’ string umbilical (Fig 5, yellow circle) since it sinks more rapidly.

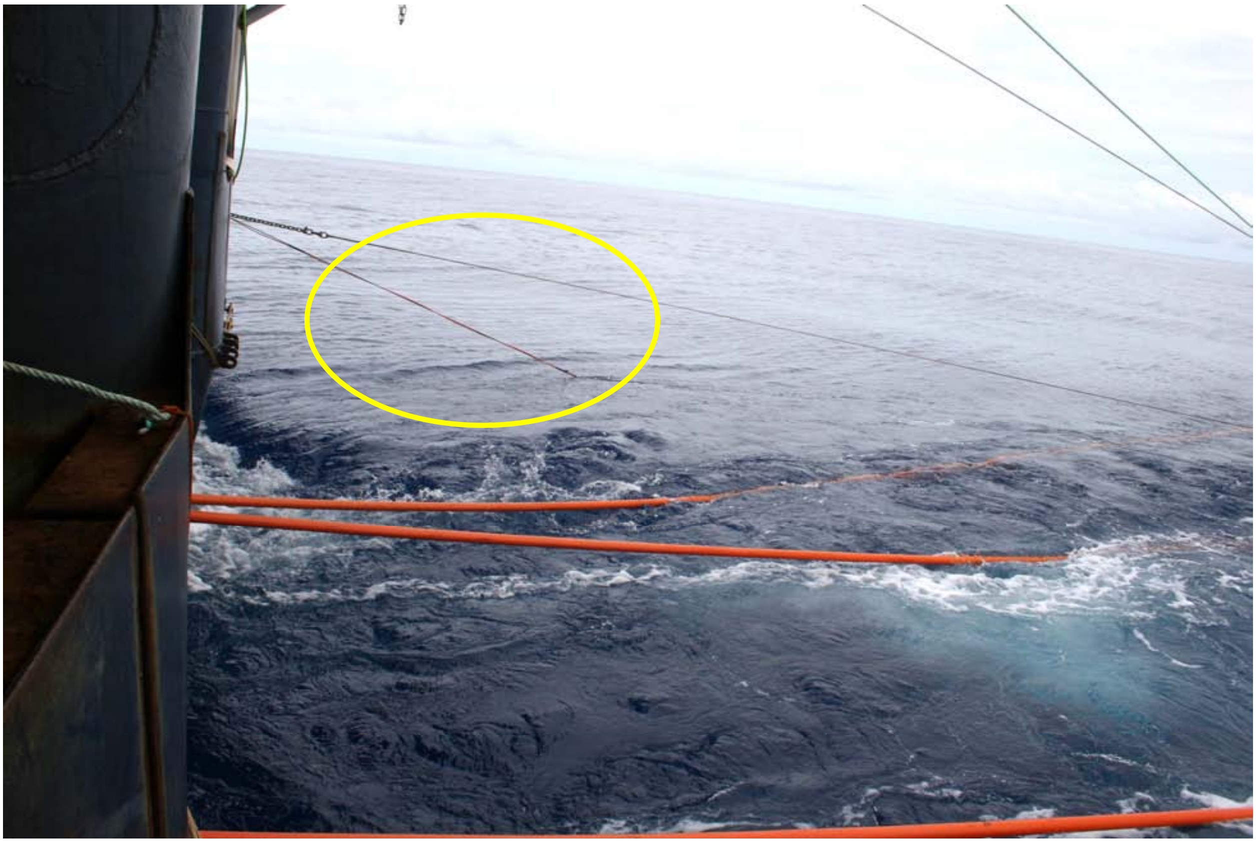
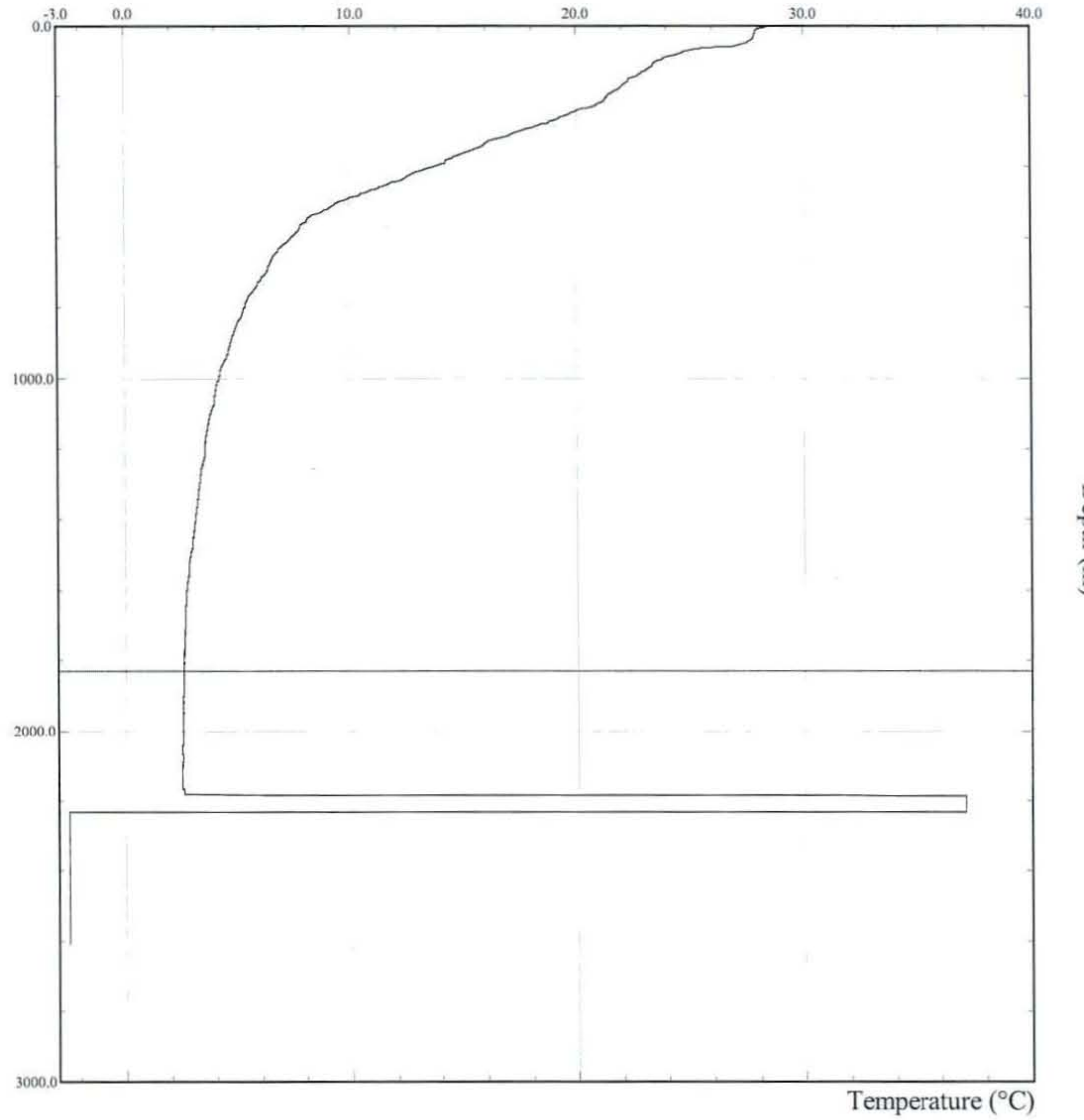


Fig 5.

The PAM streamer active section is deeper, that means a better acoustic performance. In the South Pacific (as in most of the Oceans), sound speed decreases moving from the surface to deeper layer till a variable quote, when it starts to increase again (due to pressure). Lower speed means better sound propagation. The two following pictures represent the typical shape of XBT (Expendable Bati Thermograph) casts made in the study area. Fig 6 is the temperature profile; Fig 7 is the sound speed (m/sec).



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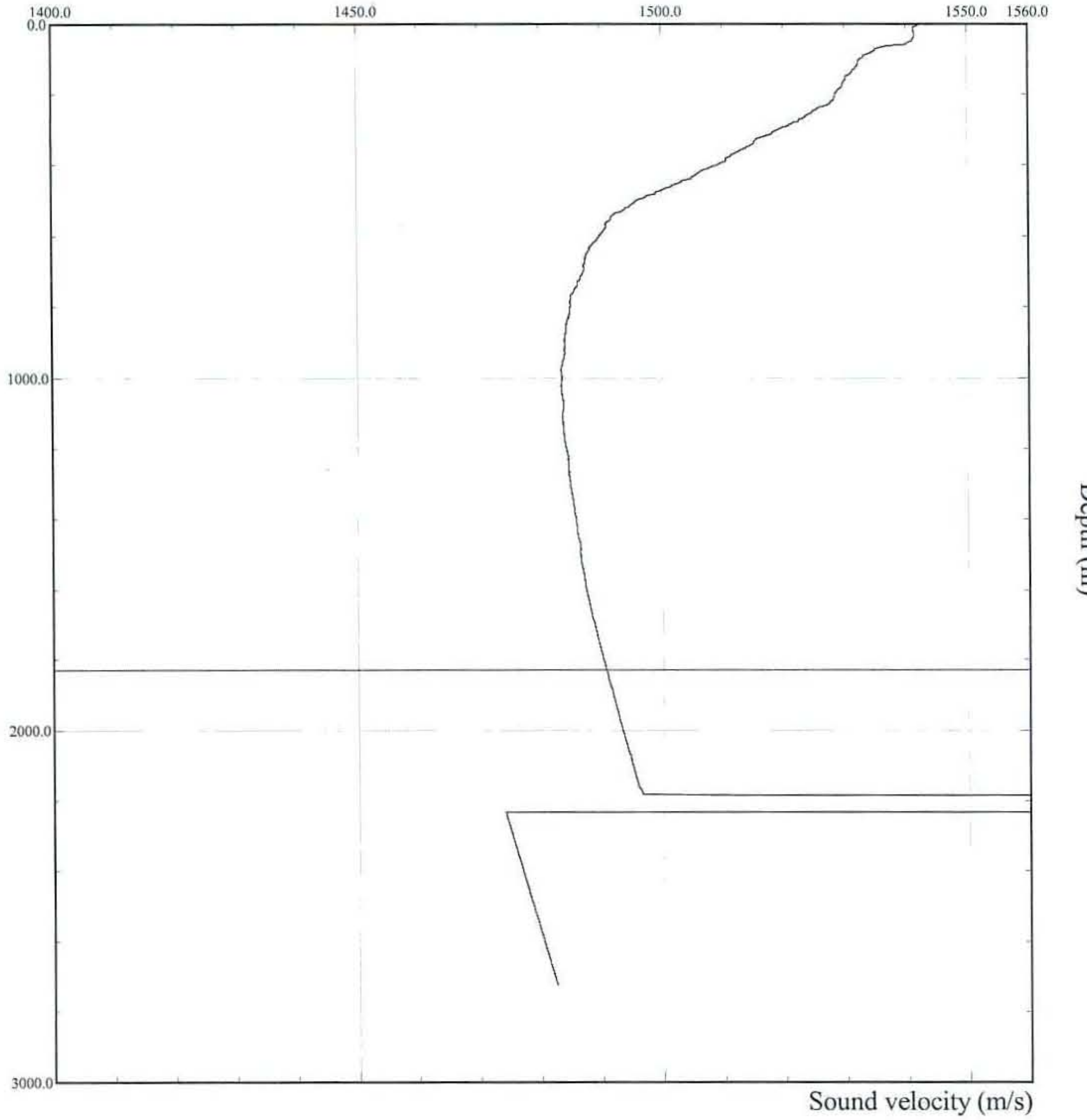
Depth Eqn: Original	Sequence #: 11
Coefficient 1: 0.0	
Coefficient 2: 6.828	Latitude: 20° 54.53979S
Coefficient 3: -0.00182	Longitude: 176° 9.33984W
Coefficient 4: 0.0	
	Serial #: 00000000

Fig 6.



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Coefficient 1: 0.0	
Coefficient 2: 6.828	Latitude: 20° 54.53979S
Coefficient 3: -0.00182	Longitude: 176° 9.33984W
Coefficient 4: 0.0	
	Serial #: 00000000

Fig 7.
The depressor presents also a backside though. The model we used is not designed for acoustics, and induces lots of vibrations. This results in heavy low frequency noise, as shown by the zigzagging shape of the waveforms (Fig 8). Input gain had therefore be kept very low, and unbalanced on the 2 channels, since the "head", closer to the tow leader, suffered the most vibrations.

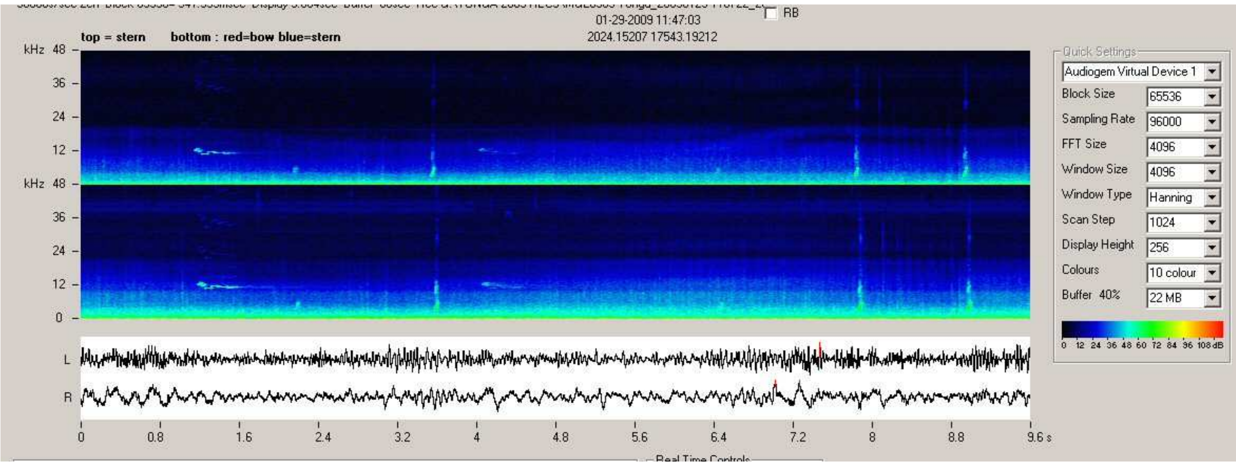


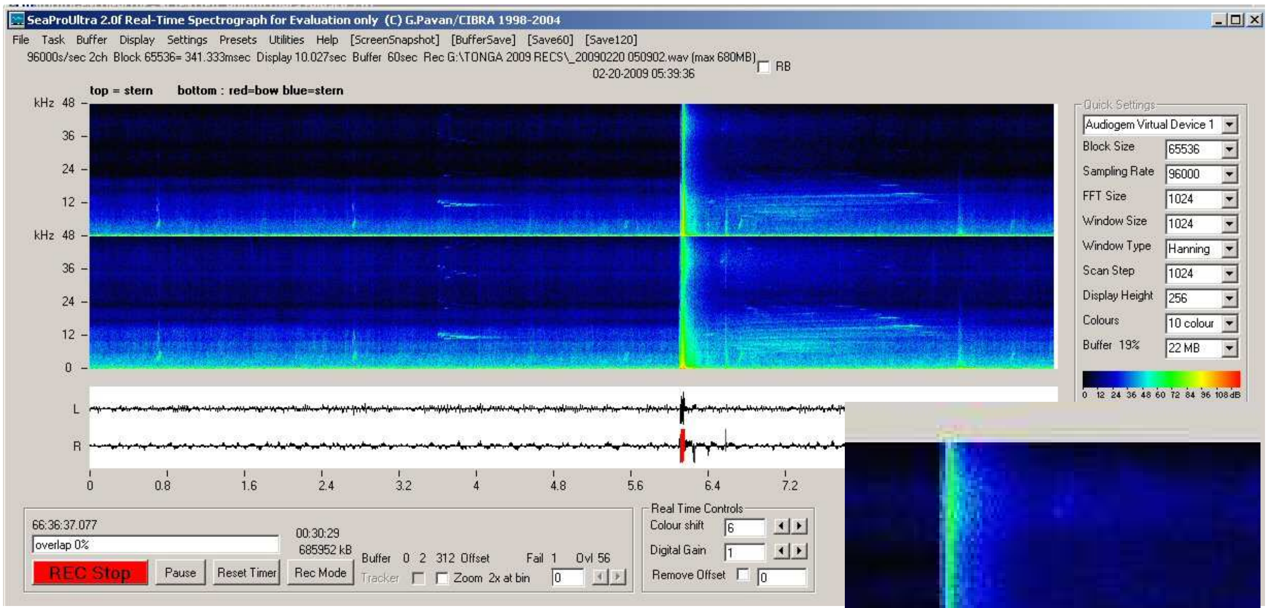
Fig 8.

Possible solutions actually under considerations are:

- high pass filter: it cuts the low freqs before they are processed by the DSPW (Digital Sound Processing Workstation). This allows to increase the amplification level of the upper part of the spectrum (> 1kHz approx).
- VIM: Vibration Isolation Modules are arrays' passive sections designed to absorb vibrations induced by the towing system. This solution allows to decrease the low freq noise without loosing eventual biological low noise signals (like Humpback whales)

Despite this problem, the overall quality of the audio signal was good. Unfortunately, no marine mammals were encountered in the area.

During this cruise, as already happened before, PAM proved to be a useful tool to alert Sound source Administrator of gun's auto-fires, miss-fires etc.
This happens when one or more guns fire off time.
The following picture is relative to one of these events. In the right part of Fig 9 (expanded) it is possible to note a thin vertical line associated with a small gun auto-fire. The PAM operator notified the Sound Source Admin that could solve the problem, avoiding to impair hours of Seismic data.



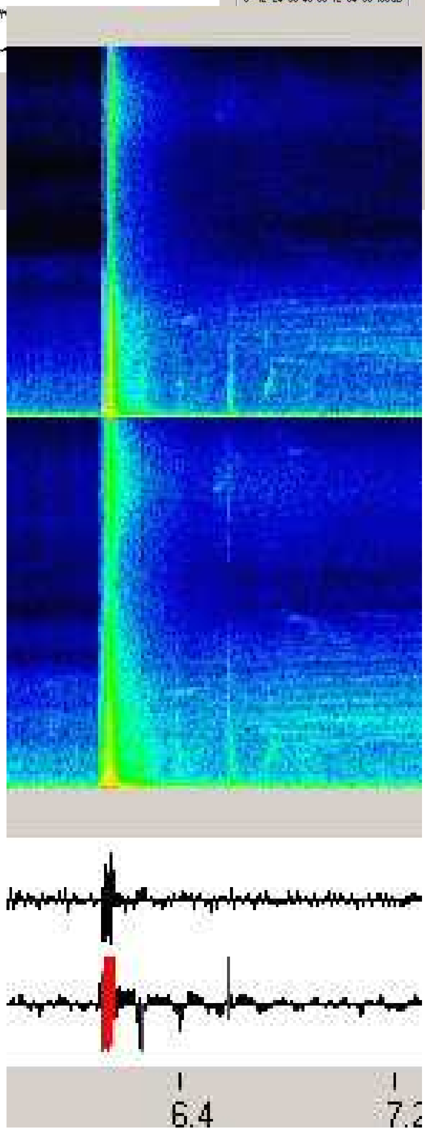


Fig 9.

Acoustic monitoring results

Despite this was quite a long cruise, 46 days spent in the research area scored zero sightings and zero acoustic contacts.
PAM was operative for a total of 539h 10min (of which 533h 05 min during seismic activity and 6h 05min before or after active seismic). This is an uncommon and interesting result.
In this document we will not speculate about the possible causes of such a peculiar result. Lack of marine mammals' data on this area anyway make impossible any confrontation with "less invasive" survey methods. We assure that PAM was conducted, after all the difficulties experienced during 2008, in a manner that made the system highly reliable. No recs mean that no vocalizing animals were encountered during the cruise. This is also supported by lack of biological low freq signals on the OBSs retrieved and analyzed during the cruise.