MARINE MAMMAL AND SEA TURTLE MONITORING DURING LAMONT-DOHERTY EARTH OBSERVATORY'S ETOMO MARINE SEISMIC PROGRAM IN THE NORTHEAST PACIFIC OCEAN, AUGUST – SEPTEMBER 2009

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for

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and

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by

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ACRONYMS AND ABBREVIATIONS

asl	above sea level
B.C.	British Columbia
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
CSI	Cetacean Society International
CV	Coefficient of Variation
cu. in.	cubic inches
dB	decibels
DFO	(Canadian) Department of Fisheries and Oceans
EA	Environmental Assessment
EEZ	Exclusive Economic Zone
ESA	(U.S.) Endangered Species Act
ETOMO	Endeavour Tomography study
$f(0)$	sighting probability density at zero perpendicular distance from survey track; equivalently, 1/(effective strip width)
ft	feet
GIS	Geographic Information System
GMT	Greenwich Mean Time
GPS	Global Positioning System
$g(0)$	probability of seeing a group located directly on a survey line
h	hours
hp	horsepower
Hz	Hertz (cycles per second)
IHA	Incidental Harassment Authorization (under U.S. MMPA)
in^3	cubic inches
ITS	Incidental Take Statement
IUCN	International Union for the Conservation of Nature
kHz	kilohertz
km	kilometer
km^2	square kilometers
km/h	kilometers per hour
kt	knots (1 knot = 1.853 km/h)
L-DEO	Lamont-Doherty Earth Observatory (of Columbia University)
µPa	microPascal
m	meters
MBES	Multibeam Bathymetric Echosounder
MCS	Multichannel Seismic
min	minutes
MMC	(U.S.) Marine Mammal Commission
MMO	Marine Mammal (and Sea Turtle) Observer

MMPA	(U.S.) Marine Mammal Protection Act
MPA	Marine Protected Area
n	sample size
n.mi.	nautical miles (1 n.mi. = 1.853 km)
NMFS	(U.S.) National Marine Fisheries Service
No.	number
NRDC	Natural Resources Defense Council
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
SARA	(Canadian) Species at Risk Act
SBP	Sub-bottom Profiler
SCP	Statement of Canadian Practice
SD	Shut Down of all the airguns—not associated with mitigation
s.d.	standard deviation
SPL	Sound Pressure Level
SZ	Shut Down of all the airguns because of a marine mammal or 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".
USFWS	U.S. Fish and Wildlife Service
WaH	Wild at Heart Legal Defense Association

EXECUTIVE SUMMARY

Introduction

This document serves to meet reporting requirements of the U.S. National Marine Fisheries Service (NMFS) and to provide information to the Canadian Department of Fisheries and Oceans (DFO) on a marine seismic survey in the Northeast Pacific Ocean conducted by Lamont-Doherty Earth Observatory (L-DEO) of Columbia University, August–September 2009. An Incidental Harassment Authorization (IHA) was issued to L-DEO by NMFS on 19 August 2009. It authorized non-lethal takes of certain marine mammals incidental to a seismic survey by the R/V *Marcus G. Langseth* off the coast of British Columbia (B.C.), Canada.

Behavioral disturbance to marine mammals is considered to be "take by harassment" under the provisions of the U.S. Marine Mammal Protection Act (MMPA). NMFS considers that marine mammals exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} might be sufficiently disturbed to be "taken by harassment". "Taking" would also occur if marine mammals close to the seismic activity experienced a temporary or permanent reduction in their hearing sensitivity, or reacted behaviorally to the airgun sounds in a biologically significant manner.

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

Seismic Program Described

L-DEO conducted a seismic survey in the Northeast Pacific Ocean off the coast of B.C. and Washington State, within the Exclusive Economic Zone (EEZ) of Canada. The study area was located between 47°N and 49°N and between 127°30'W and 130°W, and included the Canadian Endeavour Marine Protected Area (MPA). The main purpose of the Endeavour Tomography (ETOMO) study was obtain data integral to advancing scientific understanding of the sub-seafloor structure of volcanic and hydrothermal features that form as a result of movements of the Earth's plates. The ETOMO cruise took place from 22 August to 19 September 2009 in water >1000 m deep.

During the ETOMO survey, a 36-airgun array with a total discharge volume of 6600 in^3 was towed behind the *Langseth* at a depth of 9–15 m. The acoustic receiving system consisted of Ocean Bottom Seismometers (OBSs) deployed by the *Langseth*. A 12-kHz multibeam bathymetric echosounder (MBES) and a lower energy 3.5 kHz sub-bottom profiler (SBP) were also operated from the *Langseth* throughout most of the study. Marine mammal monitoring and mitigation efforts were integral to the seismic survey. In addition to visual monitoring from the *Langseth* (see next subsection), passive acoustic monitoring (PAM) for vocalizing cetaceans also took place through the use of a towed hydrophone array.

Monitoring and Mitigation Description and Methods

Six 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 radius. ***(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 in daytime but the airguns were not firing. The visual MMOs used 7×50 reticle binoculars, 25×150 Big-eye reticle binoculars, and/or the naked eye to scan the surface of the water around the vessel for marine mammals and sea turtles. The distance from the observer to the sighting was estimated using reticles in the binoculars. If a marine mammal or turtle was 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. The primary purpose of the acoustic monitoring was to aid visual observers by detecting vocalizing cetaceans. The acoustic MMO listened with headphones to sounds received from the hydrophones and simultaneously monitored a real-time spectrogram display.

Primary mitigation procedures during the ETOMO cruise 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 applicable safety radius.

Due to concerns raised by DFO, the safety radius around the airgun array for marine mammal species listed under the Canadian Species at Risk Act (SARA) was based on the distance within which the received levels of airgun sounds was expected to diminish to 160 dB re 1 μPa_{rms}. The 160-dB criterion was used to prevent harm and disturbance to SARA-listed marine mammals — i.e., to avoid any 'takes' of SARA-listed marine mammals. For all other cetacean species and sea turtles, the safety radius was based on the distance at which sounds were expected to diminish to 180 dB re 1 μPa_{rms}; for pinnipeds, the safety radius was based on 190 dB re 1 μPa_{rms}. The 180- and 190-dB re 1 μPa_{rms} distances are safety criteria specified by NMFS. If a North Pacific right whale had been seen, the airguns would have been shut down regardless of the distance from airguns to whale.

Monitoring Results

The *Langseth* traveled a total of 5518 km (654 h) during the ETOMO study (Table ES.1). A total of 3003 km of seismic operations and a total of 2515 km of non-seismic operations took place within the study area (Table ES.1). Overall, 330 h of visual observations took place during the ETOMO study (Table ES.1). Nearly all (~99%) visual effort occurred during daylight periods. MMOs were on visual watch during all 209 h of daylight seismic operations, including ramp ups. MMOs were also on watch for ~0.5 h of seismic operations during darkness, and for 120.5 daylight hours when there were no seismic operations (Table ES.1). In addition, 340 h of PAM occurred during seismic periods, and 3 h took place during non-seismic periods; however, no acoustic detections of cetaceans were made.

Mitigation decisions were based on all marine mammal and sea turtle sightings, but analyses of marine mammal data focused on sightings and survey effort in the study area during "useable" survey conditions. "Useable" conditions represented ~71% of the total visual effort in km (Table ES.1). "Useable" effort excluded periods 90 s to 6 h after airguns were turned off (referred to as post-seismic), poor visibility (<3.5 km) conditions, and periods with Beaufort Wind Force (Bf) >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

TABLE ES.1. Summary of *Langseth* operations, visual and passive acoustic monitoring (PAM) effort, and marine mammal and sea turtle sightings during the ETOMO seismic survey, 22 August to 19 September 2009.

	Post-Seismic[a]		Non-seismic		Seismic			
	Recently Exposed	Potentially Exposed	Useable[b]	Non-Useable	Useable[b]	Non-Useable	Total Useable[b]	Overall Total
Operations effort in h								
Langseth Darkness	2.0	0.9	-	108.8	-	164.9	-	**276.7**
Langseth Daylight	0.0	3.1	51.4	114.3	159.5	49.4	210.8	**377.7**
***Langseth* Total**	**2.0**	**4.0**	**51.4**	**223.1**	**159.5**	**214.3**	210.8	**654.4**
Observer Darkness	0	0	-	0	-	0.5	-	**0.5**
Observer Daylight	0.0	2.1	51.4	67.0	159.5	49.4	210.8	**329.4**
Observer Total	**0.0**	**2.1**	**51.4**	**67.0**	**159.5**	**49.9**	210.8	**329.9**
PAM Total[c]		**3.0**			**339.8**			**342.8**
Operations effort in km								
Langseth Darkness	16.1	6.3	-	1006.1	-	1328.2	-	**2356.7**
Langseth Daylight	0.2	19.4	606.1	860.9	1318.2	356.1	1924.3	**3160.9**
***Langseth* Total**	**16.3**	**25.7**	**606.1**	**1867.0**	**1318.2**	**1684.3**	1924.3	**5517.6**
Observer Darkness	0	0	-	0	-	3.5	-	**3.5**
Observer Daylight	0.2	17.5	606.1	412.0	1318.2	356.1	1924.3	**2710.1**
Observer Total	**0.2**	**17.5**	**606.1**	**412.0**	**1318.2**	**359.7**	1924.3	**2713.7**
No. Pinniped Sightings (Individuals)	0	0	1 (1)	0	0	0	1 (1)	1 (1)
No. Cetacean Sightings (Individuals)	0	1 (6)	6 (31)	1 (3)	0	0	6 (31)	8 (40)
No. Cetacean Acoustic Detections		0			0			0
No. Turtle Sightings (Individuals)	0	1 (1)	0	0	0	0	0	1(1)
No. Power/Shut Downs for Marine Mammals & Turtles								0

[a] 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.

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

[c] Useable and non-useable effort was combined for post-seismic/non-seismic and seismic periods.

glare between 90º left and right of the bow, and sightings of cryptic species (such as Dall's porpoise) in Bf>2.

During the ETOMO survey, there were nine marine mammal sightings totaling 41 individuals; 78% of sightings (seven groups totaling 32 individuals) were considered "useable" (Table ES.1). Dall's porpoise was the most frequently encountered species (five groups totaling 28 individuals). One sperm whale, one unidentified toothed whale, one group of 10 Pacific white-sided dolphins, and one northern elephant seal were also observed. The cetacean species with the highest calculated density in the study area was the Dall's porpoise. In addition, one leatherback sea turtle was also sighted. As no sightings were made during seismic operations, no shut downs of the airgun array were necessary during the ETOMO survey (Table ES.1). In addition, no ramp ups had to be delayed due to marine mammal sightings. The sighting rate of marine mammals per 1000 km of "useable" survey effort was 3.6/1000 km.

Number of Marine Mammals Present and Potentially Affected

As no marine mammals or sea turtles were seen during seismic operations during the ETOMO study, none of the observed animals were exposed to airgun sounds strong enough to require shut downs of the airguns. Minimum and maximum numbers of marine mammals potentially exposed to ≥160 and ≥170 dB re 1 μPa_{rms} were estimated based on the approximate densities of marine mammals derived by line-transect procedures. (Calculated densities were very approximate because of the very low numbers of individuals seen.) These estimates allowed for animals that may have been encountered at night as well as by day, and (insofar as possible) for animals not seen by MMOs. Based on observations during daytime non-seismic periods in the ETOMO study area, and assuming similar densities of animals at night as by day, a minimum of 439 and up to 1922 marine mammals might, prior to the approach of the *Langseth*, have been in the areas later exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms}. These estimates include exposures of up to 1275 Dall's porpoises, 542 delphinids, and 79 elephant seals. When areas with received levels ≥170 dB re 1 μPa_{rms} are considered, up to 608 Dall's porpoises, 259 delphinids, and 38 elephant seals might have been present prior to the approach of the ship.

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. During the ETOMO study, sightings were only made during non-seismic periods. However, as the duration of useable surveys and number of sightings were both small, it is not possible to make any clear determinations from this single cruise as to the effects that the ETOMO survey may have had on marine mammals. However, the estimated numbers of individual cetaceans potentially disturbed by L-DEO's survey, based on direct observation and actual density data during non-seismic periods, were lower than those authorized by NMFS. Given the mitigation measures that were applied (i.e., ramp ups; no power- or shut-downs were required) and the lack of sightings within the safety radii during airgun operations, there was no indication that any marine mammals were exposed to sufficiently strong sounds to be physically harmful.

1. INTRODUCTION

Lamont-Doherty Earth Observatory (L-DEO) of Columbia University conducted a marine seismic program in the Northeast Pacific Ocean ~250 km southwest of Vancouver Island, British Columbia (B.C.), Canada. The Endeavour Tomography (ETOMO) study took place from 22 August to 19 September 2009 within the Exclusive Economic Zone (EEZ) of Canada and included the Endeavour Marine Protected Area (MPA). The project was conducted aboard the R/V *Marcus G. Langseth*, which is owned by the U.S. National Science Foundation (NSF) and operated by L-DEO. Through L-DEO and NSF coordination, foreign vessel clearance for the *Langseth* to conduct the survey was granted to L-DEO.

The goal of the ETOMO study was to obtain data integral to advancing scientific understanding of the sub-seafloor structure of volcanic and hydrothermal features that form as a result of movements of the Earth's plates. The survey used a 36-airgun array as an energy source, with a maximum discharge volume of 6600 in^3. The geophysical investigation was under the direction of Dr. Douglas Toomey of the University of Oregon and also included Dr. Emilie Hooft of the University of Oregon, and Dr. William Wilcock of the University of Washington.

Marine seismic surveys emit strong sounds into the water (Greene and Richardson 1988; Tolstoy et al. 2004a,b, 2009; Breitzke et al. 2008) and have the potential to affect marine mammals, given the known auditory and behavioral sensitivity of many such species to underwater sounds (Richardson et al. 1995; Gordon et al. 2004; Nowacek et al. 2007; Southall et al. 2007). The effects could consist of behavioral and/or distributional changes, increased masking of natural sounds, and perhaps (for animals close to the seismic 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 offshore waters of the Northeast Pacific Ocean. Several of these species are listed as ***endangered*** under the ESA, including the humpback, sei, fin, blue, North Pacific right, and sperm whales. Under the Canadian Species at Risk Act (SARA), the North Pacific right, sei, and blue whales are listed as ***endangered***, and the humpback and fin whales are listed as ***threatened***. Other species of concern in the area include offshore killer whales (considered ***special concern*** under SARA), the leatherback turtle (listed as ***endangered*** under the ESA and SARA), and the green turtle (listed ***threatened*** under the ESA).

On 11 February 2009, L-DEO requested that the U.S. National Marine Fisheries Service (NMFS) issue an Incidental Harassment Authorization (IHA) to authorize non-lethal "takes" of marine mammals incidental to the airgun operations in the Northeast Pacific Ocean (LGL Ltd. 2009a). The IHA was requested pursuant to Section 101(a)(5)(D) of the MMPA. An Environmental Assessment (EA) was prepared to evaluate the potential impacts of the ETOMO survey (LGL Ltd. 2009b). NSF, the federal agency sponsoring the seismic study, reviewed and concurred with the conclusions of the EA that the proposed seismic survey would not have a significant impact on the environment, and a 'Finding of No Significant Impact' was issued. The IHA was issued by NMFS on 19 August 2009 (Appendix A). It authorized "potential take by harassment" of marine mammals during the ETOMO seismic program described in this report, provided that various monitoring and mitigation measures were implemented by L-DEO.

This document serves to meet reporting requirements specified in the IHA, and to provide general information on the monitoring and mitigation program as relevant to other interested groups. The primary purposes of this report are to describe the ETOMO seismic program, to describe the associated marine

mammal and sea turtle monitoring and mitigation programs and their results, and to estimate the numbers of marine mammals potentially affected by the project.

Incidental Harassment Authorization and Safety Radii

IHAs issued under provisions of the U.S. MMPA to seismic operators include provisions to minimize the possibility that marine mammals close to the seismic source might be exposed to levels of sound high enough to cause hearing damage or other injuries, and to reduce other effects insofar as practical. Similarly, the Statement of Canadian Practice (SCP; http://www.dfo-mpo.gc.ca/oceans-habitat/oceans/im-gi/seismic-sismique/pdf/statement-enonce_e.pdf), developed by the Canadian Department of Fisheries and Oceans (DFO) in consultation with other Canadian agencies and some provincial governments, seeks to standardize the mitigation measures used in Canada with respect to the conduct of marine seismic surveys in order to minimize impacts on marine mammals and sea turtles.

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

Under NMFS guidelines (e.g., NMFS 2000), "safety radii" for marine mammals around airgun arrays are customarily defined as the distances within which the received pulse levels are ≥180 dB re 1 μPa_{rms}[1] for cetaceans and ≥190 dB re 1 μPa_{rms} for pinnipeds. Those safety radii are based on an assumption that seismic pulses received at lower received levels are unlikely to injure these mammals or impair their hearing abilities, but that higher received levels *might* have some such effects. The mitigation measures required by IHAs are, in large part, designed to avoid or minimize exposure of cetaceans and pinnipeds to sound levels exceeding 180 and 190 dB re 1 μPa_{rms}, respectively. The 180-dB re 1 μPa_{rms} criterion is also typically used as the safety (shut-down) criterion for sea turtles. The Canadian SCP specifies a safety radius of 500 m without specific reference to received sound levels at particular distances.

Due to concerns raised by DFO, the safety radius around the 36-airgun array for marine mammal species listed under SARA was based on the distance within which the received levels of airgun sounds was expected to diminish to 160 dB re 1 μPa_{rms}. For all other species, the safety criteria specified by NMFS [based on levels exceeding 180 and 190 dB re 1 μPa_{rms} for cetaceans (and sea turtles) and pinnipeds, respectively] were used. The 500-m safety radius, as specified by the SCP, was used around a

[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.

single operating airgun for SARA-listed marine mammal species and sea turtles, as it was larger than the distances based on the NMFS criteria.

Disturbance to marine mammals could occur at distances beyond the safety (=shut down) radius if the mammals were exposed to moderately strong pulsed sounds generated by the airguns (Richardson et al. 1995). NMFS assumes that marine mammals exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} are likely to be disturbed appreciably. That assumption is based mainly on data concerning behavioral responses of baleen whales, as summarized by Richardson et al. (1995) and Gordon et al. (2004). Delphinids, some porpoises, and most pinnipeds are generally less responsive (e.g., Harris et al. 2001; Stone 2003; Gordon et al. 2004; Bain and Williams 2006; Weir 2008), and 170 dB re 1 μPa_{rms} may be a more appropriate criterion of behavioral disturbance for those groups (see LGL Ltd. 2009a,b). In general, disturbance effects are expected to depend on the species of marine mammal, the activity of the animal at the time, its distance from the sound source, and the received level of the sound and the associated water depth. Some individuals respond behaviorally at received levels somewhat below 160- or 170-dB re 1 μPa_{rms}, but others tolerate levels somewhat above those levels without reacting in a substantial manner.

A notice regarding the proposed issuance of an IHA for the ETOMO seismic study was published by NMFS in the U.S. *Federal Register* on 8 May 2009, and public comments were invited (NMFS 2009a). The U.S. Marine Mammal Commission (MMC), Cetacean Society International (CIS), and Wild at Heart Legal Defense Association (WaH) submitted comments.

On 19 August 2009, L-DEO received the IHA that had been requested for the seismic study. On 25 August 2009, NMFS published a second notice in the *Federal Register* to announce the issuance of the IHA (NMFS 2009b). This notice responded to the received comments and provided additional information concerning the IHA and any changes from the originally proposed IHA. A copy of the IHA, as well as the Biological Opinion's Incidental Take Statement (ITS) provided in the Biological Opinion issued by NMFS concerning the permitting action, are included in this report as Appendix A.

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

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

Mitigation and Monitoring Objectives

The objectives of the mitigation and monitoring program were described in detail in L-DEO's IHA Application (LGL Ltd. 2009a) 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 2009a,b).

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

or during ramp up to full power. In these cases, the start of airgun operations was to be delayed or ramp up discontinued until the safety 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 ETOMO seismic study that took place in the Northeast Pacific Ocean from 22 August to 19 September 2009, including the associated monitoring and mitigation program, and to present results as required by NMFS in the IHA (Appendix A) and in the ITS. This report includes four chapters:

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

Those chapters are followed by Acknowledgements and Literature Cited sections.

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

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

2. SEISMIC PROGRAM DESCRIBED

The ETOMO survey took place ~250 km southwest of Vancouver Island, B.C., Canada (Fig. 2.1). Procedures used to obtain seismic data during the study were similar to those used during previous high-energy seismic surveys conducted by L-DEO with the *Langseth*. A 36-airgun array was used as the energy source, and the acoustic receiving system consisted of OBSs.

In addition to the airgun operations, a 12-kHz MBES and a lower energy 3.5 kHz SBP were used to map the bathymetry and sub-bottom conditions. An acoustic release transponder was also used to communicate with the OBSs. The *Langseth* also towed a hydrophone array to detect calling cetaceans by PAM methods (see Chapter 3). The long hydrophone streamer(s) used as acoustic receivers during some other cruises were not deployed during this cruise.

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

Operating Areas, Dates, and Navigation

The study was within the area 47°–49°N and 127°30'–130°W (Fig. 2.1). Water depths in the survey area were >1000 m. The ship departed Astoria, Oregon, on 22 August 2009, for transit to the study area. OBSs were deployed upon arrival in the study area. Seismic operations commenced on 26 August and took place along the gray-shaded lines ("Ship Track Exposed") shown in Figure 2.1. Airgun operations occurred during the day and at night, concluding on 10 September. OBSs were recovered 10–16 September, and the vessel arrived in Astoria on 19 September. A summary of the total distances traveled by the *Langseth* during the ETOMO survey, distinguishing periods with and without seismic operations, is presented in Table ES.1 (in *Executive Summary*).

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

The airguns were configured as four identical linear arrays or "strings" (Fig. 2.2). Each string had 10 airguns; the first and last airguns in the strings were spaced 16 m apart. Nine airguns in each string fired simultaneously, whereas the tenth was kept in reserve as a spare, to be turned on in case of failure of another airgun. The four airgun strings were distributed across an approximate area of 24×16 m behind the *Langseth*. The array was towed ~100 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 or 15 m and at an average speed of ~4.5 kt (8.3 km/h). The shot spacing was ~250 m (or ~105 s) or ~500 m (or ~210 s) depending on which line was being surveyed. These are relatively long short intervals as compared with those

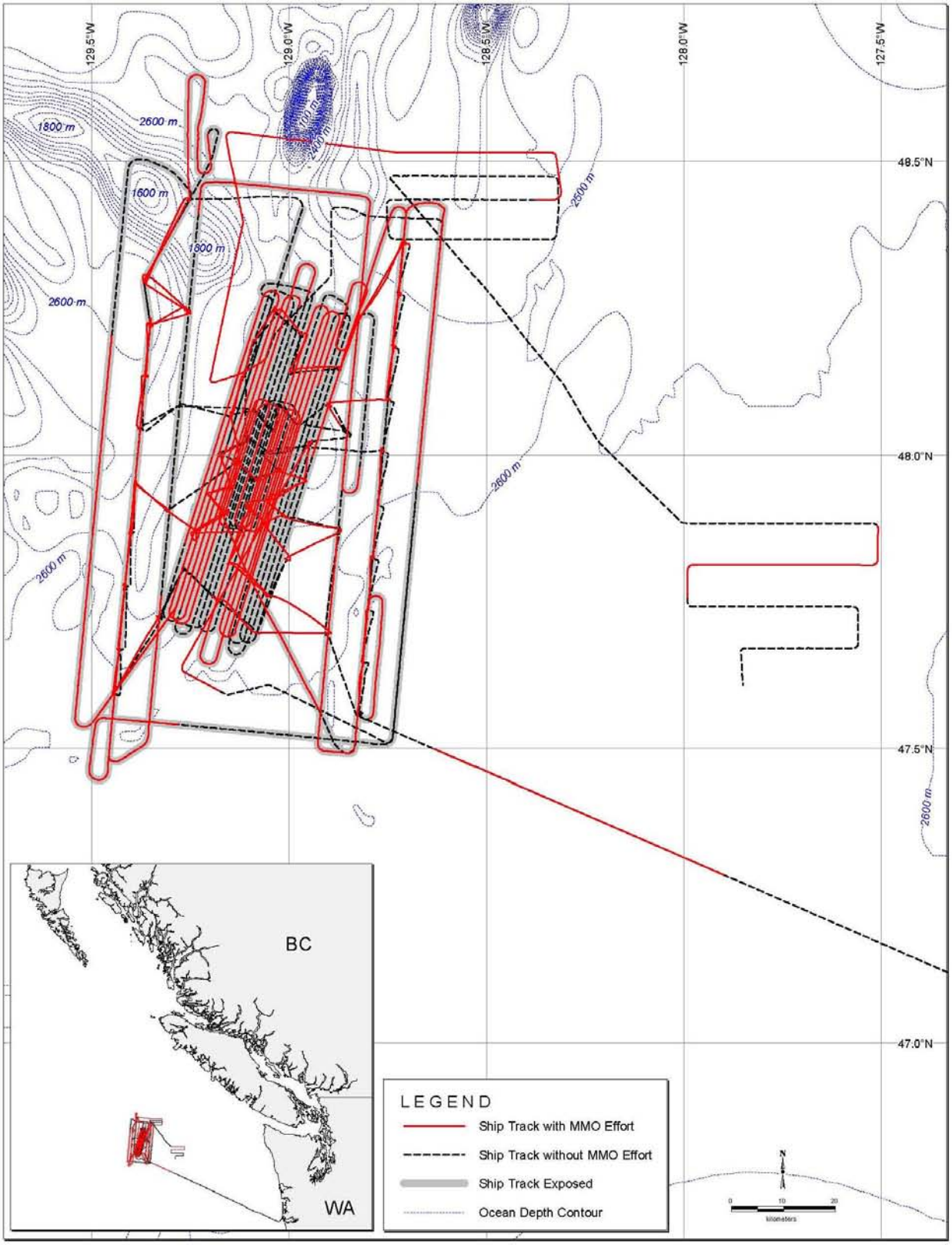

FIGURE 2.1. Map of the ETOMO study area showing ship tracks and acquired seismic lines ("Ship track exposed") during 22 August–19 September 2009.

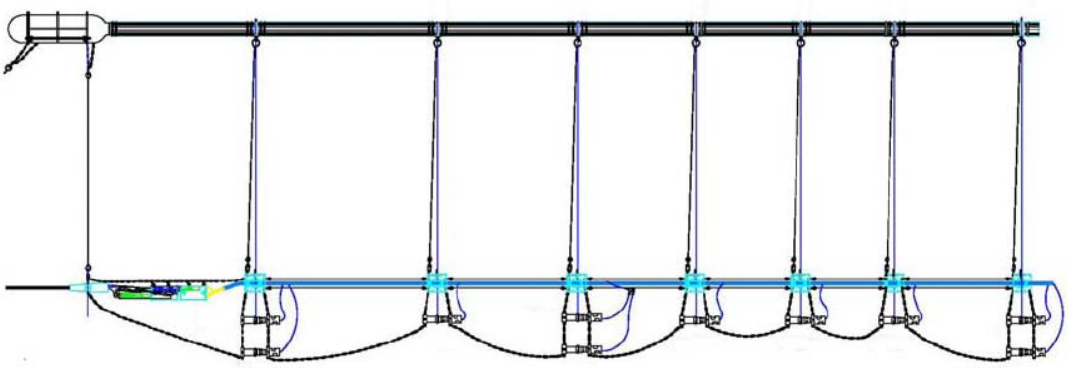

FIGURE 2.2. One of the four linear airgun arrays or strings with ten airguns. Nine airguns per string are active during seismic operations.

during many other seismic surveys, i.e., fewer shots were fired per kilometer of trackline and per hour of operations as compared with most seismic surveys.

The nominal source level for downward propagation of low-frequency energy from the 36-airgun array is shown in Table 2.1. The nominal source level would be somewhat higher if the small amount of energy at higher frequencies were considered. Because an airgun array is a distributed sound source (many airguns spread over a 24×16 m area) rather than a single point source, the highest sound level measurable at any location in the water is considerably less than the nominal source level (Caldwell and Dragoset 2000). In addition, the effective source level for sound propagating in near-horizontal directions is substantially lower than the nominal source level applicable to downward propagation because of the directional nature of the dominant low-frequency sound from the airgun array. The source level expressed on the rms basis used elsewhere in this report would be lower than the peak-to-peak and zero-to-peak source levels listed in Table 2.1, but source levels of airguns and airgun arrays are not normally determined on an rms basis by airgun manufacturers or geophysicists.

Other Airgun Operations

Airguns operated during certain other periods besides seismic acquisition (line shooting), including periods during ramp ups, after power downs, and during seismic testing and most line changes. Ramp ups were required by the IHA (see Chapter 3). Ramp ups involved a systematic increase in the number of airguns firing; additional airguns began firing every 5 min on a schedule, ensuring 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 of >9 min without airgun operations or anytime when the number of airguns was increased by a factor greater than 2×.

TABLE 2.1. Specification of the 36-airgun array used during L-DEO's ETOMO survey, 22 August to 19 September 2009.

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

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

Multibeam Bathymetric Echosounder and Sub-bottom Profiler

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

3. MONITORING AND MITIGATION METHODS

This chapter describes the marine mammal and sea turtle monitoring and mitigation measures implemented for L-DEO's ETOMO seismic study, addressing the concerns raised by DFO and the requirements specified by NMFS 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 implemented by L-DEO, as required by NMFS and identified in the SCP and by DFO, is then presented. The chapter ends with a description of the monitoring methods implemented for this cruise from aboard the *Langseth*, and a description of data analysis methods.

Monitoring Tasks

The main purposes of the vessel-based monitoring were to ensure that the provisions of the IHA, ITS, and SCP were satisfied, effects on marine mammals and sea turtles were minimized, and residual effects on animals were documented. The monitoring objectives 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.

During the ETOMO study, a total of six MMOs were aboard the *Langseth* and dedicated to the marine mammal and turtle monitoring and mitigation work (visual and passive acoustic). The MMO team included a lead MMO from biological contractor LGL Ltd., environmental research associates; a lead PAM specialist from acoustical contractor Right Waves; one Canadian MMO (recommended by DFO), and three L-DEO MMOs.

Safety and Potential Disturbance Radii

Under NMFS guidelines (e.g., NMFS 2000), "safety radii" for marine mammals around airgun arrays are customarily defined as the distances within which received pulse levels are ≥180 dB re 1 μPa_{rms} for cetaceans and ≥190 dB re 1 μPa_{rms} for pinnipeds. These safety criteria are based on an assumption that seismic pulses received at lower received levels are unlikely to injure these animals or impair their hearing abilities, but that higher received levels *might* have some such effects. Marine mammals exposed to ≥160 dB re 1 μPa_{rms} are assumed by NMFS to be potentially subject to behavioral disturbance. However, for certain groups (delphinids, some porpoises, and some pinnipeds), overt behavioral disturbance is usually not observed unless received levels are higher, e.g., ≥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; see background on sound modeling in Appendix B). The radii depend on water depth (see Tolstoy et al. 2004a,b, 2009)[2] as well as tow depth of the airgun array. A tow depth of ~9 or 15 m was used during the ETOMO survey. Following precedents established in the past by NMFS, the 180-dB distance was proposed as the safety radius for cetaceans and sea turtles, and the 190-dB distance was proposed for pinnipeds; the IHA adopted those recommendations. However, due to concerns raised by DFO, the safety radius around the 36-airgun array for marine mammal species listed under SARA was based on the distance within which the received levels of airgun sounds was expected to diminish to 160 dB re 1 μPa_{rms}. For all other species, the safety criteria specified by NMFS [based on levels exceeding 180 and 190 dB re 1 μPa_{rms} for cetaceans (and sea turtles) and pinnipeds, respectively] were used. As the SCP specifies a minimum safety radius of 500 m regardless of airgun configuration, and the distances shown in Table 3.1 for a single airgun were <500 m, a 500-m safety radius was used for SARA-listed marine mammal species and sea turtles when a single airgun was operating during the ETOMO study.

Mitigation Measures as Implemented

Ramp up, power down, and shut down of the airguns are the main mitigation measures employed during most L-DEO seismic cruises conducted under the provisions of IHAs issued by NMFS. These three measures are standard procedures and are described below and in more detail in Appendix D.

Standard mitigation measures implemented during the ETOMO 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. The safety radius for the 36-airgun array implemented for the seismic study was based on acoustic modeling specific to the *Langseth*'s airgun configurations (see Appendix B).
3. Shut-down procedures were to be implemented if a marine mammal or sea turtle was seen within or near the applicable safety radius while the airguns were operating.
4. A change in vessel course and/or speed alteration was identified as a potential mitigation measure if a marine mammal was detected outside the safety radius and, based on its position and motion relative to the ship track, was judged likely to enter the safety radius. However, substantial alteration of vessel course or speed was not practical during the seismic study, given the design of the survey. Shut downs were the preferred and most practical mitigation measures when mammals were sighted within or about to enter the safety radius.
5. Ramp-up procedures were implemented whenever the airgun array was powered up, to gradually increase the size of the operating source at a rate no greater than 6 dB per 5 min, the maximum ramp-up rate authorized by NMFS in the IHA and during past L-DEO seismic cruises. Ramp up from a shut-down condition could not be initiated in low-light (fog) or nighttime conditions if visibility was less than the estimated distance of the safety radius.
6. Ramp up could not proceed if marine mammals or sea turtles were known to be within the safety radius.

[2] The recent empirical results of Tolstoy et al. (2009) were not available when mitigation radii for this project were proposed and adopted by NMFS.

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 at two different tow depths. Distances were estimated for the 36-airgun array and for a single airgun. 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	9–15*	12	40	120	385
4 strings 36 airguns 6600 in^3	9	300	950	2900	6000
	15	380	1220	3615	7690

[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 and Tolstoy et al. 2009 for acoustic results), but the acoustic measurements were not available at the time when requirements for the ETOMO survey were being developed.

7. PAM was conducted during nearly all (91%) seismic operations. Technical difficulties precluded use of PAM during 9% of seismic operations (see Appendix G).
8. If concentrations of beaked whales were observed by MMOs or detected by PAM, at a continental slope site just prior to or during the airgun operations, L-DEO was to move those operations to another location along the slope based on recommendations by the on-duty MMO aboard the *Langseth*.
9. If concentrations of blue, humpback, fin, sei or sperm whales were observed by MMOs or detected by PAM prior to or during the airgun operations, L-DEO was to power down/shut down and/or move the operations to another location based on recommendations by the on-duty MMO aboard the *Langseth*.

In addition, one cruise-specific mitigation measure was also identified by NMFS in the IHA before the start of the ETOMO survey (see Appendix A):

10. If a North Pacific right whale (*Eubalaena japonica*) was visually sighted, the airgun array was to be shut down regardless of the distance of the animal(s) to the sound source. The array would not resume firing until 30 min after the last documented whale visual sighting. [As the North Pacific right whale is a SARA-listed species, the period was extended to 60 min – see below].

However, due to concerns raised by DFO regarding SARA-listed species, more stringent monitoring and mitigation measures were adopted by L-DEO, and some other measures were modified. These procedures are in excess of the conservative measures normally adhered to in accordance with NMFS (as listed above).

11. The NMFS IHA and ITS, as well as the CSP, shall be used for all marine mammals regardless of their stock's status. The mitigation measures outlined in the SARA application to DFO will apply to SARA-listed species.

12. Marine exclusion zone: a SARA-listed marine mammal exclusion zone based on the estimated 160 dB re 1 μPa_{rms} isopleth around the airgun array shall be used when conducting seismic acquisition. For example, the exclusion zone radius will be 7690 m when the full source (6600 in^3) is towed at a depth of 15 m (see Table 3.1). A 500-m exclusion zone will be used when operating the single mitigation airgun (40 in^3).
13. Pre-operations monitoring: the exclusion zone shall be monitored for a minimum of 60 min prior to initial ramp up of the airgun array or resumption of operations following a shut down due to a SARA-listed marine mammal sighting within the exclusion zone.
14. Ramp-up, power-down, and shut-down triggers: ramp ups of the full airgun array will begin with a single airgun and will be gradually increased over ~35 min. A power down to a single 40-in^3 airgun will take place if a SARA-listed marine mammal is observed within or about to enter the 160-dB exclusion zone for the respective source. Following a power down, if the marine mammal approaches the 500-m exclusion zone, the airguns will be shut down immediately.
15. Start-up procedures following shut downs and power downs: airguns will not be ramped up following a shut down unless the 160-dB exclusion zone is visible and monitored by MMO's for at least 60 min. Should a complete shut down occur for more than 9 min when the exclusion zone is not visible (i.e., rough seas, fog, darkness), array ramp up will not be initiated until the entire zone is visible. If for any reason the MMO cannot see the entire radius for the entire 60 min or if SARA-listed marine mammals are near, approaching, or in the safety radius, L-DEO will not start up the airguns. If one airgun is already operating, L-DEO may start the second airgun without observing the entire safety radius for 60 min prior, provided that no SARA-listed marine mammals are known to be near the safety radius.
16. If a SARA-listed marine mammal is observed in the 160-dB exclusion zone, the array is powered down, and the animal is subsequently observed to leave the 160-dB exclusion zone, the array will be powered up upon confirmation that the animal is outside the exclusion zone.
17. In the event that the array is powered down due to a SARA-listed marine mammal sighting, and the animal is not observed to have left the safety radius, ramp up from the single airgun will resume 60 min after the last sighting was made.
18. Passive acoustic monitoring: L-DEO will utilize PAM to the maximum extent practicable, to detect and allow some localization of marine mammals around the *Langseth* during all airgun operations and during most periods when airguns are not operating. One MMO will monitor the PAM at all times in shifts of 1–6 h. A bioacoustician shall design and set up the PAM system, be present to operate or oversee PAM, and be available when technical issues occur during the survey.
19. Use of the multibeam, echosounder, and OBS acoustics is unrestricted.
20. If a North Pacific right whale is visually sighted, the airgun array will be shut down regardless of the distance of the animal(s) to the sound source. Ramp up may occur after the animal(s) has not been seen for 60 min.
21. As no takes were specified by NMFS for elephant seals, the array will be shut down in the unlikely event that an elephant seal sighting is made during seismic operations.
22. L-DEO will ramp down to a radii of 180 dB or 500 m (whichever is larger) for sea turtles.

Visual Monitoring Methods

Visual monitoring methods were designed to meet the requirements identified in the IHA (see above and Appendix A) and to address the concerns raised by DFO. 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 strong airgun sounds. ***(2)*** Document numbers of marine mammals and sea turtles present, and any reactions to seismic activities. The data collected were used to estimate the number of marine mammals potentially affected by the project. Results of the monitoring program for marine mammals and sea turtles are presented in Chapter 4.

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

In summary, during the seismic study, six trained MMOs were aboard the *Langseth* during the period of operations to conduct visual observations and PAM. Two or more MMOs were on watch during 82% of visual observation periods, and one MMO was on watch for the other 18% of that time. Visual observations were generally conducted from the *Langseth*'s observation tower. Observers focused search effort forward of the vessel but also searched aft of the vessel while it was underway. Watches were conducted with the naked eye, Fujinon 7×50 reticle binoculars, and mounted 25×150 Big-eye reticle binoculars. Nighttime visual watches were only required before and during any nighttime startups of the airguns; nighttime visual observations 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) and recommended by the SCP. A requirement for PAM during large-source seismic cruises was first specified by IHAs issued to L-DEO in 2004. Visual monitoring typically is not effective during periods of bad weather or at night, and even with good visibility, is unable to detect marine mammals when they are below the surface or beyond visual range. Acoustical observations can be used in addition to visual observations to improve detection and (at times) 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) which 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, day and night, at most times when the airguns were operating so the visual observers (when on duty) could be advised when cetaceans were heard. This approach had been implemented successfully during previous L-DEO seismic cruises.

The Right Waves towed hydrophone array was the main tool used for PAM during the ETOMO study; a hull-mounted hydrophone was used at times when the towed array could not be used (see Appendices E & H for a description of these systems). Acoustic monitoring software developed by CIBRA (University of Pavia, Italy) was used to display and record cetacean calls detected by the hydrophones (see Appendix D). One MMO monitored the acoustic detection system by listening to the

signals via headphones and by watching a real-time spectrogram display for frequency ranges produced by cetaceans. MMOs monitoring the acoustical data were usually on shift for 1–6 h at a time.

When a cetacean call was heard, the visual observer (if on duty) was immediately notified of the presence of calling marine mammals. Each acoustic "encounter" was 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 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., 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", "non-seismic", or "post-seismic". "Seismic" included all data collected while the airguns were operating, including ramp ups, and periods up to 90 s (1.5 min) after the airguns were shut off. "Non-seismic" data were all data obtained before airguns were activated (pre-seismic) or >6 h after the airguns were turned off. Data collected during "post-seismic" periods from 1.5 min to 6 h after cessation of seismic were considered either "recently exposed" (1.5 min–2 h) or "potentially exposed" (2–6 h) to seismic. The "recently exposed" sub-category was not included in either the "seismic" or "non-seismic" category. The "potentially exposed" sub-category was included under "non-seismic" for sea turtles and pinnipeds, but both post-seismic sub-categories were excluded from all cetacean analyses. The 6-h post-seismic cut-off is the same cut-off used during previous L-DEO cruises that used moderate-sized or large (10–36 airgun) airgun arrays (e.g., Smultea et al. 2004, 2005; Holst et al. 2005b; Holst and Beland 2008; Holst and Smultea 2008; Hauser et al. 2008; Hauser et al. 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 survey operations were sufficiently far in the past that it can be assumed that they had no effect on current behavior and distribution of animals as observed from the ship. Since the rate of recovery to "normal" behavior is unknown, the post-seismic period was defined so as to be sufficiently long (6 h for cetaceans and 2 h for turtles and pinnipeds) 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

Sightings during the "seismic" and "non-seismic" periods were used to calculate sighting rates (#/1000 km). Sighting rates were then used to calculate the corresponding densities (#/km^2) of marine mammals near the survey ship during seismic and non-seismic periods. Density calculations were based on line transect principles (Buckland et al. 2001). Because of assumptions associated with line-transect surveys [sightability, $f(0)$, $g(0)$, etc.], only "useable" effort and sightings were included in density calculations. Effort and sightings were defined as "useable" when made under the following conditions: daylight periods within the seismic survey area, excluding post-seismic periods 90 s to 6 h (cetacean) or

90s to 2 h (pinnipeds and turtles) after airguns were turned off, or when ship speed <3.7 km/h (2 kt), or with seriously impaired sightability. The latter included all nighttime observations, and daytime periods with one or more of the following: visibility <3.5 km, Beaufort Wind Force (Bf)>5, or >60º of severe glare between 90º left and 90º right of the bow. Also, sightings beyond the truncation distance (used for density calculations) were considered non-useable. Although "non-useable" sightings (and associated survey effort) were not considered when calculating densities of marine mammals, such sightings were taken into account when determining the need for real-time mitigation measures (e.g., power downs or shut downs).

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

As for previous related L-DEO cruises, densities during non-seismic periods were used to estimate the numbers of animals that presumably would have been present in the absence of seismic activities. Densities during seismic periods were used to estimate the numbers of animals present near the seismic operation and exposed to various sound levels. The difference between the two estimates can 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. The short duration of the ETOMO seismic operations and the low number of sightings (see Chapter 4) limited the usefulness of this approach in the present survey. Further details on the line transect methodology used during the survey are provided in Appendix D.

Estimating Numbers of Marine Mammals Potentially Affected

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

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

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

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

The two approaches (when based on adequate density data) can be interpreted as providing maximum and minimum (respectively) estimates of the number of marine mammals exposed to sound levels

≥160 dB re 1 μPa_{rms}, or that would have been so exposed had they not moved away from the approaching seismic vessel. The actual number exposed and/or moving away is probably somewhere between these two estimates. This approach was originally developed to estimate numbers of seals potentially affected by seismic surveys (Harris et al. 2001). The approach has been used in various L-DEO reports to NMFS (e.g., Haley and Koski 2004; Smultea et al. 2004, 2005; MacLean and Koski 2005; Holst et al. 2005a,b; Holst and Beland 2008; 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. As noted above, for the present seismic survey, the results were limited by uncertainties in the density data resulting from the short duration of the ETOMO seismic operations and the low number of sightings.

4. MONITORING RESULTS

Introduction

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

Status of Marine Mammals in the ETOMO Study Area

Thirty-three marine mammal species are known to occur off the coast of B.C., including 20 odontocete species (toothed cetaceans, such as dolphins), seven mysticete species (baleen whales), five pinniped species, and the sea otter (see Appendix E). Six of these species are listed as ***endangered*** under the U.S. ESA, including the humpback, sei, fin, blue, North Pacific right, and sperm whales. The eastern stock of Steller sea lions is listed as ***threatened***, as is the northern sea otter. Under the Canadian SARA, the sei, blue, and right whales are listed as ***endangered***; the fin and humpback whales are listed as ***threatened***; and the gray whale, offshore killer whale, harbor porpoise, Steller sea lion, and sea otter are of ***special concern***.

The study area was located ~250 km offshore from B.C. and west of the Olympic Peninsula of Washington State over water depths up to 3000 m deep (Fig. 2.1). Thus, three of the above-mentioned 33 species were not expected in the ETOMO study area because their occurrence off B.C. and Washington is limited to shallow, coastal waters: the gray whale, long-beaked common dolphin, and the sea otter. In the U.S.A., the sea otter is managed by the Fish and Wildlife Service (USFWS) rather than by NMFS. Three other species, the California sea lion, Steller sea lion, and harbor seal, are also mainly coastal. The four most common species in the pelagic waters off the coast of B.C. and Washington are thought to be the Pacific white-sided dolphin, northern right whale dolphin, Risso's dolphin, and Dall's porpoise. Abundances of the Pacific white-sided dolphin and Risso's dolphin are typically highest in spring (Green et al. 1992, 1993; Buchanan et al. 2001; Barlow 2003).

Additional information on the occurrence, distribution, population size, and conservation status for marine mammal species occurring off the coast of southern B.C. is presented in Appendix E.

Status of Sea Turtles in the ETOMO Study Area

Only the leatherback turtle (*Dermochelys coriacea*) and green turtle (*Chelonia mydas*) have been reported in B.C. waters (McAlpine et al. 2004). There are 26 mappable reports of leatherback turtles and 16 mappable reports of green turtles in B.C. waters (McAlpine et al. 2004). Another two species, the loggerhead turtle (*Caretta caretta*) and the olive ridley turtle (*Lepidochelys olivacea*) have been documented off the coasts of Oregon or Washington as strandings, and have also been reported off Alaska. However, they are generally warm-water species and are considered extralimital in those areas (Bowlby et al. 1994; Buchanan et al. 2001; Hodge and Wing 2000 *in* McAlpine et al. 2004).

Visual Monitoring Effort

Here we summarize the visual monitoring effort and sightings from the *Langseth* during the ETOMO seismic survey, 22 August to 19 September 2009. This section summarizes the monitoring results, and Appendix F provides detailed data summaries including visual survey effort subdivided by seismic activity and Beaufort wind force. Table ES.1 shows a general summary of effort and sightings.

The *Langseth* traveled a total of ~5518 km (654 h) during the ETOMO cruise (Table ES.1). Visual observations were obtained for a total of ~2714 km (330 h) within the study area (Table ES.1). One or more observers (usually two) 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 ~3.5 km (0.5 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.

All seismic operations occurred in water >1000 m deep. During the ETOMO survey, most (84%) seismic operations took place with the 36-airgun array. The remaining operations occurred during ramp up, line changes, or operations with fewer airguns. Observation effort with various airgun configurations is shown in Appendix F.

The majority of all visual effort (~62%) took place during seismic periods (Fig. 4.1). Survey conditions were considered "useable" for systematic analysis during ~71% of total visual effort in the study area (Table ES.1). "Useable" effort within the study area excluded nighttime observations, periods 90 s to 6 h after airguns were turned off, poor visibility conditions (visibility <3.5 km or extensive glare), Bf >5, and ship speed <3.7 km/h (2 kt). Also, sightings whose lateral distances from the trackline were outside the truncation distance (used to determine densities) were considered "non-useable", as were sightings of cryptic species in Bf>2 (e.g., Dall's porpoise). Beaufort wind force during observations aboard the *Langseth* ranged from two to seven; most "useable" observations (71%) took place during Bf 3–4 (Fig. 4.2; Appendix F). Sightings and survey effort during "non-useable" conditions were excluded when calculating densities, but were included when determining when power downs or shut downs were necessary because of marine mammals or turtles within the safety zone.

Marine Mammal Sightings

A total of 41 marine mammals in nine groups were sighted during the ETOMO survey (Fig. 4.3; Table 4.1; Appendix F). Dall's porpoise was the most frequently sighted species (5 of 9 sightings, totaling 28 individuals; Table 4.1). A single sperm whale, one group of 10 Pacific white-sided dolphins, one unidentified toothed whale, and one northern elephant seal were also observed. There were no sightings of baleen whales. Except for two Dall's porpoise sightings totaling nine individuals, all other sightings were made during "useable" observation effort (Table 4.1). Only "useable" sightings, along with the corresponding effort data, are considered in the ensuing analyses of detection rates and densities of marine mammals.

Sightings by Seismic State

Eight of the nine marine mammal sightings were made during non-seismic periods (Table 4.1). One group of six Dall's porpoises was potentially exposed, as it was seen ~4 h after the airgun array was shut down (Table 4.1). As no sightings were made during seismic periods, no shut downs of the airgun array were necessary. In addition, no ramp ups needed to be delayed due to marine mammal sightings.

Detection Rate

The detection rate (number of marine mammal groups sighted per 1000 km of "useable" effort) was based on ~1924 km of useable effort, of which 606 km was non-seismic and 1318 km was seismic. Considering all useable sightings and effort during all activities, ~3.6 marine mammal groups were detected per 1000 km (n = 7). Overall detection rates were highest during Bf 2, and lower during higher Bf values (Fig. 4.4). During marine mammal surveys, detection rates are typically related to sea state and wind speed, i.e., Bf, and rougher sea conditions make it more difficult for observers to detect animals, particularly as distance increases (e.g., Buckland et al. 2001).

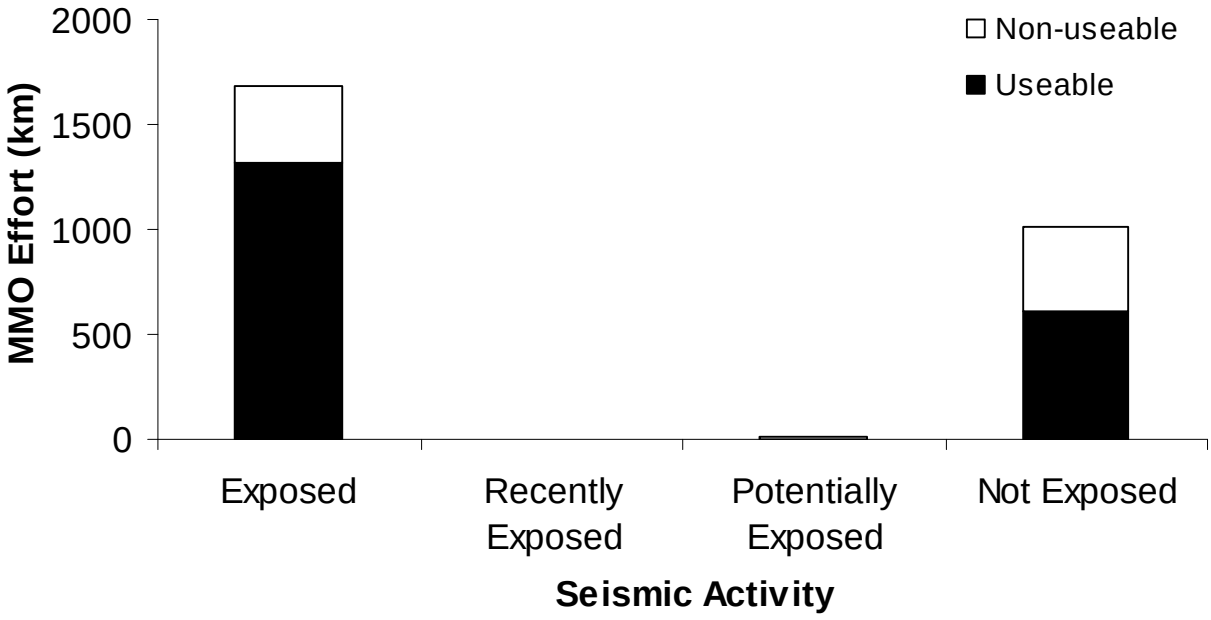

FIGURE 4.1. Total observer effort, categorized by seismic activity, during operations of the *Langseth* in the ETOMO study area, 22 August to 19 September 2009. Recently Exposed includes periods 90 s to 2 h after airguns were turned off. Potentially Exposed includes periods 2−6 h after airguns were turned off.

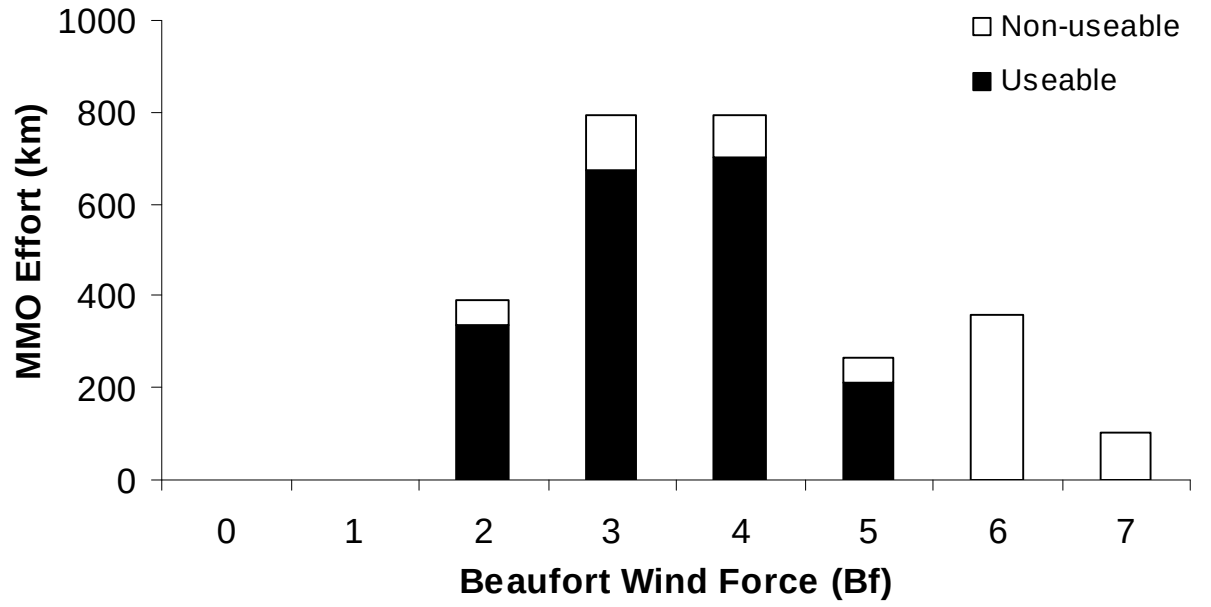

FIGURE 4.2. Total observer effort, categorized by Beaufort wind force, during operations of the *Langseth* in the ETOMO study area, 22 August to 19 September 2009. Sightings of cryptic species (e.g., Dall's porpoise) in Bf>2 are considered non-useable.

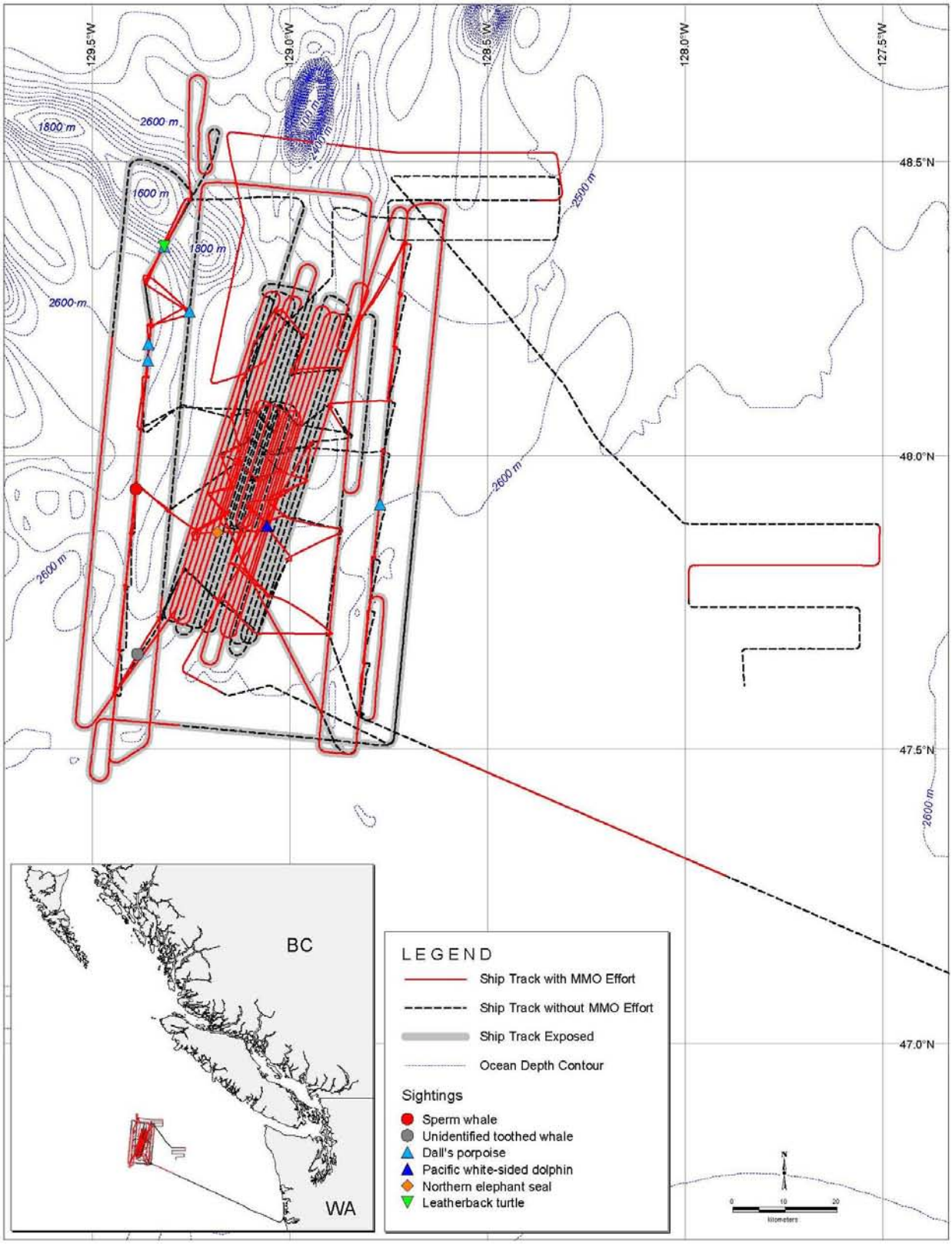

FIGURE 4.3. The ETOMO survey showing the ship track, seismic lines, and sightings of marine mammals and sea turtles, 22 August to 19 September 2009. Airguns operated along the shaded lines ("Ship track exposed").

TABLE 4.1. Numbers of marine mammals observed from the *Langseth* during the ETOMO seismic survey, 22 August to 19 September 2009. There were no sightings during "seismic" or "recently-exposed" periods.

	Potentially Exposed		Non-seismic		Total	
Species	Groups	Indiv.	Groups	Indiv.	Groups	Indiv.
All Sightings						
Sperm whale	0	0	1	1	**1**	**1**
Pacific white-sided dolphin	0	0	1	10	**1**	**10**
Unidentified toothed whale	0	0	1	1	**1**	**1**
Dall's porpoise	1	6	4	22	5	28
Northern elephant seal	0	0	1	1	**1**	**1**
Total	**1**	**6**	**8**	**35**	9	41
Useable Sightings[a]						
Sperm whale	0	0	1	19	**1**	**1**
Pacific white-sided dolphin	0	0	1	10	**1**	**10**
Unidentified toothed whale	0	0	1	1	**1**	**1**
Dall's porpoise	0	0	3	19	3	19
Northern elephant seal	0	0	1	1	**1**	**1**
Total	**0**	**0**	**7**	**50**	7	32

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

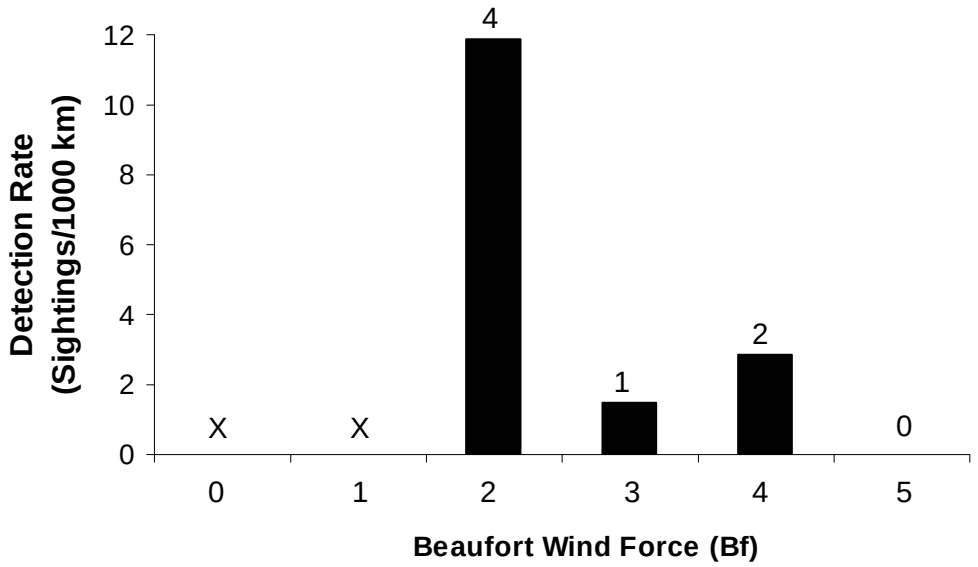

FIGURE 4.4. Marine mammal detection rates (based on useable sightings and effort) from the *Langseth* during different Beaufort wind force conditions during the ETOMO seismic survey, 22 August to 19 September 2009. X = insufficient survey effort. Number of sightings above bars.

Densities

Calculated densities were based on the number of "useable" sightings during seismic and non-seismic periods of the ETOMO survey (Table 4.2). As there were no sightings during airgun operations, densities within visual range of the ship during seismic periods were zero (Table 4.2). Based on observations during non-seismic periods, Dall's porpoise had the highest density in the study area (0.03 animals/km^2), followed by the Pacific white-sided dolphin (0.01 animals/km^2). As noted in Chapter 3, the reliability of the calculated densities was limited by sample size issues.

Distribution and Behavior

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

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

The position of the MMOs on the vessel, and where they focused their observation efforts, yielded a distribution of animal sightings relative to the *Langseth* that was skewed toward the front of the vessel. Most (86% of "useable") initial sightings were of animals in the forward 180º relative to the vessel.

Closest Point of Approach

During the ETOMO survey, the closest observed points of approach for "useable" marine mammal sightings, all during non-seismic periods, were seen ~121–1541 m from the (non-operating) airgun array (Table 4.3). The group of 10 Pacific white-sided dolphins made the closest approach to the non-operating array, with a CPA of 121 m. The farthest sighting involved a group of four Dall's porpoises with a CPA of 1541 m.

TABLE 4.2. Sightings and approximate densities of marine mammals during "useable" survey effort in the ETOMO study area, 22 August to 19 September 2009. Effort consisted of 606 km during non-seismic periods and 1318 km during seismic periods. Marine mammal densities were corrected for *f*(0) and *g*(0) using values from Koski et al. (1998) and Barlow (1999).

	Non-Seismic				Seismic			
	Number of Sightings	Mean group size	Average corrected density (#/km^2)		Number of Sightings	Mean group size	Average corrected density (#/km^2)	
			Density	CV[a]			Density	CV[a]
Sperm whale	1	1	0.00066	0.94	0	-	0	-
Pacific white-sided dolphin	1	10	0.01285	0.94	0	-	0	-
Unidentified toothed whale	1	1	0.00129	0.94	0	-	0	-
Dall's porpoise	3	6	0.03321	0.76	0	-	0	-
Northern elephant seal	1	1	0.00206	0.94	0	-	0	-
	7		**0.05007**	**0.57**	**0**		**0**	

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

TABLE 4.3. Summary of closest observed point of approach (CPA) distances of "useable" marine mammals to the (quiet) airgun array during non-seismic periods in the ETOMO study area, 22 August to 19 September 2009.

	Non-seismic			
Species	**Mean CPA (m)**	**s.d.**	***n*** [a]	**Range (m)**
Sperm whale	579	-	1	-
Pacific-white sided dolphin	121	-	1	-
Unidentified toothed whale	920	-	1	-
Dall's porpoise	773	691	3	199 - 1541
Northern elephant seal	348	-	1	-

Note: s.d. = standard deviation; N/A = Not Applicable.

[a]Useable sightings made during useable visual effort as defined in *Acronyms and Abbreviations* .

Movement and First Observed Behavior

Marine mammals were most often observed to be moving parallel to the vessel, although Dall's porpoises were also seen swimming away, toward, and perpendicular to the vessel (Table 4.4). The northern elephant seal was traveling toward the vessel. The most frequently observed behavior for Dall's porpoises was swimming (4 of 5 sightings; Table 4.5); one group was recorded as bowriding. Other observed marine mammal behaviors included travel, dive, and look (Table 4.5).

Distribution

None of the marine mammal sightings were within the Endeavour MPA, although the northern elephant seal and Pacific white-sided dolphin group were seen just south of the MPA. Sightings of Dall's porpoises were made along the eastern and western portions of the study area, and the sperm whale and unidentified toothed whale were seen in the western part of the study area. Only one sighting (the group of 10 Pacific white-sided dolphins) was obtained before the start of seismic operations; all other sightings were made after seismic operations had ceased. Although Dall's porpoises, Pacific white-sided dolphins, northern right whale dolphins, and Risso's dolphins were all expected to be common in the ETOMO study area, no northern right or Risso's dolphins were seen either before or after seismic operations.

Sea Turtle Sightings

On 11 September, one leatherback sea turtle was sighted in the northwestern portion of the study area when the airgun array was not operating. The turtle was seen swimming 10 m off the port side.

Other Vessels

No vessels were seen within 5 km of the *Langseth* when a marine mammal or sea turtle sighting was made. However, several vessels were seen at other times during the study, including tankers and cargo ships.

TABLE 4.4. Movement categories relative to the *Langseth* for all marine mammal sightings during the ETOMO survey, 22 August to 19 September 2009. All sightings were made during periods when the airguns were not operating.

	Useable Sightings[a]			Non-useable Sightings	
Species	Away	Toward	Parallel	Parallel	Perpendicular
Sperm whale	-	-	1	-	-
Pacific-white sided dolphin	-	-	1	-	-
Unidentified toothed whale	-	-	1	-	-
Dall's porpoise	1	1	1	1	1
Northern elephant seal	-	1	-	-	-

[a]Useable sightings made during useable visual effort as defined in *Acronyms and Abbreviations*.

TABLE 4.5. First observed behavior of all marine mammal sightings from the *Langseth* during the ETOMO survey, 22 August to 19 September 2009. All sightings were made during periods when the airguns were not operating.

	Useable Sightings[a]				Non-useable Sightings	
Species	Swim	Travel	Dive	Look	Swim	Bowride
Sperm whale	1	-	-	-	-	-
Pacific-white sided dolphin	-	1	-	-	-	-
Unidentified toothed whale	-	-	1	-	-	-
Dall's porpoise	3	-	-	-	1	1
Northern elephant seal	-	-	-	1	-	-

[a]Useable sightings made during useable visual effort as defined in *Acronyms and Abbreviations*.

Acoustic Monitoring Effort and Detections

During the ETOMO survey, 22 August to 19 September 2009, 340 h of PAM took place during seismic operations, and 3 h occurred during non-seismic periods (see Appendix G). No acoustic detections of cetaceans were made during the cruise (Appendix G). The PAM system was not operational during any of the eight occasions when odontocetes were detected by visual observers. No odontocete calls were detected on these (or other) occasions.

Mitigation Measures Implemented

Ramp ups, power downs, and shut downs of the airgun array were three of the main mitigation measures planned for use during the ETOMO study; associated visual and acoustic monitoring procedures are outlined in Chapter 3. Ramp ups were conducted whenever the airguns were started up after a prolonged (>9 min) period of inactivity; that occurred only in daylight. Ramp ups also occurred 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). As no marine mammal or turtle sightings were made during seismic periods, power downs and shut downs were not necessary during the ETOMO cruise. No ramp ups needed to be delayed due to sightings.

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

In order to minimize the incidental 'taking' of marine mammals and sea turtles, including those listed under the ESA, L-DEO implemented (or was prepared to implement, if necessary) all the mitigation measures listed in Chapter 3, including shut downs for animals sighted near or within the safety radius. No humpback, blue, fin, sei, or North Pacific right whales were seen during the ETOMO survey; therefore, few if any individuals of these species are likely to have occurred within the safety radius.

In addition to the typical monitoring and mitigation measures such as ramp ups, power downs, and shut downs (see Chapter 3), the ITS and IHA also specified the immediate shut down of airguns in the event a North Pacific right whale was sighted at any distance from the vessel. In addition, the IHA specified avoidance of concentrations of beaked, blue, humpback, sei, and sperm whales. No right whale or concentration of marine mammals was seen during the survey. One sperm whale and one leatherback turtle were seen during the ETOMO survey during non-seismic periods. Thus, these individuals were not exposed to strong sounds from the airgun array. In addition, no injured Pacific salmon, steelhead, or other fish or fish-kills were observed during the ETOMO 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 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, 2009).

Any marine mammal that might have been exposed to airgun pulses with received sound levels ≥160 dB re 1 μPa_{rms} (flat-weighted) was assumed to have been potentially disturbed. Although such disturbance was authorized by the IHA, L-DEO agreed not to expose SARA-listed marine mammals to sounds exceeding 160 dB. Since the 160-dB criterion was developed by NMFS from studies of baleen whale reactions to seismic pulses (Richardson et al. 1995), the criterion likely is not appropriate for delphinids, some porpoises, and pinnipeds. The hearing of small odontocetes is relatively insensitive to low frequencies, and behavioral reactions of most small odontocetes (including some porpoises) to airgun sounds indicate that they are usually less responsive than are some baleen whales (Richardson et al. 1995; Gordon et al. 2004). We estimate the numbers of all marine mammals that were exposed to ≥160 dB re 1 μPa_{rms}, as required by the IHA, but we also estimate numbers of delphinids, Dall's porpoises, and elephant seals that might have been exposed to ≥170 dB re 1 μPa_{rms}, an alternative and more realistic criterion of disturbance to delphinids, some porpoises, and pinnipeds.

Table 3.1 shows the predicted received sound levels at various distances from the airgun(s) deployed from the *Langseth* in deep water. The ≥160-dB radius is an assumed behavioral disturbance criterion. As discussed above, the 170 dB-radius was used as an alternative criterion in estimating potential disturbance of delphinids, Dall's porpoises, and northern elephant seals. During this project, NMFS and DFO required that mitigation measures be applied to avoid, or minimize, the exposure of marine mammals to strong seismic sounds. As no marine mammals were sighted during seismic operations, no power downs or shut downs were required during the ETOMO survey.

The estimated distances in Table 3.1 are the *maximum* distances from the airgun array where sound levels were expected to exceed certain values. These distances would apply at the water depth with maximum received level and in the direction (from the airgun array) where the sounds were strongest. Thus, there are complications in assessing the maximum level to which any specific individual mammal might have been exposed:

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

This section applies two methods to estimate the number of marine mammals possibly exposed to seismic sound levels strong enough that they might have caused disturbance or other potential impacts.

The procedures include ***(A)*** minimum estimates based on the direct observations of marine mammals by MMOs, and ***(B)*** estimates based on observed marine mammal densities obtained during this study allowing for animals not seen by MMOs. The actual numbers of individual marine mammals exposed to, and potentially affected by, seismic survey sounds likely were between the minimum and maximum estimates provided in the following sections. The estimates provided here are based on observations during this project. In contrast, the estimates provided in the IHA Application and EA for this project (LGL Ltd. 2009a,b) were based on survey and other information available prior to the fieldwork.

Estimates from Direct Observations

Generally, the number of marine mammals observed close to the *Langseth* during a given seismic study provides a minimum estimate of the number potentially affected by seismic sounds. During the ETOMO study, no marine mammals were seen while the airguns were operating; thus, none of the observed animals were exposed to strong airgun sounds.

However, even during daylight, it is unlikely that MMOs were able to detect all of the marine mammals near the vessel trackline, and some animals probably moved away before coming within visual range of MMOs. During daylight, animals are missed if they are below the surface when the ship is nearby. Some other marine mammals, even if they surface near the vessel, are missed because of limited visibility (e.g., fog), glare, or other factors limiting sightability. Also, sound levels were estimated to be ≥160 dB re 1 μPa_{rms} out to as much as ~7.7 km when the 36-airgun array was in use (see Table 3.1)[3]; thus, some marine mammals (especially the smaller or less conspicuous species) exposed to ≥160 dB (rms) may have been missed even with good sighting conditions.

Furthermore, marine mammals cannot be seen effectively during periods of darkness. Airgun operations occurred at night as well as during daytime. MMOs were generally not required to be (and usually were not) on duty at night given the recognition that nighttime visual observations are largely ineffective. During the ETOMO study, ~42% of the airgun operations occurred at night, but only 0.5 h of survey effort occurred during darkness. Even during the periods when MMOs were on duty at night, they had much reduced ability to sight mammals.

Notwithstanding these limitations, it is likely that few marine mammals occurred close to the ship during airgun operations either by day or by night, given the lack of sightings during daytime and the lack of acoustic detections either by day or by night.

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 (rms) radii around the source (i.e., up to 7.7 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 marine mammals 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 marine mammals might be affected by the airguns

[3] Empirical data on underwater sound levels near the *Langseth*'s 36-airgun array operating at 6-m depth in the northern Gulf of Mexico became available after procedures for the ETOMO survey had been defined. The empirical data indicate that, at least in the northern Gulf of Mexico, levels ≥160 dB re 1 μPa_{rms} *typically* extend out to ~2.7 km (not 6 km, *cf.* Table 3.1) in deep water and to ~12.5 km in shallow water; the 160 dB distance *occasionally* extended to ~3 km (deep water) and ~16 km (shallow water) (Tolstoy et al. 2009). Corresponding empirical distances for 170 dB re 1 μPa_{rms} were typically ~1.3 km (deep) and 3.7 km (shallow), and occasionally as much as ~1.6 and 5.2 km. In this report, estimated numbers of exposures to various sound levels are based on radii specified in the IHA (Table 3.1 and Appendix A).

beyond the distance at which they are detectable by MMOs is impossible to determine from shipboard MMO data.

Estimates Extrapolated from Marine Mammal Density

The methodology used to estimate the areas exposed to received levels ≥160 dB, ≥170 dB, and ≥180 dB re 1 μPa_{rms}, and to estimate corrected marine mammal densities, was described briefly in Chapter 3 *Analyses* and in further depth in Appendix D. Densities were based on the number of "useable" sightings during the survey. Densities calculated from non-seismic periods represent the densities of mammals expected to occur "naturally" within the area (assuming that, during non-seismic periods, there was little bias associated with avoidance of or attraction to the ship). Densities calculated from useable sightings (if any) and effort during seismic periods represent the densities of mammals that apparently remained within the area exposed to strong airgun pulses; densities during seismic periods for the ETOMO survey were zero. The corrected densities can be used to estimate the number of marine mammal exposures to 160 dB and 170 dB, and the number of different individuals exposed (or the numbers that would have occurred if the animals had not moved away before airgun sound levels reached 160 or 170 dB). These numbers provide estimates of the number of animals potentially affected by seismic operations, as described in Chapter 3 and Appendix D.

Estimated Numbers of Cetaceans Exposed to (or Avoiding) ≥160 or ≥170 dB.—For all types of marine mammals, Table 4.5 shows numbers estimated to be exposed to ≥160 dB re 1 μPa_{rm} (or that would have been exposed if they had not avoided), based on data from non-seismic periods. That table also shows estimated numbers of delphinids, Dall's porpoises, and seals exposed to (or avoiding) ≥170 dB. It is assumed that non-delphinid cetaceans (e.g., sperm whales) are likely to be disturbed appreciably if exposed to received levels of seismic pulses ≥160 dB re 1 μPa_{rms}. It is assumed that delphinids and some porpoises and pinnipeds are unlikely to be disturbed appreciably unless exposed to received levels ≥170 dB, but we also estimate the (larger) numbers of animals exposed to (or avoiding) levels ≥160 dB. These are not considered to be "all-or-nothing" criteria; some individual mammals may react strongly at lower received levels, but others are unlikely to react strongly unless levels are substantially above 160 or 170 dB. The data used to calculate these numbers include the densities presented in Table 4.2 and the ensonified areas presented in Table 4.6 (which in turn are based on the estimated 160 and 170 dB radii listed in Table 3.1).

"Corrected" estimates of the densities of marine mammals present during non-seismic periods are given in Table 4.2. These corrected densities were used to estimate the number of marine mammals that were exposed to (or avoided) levels ≥160 and ≥170 dB, and thus potentially disturbed by seismic operations (Tables 4.5). Because of the low number of sightings during non-seismic periods (Table 4.1), among other considerations, these estimates should be considered very approximate.

(A) 160 dB re 1 μPa_{rms}: We estimate that there would have been ~1922 exposures of ~439 different individual marine mammals to ≥160 dB during the seismic survey if no marine mammals moved out of the ≥160-dB zone in response to the approaching airguns (Table 4.5). These estimates include 26 exposures of six individual sperm whales—the one ESA-listed species that was sighted during the project. The "exposures" estimate would be reasonable if marine mammals did not react to the approaching seismic vessel. The "individuals" estimate would be reasonable if there was no reaction, and if marine mammals remained largely stationary throughout the study.

Both of these assumptions are unlikely. The actual numbers of individuals that were exposed to ≥160 dB re 1 μPa_{rms}, or that moved away in response to the approaching seismic vessel before levels

TABLE 4.5. Estimated numbers of exposures and minimum number of individual marine mammals potentially exposed to (or avoiding) airgun sounds with flat-weighted received levels ≥160 dB re 1 μPa_{rms} and ≥170 dB during non-seismic and seismic periods of the ETOMO survey, 22 August to 19 September 2009. These estimates are based on acoustic radii listed in Table 3.1, ensonified areas listed in Table 4.6, and "corrected" marine-mammal densities during non-seismic and seismic periods (Table 4.2). "Observed' densities were corrected using the best-available *f*(0) and *g*(0) adjustments (Table 4.2). Requested takes and takes authorized by NMFS are also shown (see Appendix A; LGL Ltd. 2009a,b). ESA-listed species are shown in italics.

	Non-Seismic				Seismic		
	No. of Exposures		No. of Individuals		No. of Exposures	No. of Individuals	Requested/ Authorized Take
Species	≥160 dB	≥170 dB	≥160 dB	≥170 dB			
Balaenopteridae							
North Pacific right whale	0	-	0	-	0	0	0
Humpback whale	0	-	0	-	0	0	6
Minke whale	0	-	0	-	0	0	5
Sei whale	0	-	0	-	0	0	1
Fin whale	0	-	0	-	0	0	8
Blue whale	0	-	0	-	0	0	2
Physeteridae							
Sperm whale	26	-	6	-	0	0	**10**
Dwarf sperm whale	0	-	0	-	0	0	**9**
Kogia sp.	0	-	0	-	0	0	**0**
Ziphiidae							
Cuvier's beaked whale	0	-	0	-	0	0	**0**
Baird's beaked whale							**13**
Blainville's beaked whale	0	-	0	-	0	0	**2**
Hubb's beaked whale	0	-	0	-	0	0	**2**
Stejneger's beaked whale	0	-	0	-	0	0	**2**
Delphinidae							
Bottlenose dolphin	0	0	0	0	0	0	**0**
Pacific white-sided dolphin	493	235	113	86	0	0	**181**
Striped dolphin	0	0	0	0	0	0	**0**
Short-beaked common dolphin	0	0	0	0	0	0	**104**
Risso's dolphin	0	0	0	0	0	0	**95**
Northern right-whale dolphin	0	0	*0*	0	0	0	**142**
False killer whale	0	0	*0*	0	0	0	**0**
Killer whale	0	0	0	0	0	0	**12**
Short-finned pilot whale	0	0	*0*	0	0	0	**0**
Unidentified toothed whale	*49*	24	11	9	0	0	-
Phocoenidae							
Harbor porpoise	0	-	0	-	0	0	**0**
Dall's porpoise	1275	608	291	223	0	0	**1081**
Pinnipeds							
Northern elephant seal	79	38	18	14	0	0	-
Northern fur seal	0	0	0	0	0	0	**73**
Total Marine Mammals	**1922**	**905**	**439**	**331**	**0**	**0**	**1748**

TABLE 4.6. Estimated areas ensonified to ≥160 and ≥170 dB re 1 μPa_{rms} (averaged over pulse duration) in the ETOMO study area, with and without overlapping areas; overlapping ensonified area was used for estimating the number of exposures, and non-overlapping ensonified area was used for estimating the number of individuals exposed. Ensonified areas are calculated two ways, with areas that were ensonified to ≥160 or ≥170 dB more than once being re-counted in the "With Overlap" column but not in the "No Overlap" column.

	Ensonified Area (km^2)	
dB re 1 μPa_{rms} Criteria	With Overlap	No Overlap
160	38381	8767
170	18310	6704

reached 160 dB, are expected to be somewhere between the "exposures" and "individuals" estimates shown in Table 4.5.

(B) 170 dB re 1 μPa_{rms}: On average, delphinids, Dall's porpoise, and pinnipeds may be disturbed only if exposed to received levels of airgun sounds ≥170 dB re 1 μPa_{rms} (flat-weighted). If so, then the estimated number of exposures would be ~50% of the corresponding estimates for ≥160 dB, based on the proportionally smaller area exposed to ≥170 dB. Based on densities estimated from MMO observations during non-seismic periods, the estimated number of exposures to (or cases of avoidance of) ≥170 dB included 608 Dall's porpoises, ~259 delphinids, and 38 northern elephant seals (Table 4.5). The number of individuals exposed to ≥170 dB (or that moved away before the received level reached 170 dB) is estimated as ~223 porpoises, 95 delphinids, and 14 northern elephant seals (Table 4.5).

Summary of Exposure Estimates.—Estimates of the numbers of exposures to strong sounds are considered *maximum* estimates of the number of mammals exposed. In this method, repeated exposures of some of the same animals are counted separately, with no allowance for overlapping survey lines. This method, when based on densities during non-seismic periods, also assumes that no mammals move far enough away, before received sound levels reach the sound level in question, to avoid exposure to that sound level. Based on corrected densities of marine mammals during non-seismic periods, ~1922 potential marine mammal exposures to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} might have occurred during the survey, involving ~439 individuals. The estimates during seismic periods were zero, given the lack of sightings by MMOs on the seismic vessel during airgun operations. If delphinids, Dall's porpoises, and pinnipeds are assumed to be disturbed at an average received level 170 dB rather than 160 dB re 1 μPa_{rms}, these estimates are reduced (Table 4.5).

The lack of sightings during airgun operations indicates that some avoidance of the approaching vessel occurred. However, the estimated 170 dB (rms) distance and especially the 160 dB (rms) distance (Table 3.1) were the distances where MMOs can reliably detect various marine mammal species. Thus, it is not known what proportion of the animals estimated to be present based on non-seismic densities began avoiding the approaching seismic vessel at a distance sufficiently large to avoid exposure to ≥160 dB or ≥170 dB. Following the practice during analysis of results from other recent L-DEO seismic projects, we assume that the number of animals estimated as either exposed to ≥160 dB or avoiding such exposure by moving away should be considered in relation to the number of "takes" authorized by NMFS.

The calculated numbers of individual cetaceans exposed to (or avoiding) ≥160 dB (rms) were lower than the requested and authorized takes. The requested and authorized takes were based on ***best estimates*** of the numbers of marine mammals that might occur in the survey area during the survey period, an

approach that tends to overestimate the number ***likely*** to be there. The requested takes were also calculated based on marine mammal densities found in the literature, rather than the actual densities observed during the 2009 study period at times when airguns were silent. Note that the estimates *do* include approximate allowance for animals missed by the observers during daytime, and for the animals assumed to be present at night. The allowance for missed animals is based on application of "best available" correction factors [i.e., $f(0)$ and $g(0)$ factors] during daytime.

Summary and Discussion

During the ETOMO cruise, one or more (usually two) MMOs were on watch for ~330 h, and during this time there were eight sightings totaling 40 cetaceans, one northern elephant seal, and one leatherback sea turtle. As none of these sightings were made during seismic operations, it was never necessary to power down or shut down the airgun array in response to marine mammal or sea turtle sightings.

The seismic program included 211 h of "useable" visual observation effort and 343 h of PAM effort. No acoustic detections were made. Dall's porpoise was the most commonly observed marine mammal species during the ETOMO study. Considering all "useable" survey effort and sightings, ~3.6 marine mammal groups were detected per 1000 km. During non-seismic periods, Dall's porpoise had the highest density.

During non-seismic periods within the ETOMO study area, swimming was the most frequently observed behavior of marine mammals, and most groups were moving parallel to the vessel. Behavior and movement of marine mammals could not be compared during seismic and non-seismic periods because there were no sightings during seismic periods.

The estimated number of exposures to (or cases of avoidance of) received levels ≥160 dB re 1 μPa_{rms} was based on sightings and effort during non-seismic periods. Although the duration of observations was limited and there was a correspondingly low number of sightings, these data contribute to the overall accumulation of similar data across this and other L-DEO seismic surveys. In any case, the estimated numbers of individual cetaceans exposed to strong airgun sounds during L-DEO's ETOMO survey was lower than that authorized by NMFS. Also, based on direct observation, the number of elephant seals potentially exposed to levels ≥160 dB re 1 μPa_{rms} was zero.

Although no marine mammal sightings were made within the Endeavour MPA during the ETOMO cruise, seismometers that were deployed near the hydrothermal vent fields from 2003-2006 detected fin and blue whale calls every year (Soule et al. 2009). Call rates showed seasonal variability, with the highest rates recorded from November through January and fewest calls from May to August (Soule et al. 2009). Although enhanced concentrations of zooplankton have been documented above hydrothermal vent fields, it is uncertain whether this translates into higher densities of whales above the vent fields (Gisiner et al. 2009; Soule et al. 2009). Blue and fin whale calls have been detected by bottom-mounted hydrophones deployed in/near B.C. waters by McDonald et al. (1995) and Stafford et al. (2001), and recent sightings of blue whales have been reported for B.C. (Calambokidis et al. 2009).

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APPENDIX A:[4]
INCIDENTAL HARASSMENT AUTHORIZATION ISSUED TO L-DEO FOR THE ETOMO SEISMIC STUDY

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

Incidental Harassment Authorization

Lamont-Doherty Earth Observatory, Columbia University, P.O. Box 1000, 61 Route 9W, Palisades, New York 10964-8000, is hereby authorized under section 101(a)(5)(D) of the Marine Mammal Protection Act (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 northeast Pacific Ocean, August – October, 2009:

1. This Authorization is valid from August 19 through October 13, 2009.

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

    (a) The Endeavour Marine Protected Area (MPA) in the northeast Pacific Ocean, approximately 250 kilometers (km) off the coast of Vancouver Island, British Colombia. The overall area for the marine geophysical survey will encompass the area 47°30'-48°30'N, 128°30'-130°W which is in the Exclusive Economic Zone of Canada. Water depths in the survey area range from 1200 meters (m) (feet (3937 ft)) to 3000 m (9842 ft).

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 conditions 3(b)(i-ii) of this Authorization.

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

        (i) Mysticetes – blue whale *(Balaenoptera musculus),* fin whale *(Balaenoptera physalus),* humpback whale *(Megaptera novaeangliae),* minke whale *(Balaenoptera acutorostrata),* and sei whale *(Balaenoptera borealis).*

        (ii) Odontocetes – Baird's beaked whale *(Berardius bairdii),* Blainville' beaked whale *(Mesoplodon densirostris),* Dall's porpoise *(Phocoenoides dalli),* Hubbs' beaked whale *(Mesoplodon carlhubbsi),* killer whale *(Orcinus orca),* northern right whale dolphin *(Lissodelphis borealis),* Pacific white-sided dolphin *(Lagenorhynchus obliquidens),* pygmy sperm whale *(Kogia breviceps),* Risso's dolphin *(Grampus griseus),* sperm whale *(Physeter macrocephalus),* short-beaked

[4] This is a verbatim copy (retyped) of the IHA. This is the second modification to the originally-issued IHA.

common dolphin *(Delphinus delphis);* and Stejneger's beaked whale *(Mesoplodon stejnegeri).*

(iii) Pinnipeds - northern fur seal *(Callorhinus ursinus).*

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

(i) a 36 Bolt airgun array that may range in size from 40 to 360 cubic inches (in^3) 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) an 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 Canadian government regarding the proposed seismic activity.

7. Mitigation Requirements

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 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, wherever possible.

In addition, the holder of this Authorization must follow the conditions listed below when conducting the seismic survey to achieve the least practicable adverse impact on affected marine mammal species or stocks:

(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 30 minutes 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 powerdown 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 and pinnipeds) or 30 minutes (rnysticetes 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).

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

(d) 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 9 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 five-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 the full safety zone as described in 6(a)(iv).

(e) 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 µPa (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 two (except meal times, where the Holder may utilize one), NMFS-qualified, vessel-based marine 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 conduct monitoring onboard the *Langseth* while the seismic array is being deployed or recovered 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)(ii)(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) Passive Acoustic Monitoring (PAM)

(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 Requirements

The Holder of this Authorization is required to:

(a) submit a draft report on all activities and monitoring results to the Office of Protected Resources, NMFS, within 90 days 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, 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 are 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 sound source 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.

AUG 19 2009

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

Attachments

Attachment

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

Mysticetes	
humpback whale	6
Minke whale	5
Sei whale	1
fin whale	8
blue whale	2
Odontocetes	
Baird's beaked Whale	13
Blainville's beaked whale	2
Dall's porpoise	1081
Hubbs' beaked whale	2
killer whale	12
northern fur seal	73
northern right whale dolphin	142
Pacific white-sided dolphin	181
pygmy sperm whale	9
Risso's dolphin	95
short-beaked common dolphin	104
sperm whale	10
Stejneger's beaked whale	2

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	6-15*	12	40	385
4 strings 36 airguns 6600 in^3	6	220	710	4670
	9	300	950	6000
	12	340	1120	6850
	15	380	1220	7690

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

INCIDENTAL TAKE STATEMENT

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

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

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

The NMFS anticipates the incidental harassment of the blue whale *(Balaenoptera musculus),* fin whale *(Balaenoptera physalus),* sei whale *(Balaenoptera borealis),* humpback whale *(Megaptera novaeangliae),* sperm whale *(Physeter macrocephalus),* leatherback sea turtle *(Dermochelys coriacea),* Lower Columbia River Chinook salmon *(Oncorhynchus tschawytscha),* Upper Columbia River spring-run Chinook salmon *(Oncorhynchus tschawytscha),* Puget Sound Chinook salmon *(Oncorhynchus tschawytscha),* Snake River fall-run Chinook salmon *(Oncorhynchus tschaWytscha),* Snake River spring/summer-run Chinook salmon *(Oncorhynchus tschawytscha),* Upper Willamette River Chinook salmon *(Oncorhynchus tschawytscha),* Columbia River chum salmon *(Oncorhynchus keta),* Hood Canal summer-run chum salmon *(Oncorhynchus keta),* Lower Columbia River coho salmon *(Oncorhynchus kisutch),* Oregon coast coho salmon *(Oncorhynchus kisutch),* Ozette Lake sockeye salmon *(Oncorhynchus nerka),* Snake River sockeye salmon *(Oncorhynchus nerka),* Lower Columbia River steelhead *(Oncorhynchus mykiss),* Middle Columbia River steelhead *(Oncorhynchus mykiss),* Puget Sound steelhead *(Oncorhynchus mykiss),* Snake River steelhead *(Oncorhynchus mykiss),* Upper Columbia River steelhead *(Oncorhynchus mykiss),* and Upper Willamette River steelhead *(Oncorhynchus mykiss)* during the proposed seismic activities.

Amount or extent of take

The NMFS anticipates the proposed seismic survey in the Pacific Ocean off ¯Vancouver Island might result in the incidental take of listed species. The proposed action is expected to take 2 blue whales, 8 fin whales, 1 sei whale, 6 humpback whales, and 10 sperm whales by exposing individuals to received seismic sound levels greater than 160 dB re 1 µPa by harassment. These estimates are based on the best available information of whale densities in the area to be ensonified above 160 dB re 1 µPa during the proposed activities. This incidental take would result primarily from exposure to acoustic energy during

seismic operations would be in the form of harassment, and is not expected to result in the death or injury of any individuals that are exposed.

We expect the proposed action will also take individual leatherback sea turtles as a result of exposure to acoustic energy during seismic studies, and we expect this take would also be in the form of harassment, with no death or injury expected for individuals exposed. Harassment of sea turtles is expected to occur at received levels above 166 dB re 1 μPa.

Further, we expect the proposed seismic survey will also take individual salmonids as a result of exposure to acoustic energy during seismic surveys.

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

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

Reasonable and Prudent Measures

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

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

2. The implementation and effectiveness of mitigation measures incorporated as part of the Reasonable and Prudent Measure mentioned above and the associated Terms and Conditions must be monitored.

Terms and Conditions

In order to be exempt from the prohibitions of Section 9 of the ESA, the NSF, Permits Division, and L-DEO must comply with the following terms and conditions, which implement the Reasonable and Prudent Measures described above. These terms and conditions are non-discretionary.

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

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

APPENDIX B:
DEVELOPMENT AND IMPLEMENTATION OF SAFETY RADII

This appendix provides additional background information on the development and implementation of safety radii as relevant to L-DEO seismic studies. The safety radii used for recent L-DEO surveys are based on modeling and empirical data from L-DEO's 2003 calibration study conducted with various configurations of the *Ewing*'s airgun arrays (see Smultea et al. 2003, Tolstoy 2004a,b). The empirical data from the 2007/8 calibration study of the *Langseth*'s airgun configurations had not been published when procedures for the ETOMO survey were being developed in consultation with NFMS and DFO. Some of the key data have subsequently been published by Tolstoy et al. (2009).

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

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 [5], 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

[5] 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).

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

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

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

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 array used during the ETOMO seismic survey (for two different tow depths), and Figure B.2 shows the sound fields for a single airgun. 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 (6–20 airguns during 2003) 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:

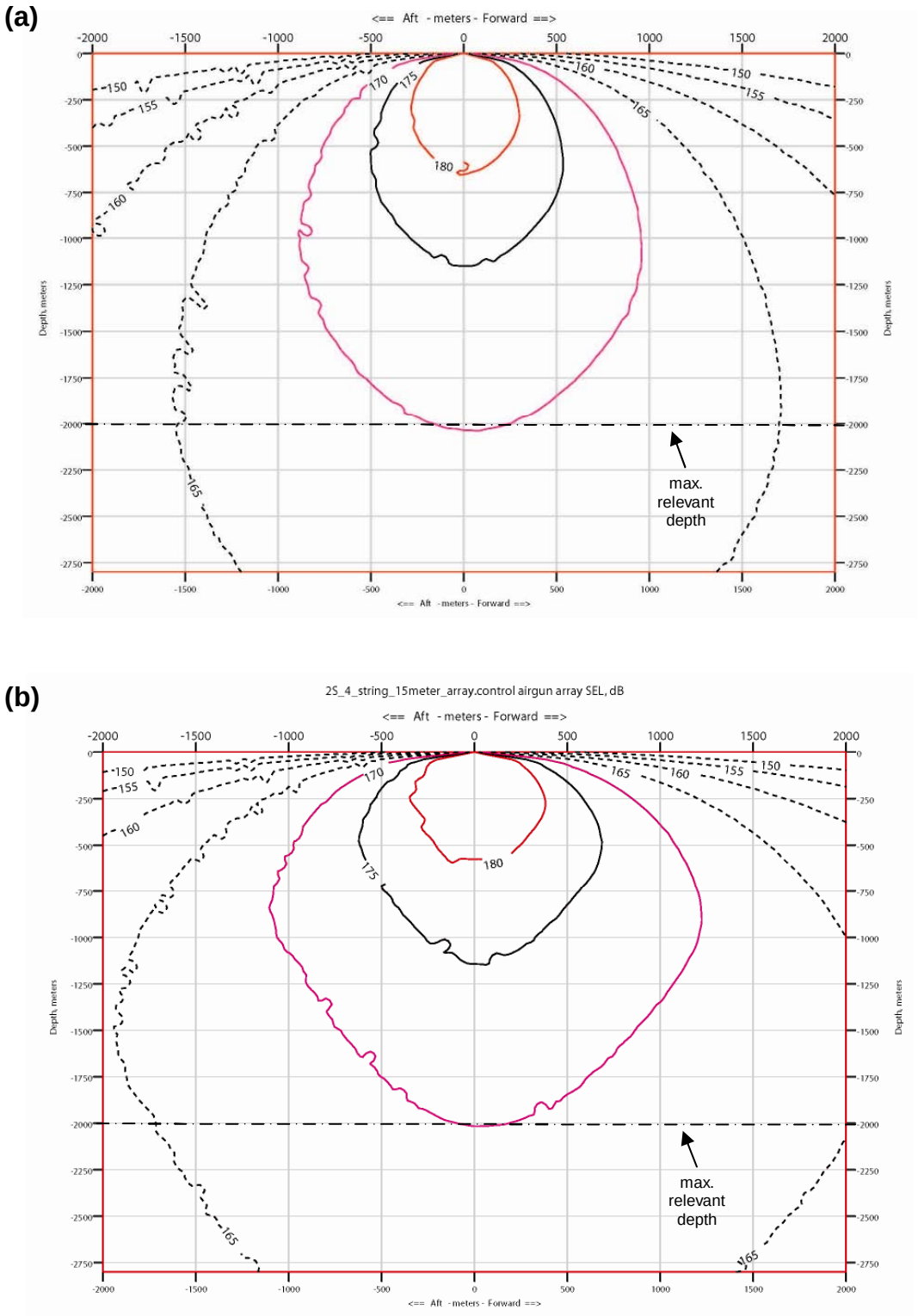

FIGURE B.1. Modeled received sound levels (SELs) from the 36-airgun array operated at a tow depth of (a) 9 m and (b) 15 m during the ETOMO survey, 22 August to 19 September 2009. Received rms levels (SPLs) are expected to be ~10 dB higher. Maximum relevant depth as applicable to marine mammals is indicated.

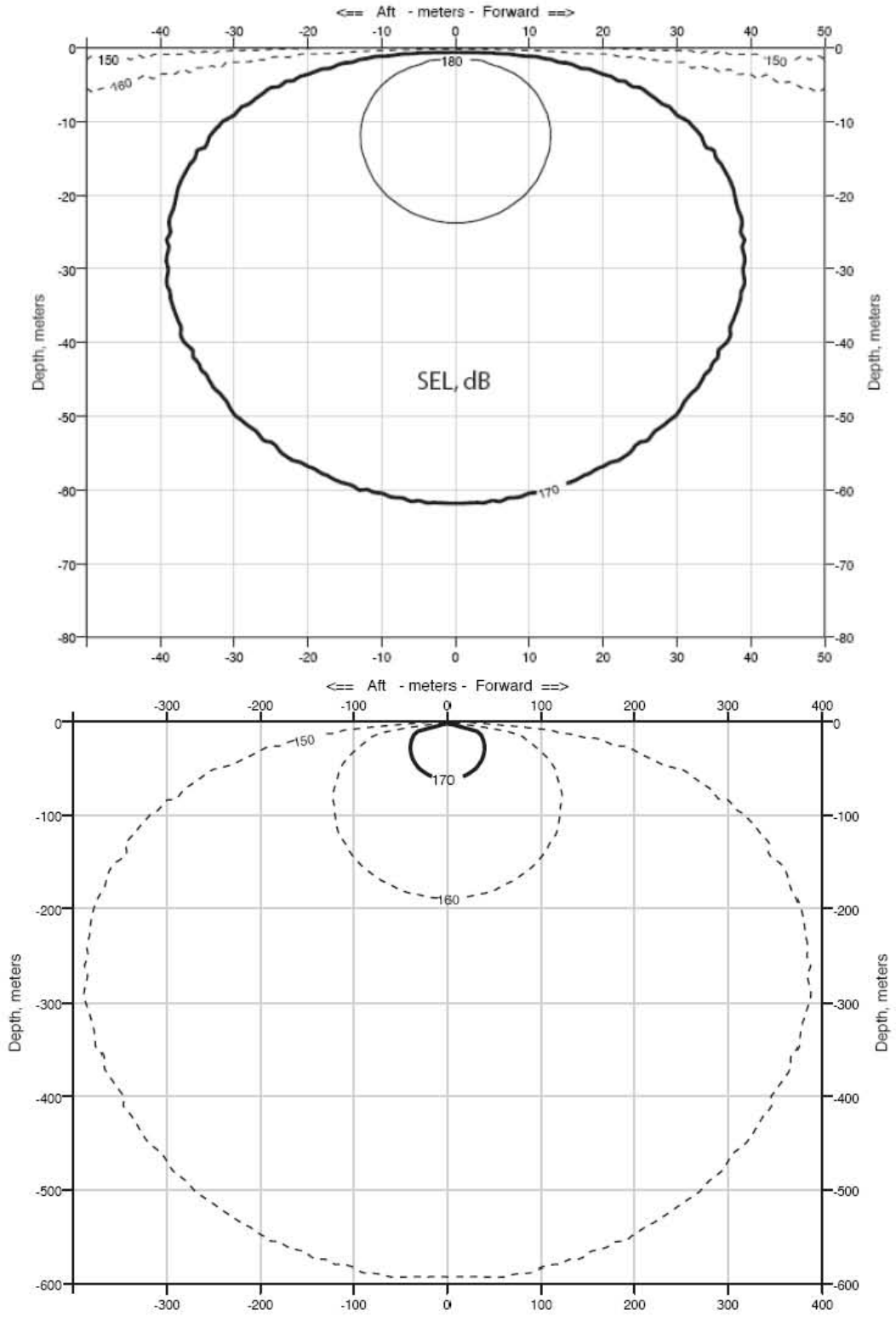

FIGURE B.2. Modeled received sound exposure levels (SELs) from a single 40 in^3 airgun as used during the ETOMO survey, 22 August to 19 September 2009. Otherwise same as above.

- 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.
- 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).
- 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.

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.

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

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

Other details of the *Langseth* include the following:

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

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

Multibeam Bathymetric Echosounder and Sub-bottom Profiler

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

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

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

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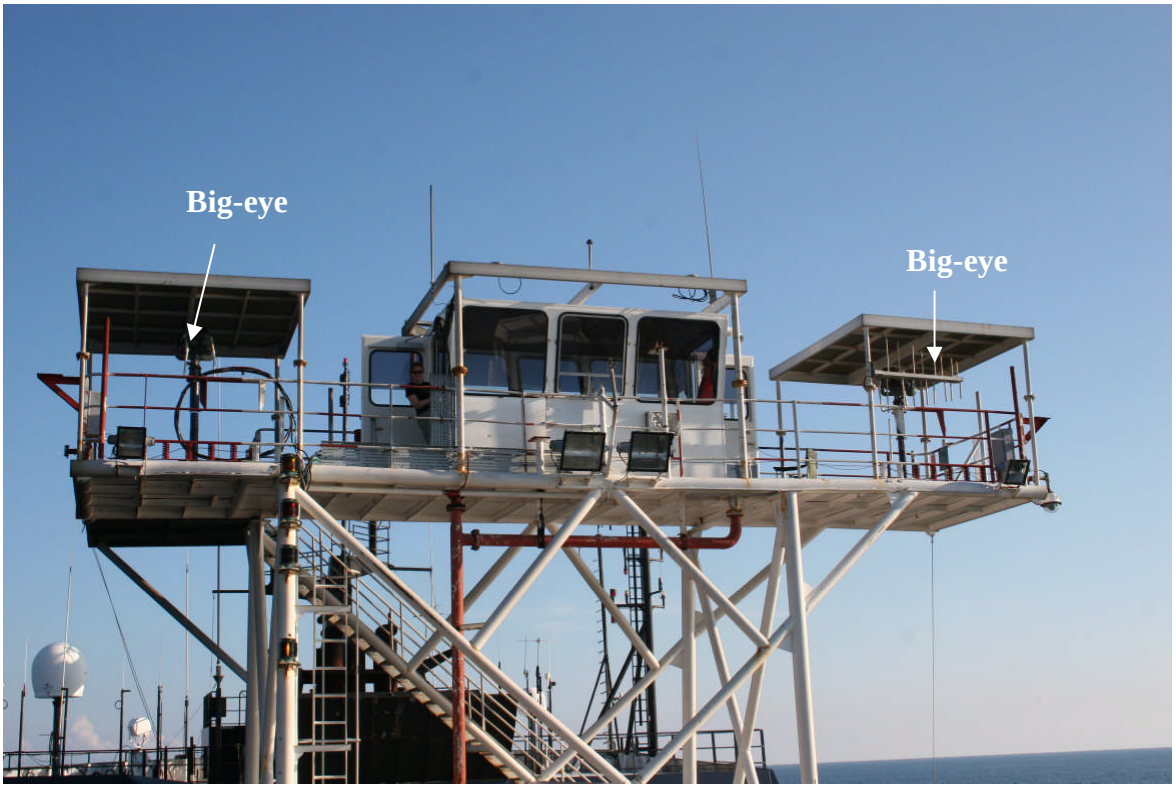

FIGURE C.3. The observation tower on the R/V *Marcus G. Langseth* from which visual observations for marine mammals and sea turtles were made. The locations of two mounted 25x150 "Big-eye" binoculars used during the study is shown. The steel booth in the middle has been replaced by a plastic-coated canvas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

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

Langseth Sub-bottom Profiler Specifications

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

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

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

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

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

Visual Monitoring Methods

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

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

Six 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 ~8–10 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 most often two MMOs were on duty, especially before and during ramp ups. During most L-DEO surveys, MMOs are on watch at least 30 min before ramp up of the airgun array. During the ETOMO survey, MMOs were on watch for at least 60 min prior to ramp up.

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

sightings when MMOs were not on active duty. Bridge personnel would also look for marine mammals and turtles during the day, when MMO(s) were on duty.

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

For each sighting, the following information was recorded: species, number of individuals seen, direction of movement relative to the vessel, vessel position and activity, sighting cue, behavior when first sighted, behavior after initial sighting, heading (relative to vessel), bearing (relative to vessel), distance, behavioral pace, species identification reliability, and environmental conditions. Codes that were used to record this information during the cruise are shown in Table E.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 were to alert the geophysicists if 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. During most of the ETOMO cruise, the Right Waves hydrophone array was used, but during technical difficulties with the array, the *Langseth*'s hull-mounted hydrophone was used (see Appendix G). The hydrophone array is deployed from the back deck. The depth at which the hydrophone array is towed can be adjusted by adding or removing weights. Generally, the array is towed at a depth of ~20 m.

Table D.1. 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
PD	Power Down
RC	Recovering Equipment
SH	Shooting Between/Off.Lines
ST	Seismic Testing
SD	Mechanical Shut Down
SZ	Safety Zone Shut-Down
OT	Other (comment and describe)

 # GUNS
Enter Number of Operating Airguns, or

X	Unknown

ARRAY VOLUME
Enter operating volume, or

X	Unknown

(BEAUFORT) SEA STATE
See Beaufort Scale sheet.

LIGHT OR DARK

L	Light (day)
D	Darkness

GLARE AMOUNT

NO	None
LI	Little
MO	Moderate
SE	Severe

POSITION
Clock Position, or

V	Variable (vessel turning)

WATER DEPTH
In meters

MARINE MAMMAL SPECIES

Baleen Whales

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

Large Toothed Whales

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

Beaked Whales

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

Dolphins

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

Porpoises

DP	Dall's Porpoise
HP	Harbor Porpoise
FP	Finless Porpoise

TURTLE SPECIES

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

MOVEMENT

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

INDIVIDUAL BEHAVIOR

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

GROUP BEHAVIOR (BEHAVIORAL STATES)

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

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

0 to 16	Number of reticles
E	Estimate, by eye

SIGHTING CUE

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

IDENTIFICATION RELIABILITY

MA	Maybe
PR	Probably
PO	Positive

BEHAVIOR PACE

SE	Sedate
MO	Moderate
VI	Vigorous

WITH ABOVE RECORD?

Y	Yes
(blank)	not with above record

The Right Waves array consists of four hydrophones, two of which are monitored simultaneously, and the active section of the array is ~30 m long. The array is attached to the vessel by a 250-m electromechanical lead-in cable and a 50-m long deck lead-in cable. However, not the entire length of lead-in cable is used; thus, the hydrophones are typically located 120 m behind the stern of the ship. The deck cable is connected from the array to a computer in the laboratory where signal conditioning and processing takes place. The digitized signal is then sent to the main laboratory, where the acoustic MMO monitors the system.

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

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

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

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

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

Mitigation

Ramp-up, power-down, and shut-down procedures are described in detail below. These are the primary forms of mitigation implemented during L-DEO 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).

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 power down or shut down lasting ~9 min or longer.

During the daytime, the entire safety radius needed to be visible (i.e., not obscured by fog, etc.) and monitored for 60 min (typically 30 min) prior to and during ramp up; ramp up could only commence if no marine mammals or sea turtles were detected within the safety radius during this period. Throughout the ramp up, 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: ***(1)*** seen outside the safety radius; ***(2)*** had not been seen for a specified amount of time [typically 15 min (for small odontocetes and pinnipeds) or 30 min (for mysticetes and large odontocetes including sperm, pygmy sperm, dwarf sperm, killer, and beaked whales), but 60 min for SARA-listed marine mammal species during the ETOMO cruise]; or ***(3)*** 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 ~100 m behind the *Langseth's* stern during the ETOMO survey. The decision to initiate a power down was based on the distance from the observers rather than from the airgun array unless the animals were sighted close to the array. This was another precautionary measure, given that most sightings were ahead of the vessel.

Analyses

This section describes the analyses of the marine mammal and sea turtle sightings and survey effort as documented during the cruise. It also describes the methods used to calculate densities of marine mammals and estimate the number of marine mammals potentially exposed to seismic sounds associated with the seismic study. The analysis categories that were used were identified in Chapter 3. The primary analysis categories used to assess potential effects of seismic sounds on marine mammals were the "seismic" (airguns operating with shots at <1.5 min spacing) and "non-seismic" categories (periods before seismic started, and >6 h after airguns are turned off. The analyses for effort and cetaceans excluded the "post-seismic" period 1.5 min to 6 h after the airguns were turned off. The justification for

the selection of these criteria is based on the size of the airgun array in use and is provided below. These criteria were discussed in earlier L-DEO cruise reports to NMFS (see Haley and Koski 2004; Smultea et al. 2004, 2005; MacLean and Koski 2005; Holst et al. 2005a,b; Holst and Beland 2008; Holst and Smultea 2008; Hauser et al. 2008):

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

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

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

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

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

Number of Marine Mammal Exposures

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

- area assumed to be ensonified to ≥160 dB (depending on the airgun(s) in use at the time; Table 3.1; Table 4.6), and
- "corrected" densities of marine mammals estimated by line transect methods.

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

Number of Individuals Exposed

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

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

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

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

TABLE E.1. The habitat, abundance, and conservation status of marine mammals that occur in the Northeast Pacific Ocean (taken from the EA/IHA Application; LGL Ltd. 2009a,b). Regional abundance estimates are also given.

Species	Abundance for North Pacific	U.S. ESA[a]	IUCN[b]	SARA[c]	CITES[d]
Mysticetes					
North Pacific right whale (*Eubalaena japonica*)	100-200[e]	EN	EN	EN	I
Gray whale (*Eschrichtius robustus*) *	18,813[t]	-	LC	SC	I
Humpback whale (*Megaptera novaeangliae*)	>6000[f]	EN	LC	T	I
Minke whale (*Balaenoptera acutorostrata*)	9000[g]	-	LC	-	I
Sei whale (*Balaenoptera borealis*)	7260-12,620[h]	EN	EN	EN	I
Fin whale (*Balaenoptera physalus*)	13,620-18,680[i]	EN	EN	T	I
Blue whale (*Balaenoptera musculus*)	1186[j, v]	EN	EN	EN	I
Odontocetes					
Sperm whale (*Physeter macrocephalus*)	24,000[k]	EN	VU	-	I
Pygmy sperm whale (*Kogia breviceps*)	-	-	DD	-	II
Dwarf sperm whale (*Kogia sima*)	11,200[l]	-	DD	-	II
Cuvier's beaked whale (*Ziphius cavirostris*)	20,000[l]	-	LC	-	II
Baird's beaked whale (*Berardius bairdii*)	6000[m]	-	DD	-	I
Blainville's beaked whale (*Mesoplodon densirostris*)	603[j]	-	DD	-	II
Hubb's beaked whale (*Mesoplodon carlhubbsi*)	421[n]	-	DD	-	II
Stejneger's beaked whale (*Mesoplodon stejnegeri*)	421[n]	-	DD	-	II
Bottlenose dolphin – offshore ecotype (*Tursiops truncatus*)	3257[j, v]	-	LC	-	II
Striped dolphin (*Stenella coeruleoalba*)	23,883[j, v]	-	LC	-	II
Short-beaked common dolphin (*Delphinus delphis*)	487,622[j,v]	-	LC	-	II
Long-beaked common dolphin * (*Delphinus capensis*)	21,902[o]	-	LC	-	II
Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)	931,000[p]	-	LC	-	II
Northern right whale dolphin (*Lissodelphis borealis*)	15,305[j, v]	-	LC	-	II
Risso's dolphin (*Grampus griseus*)	12,093[j, v]	-	LC	-	II
False killer whale (*Pseudorca crassidens*)	-	-	DD	-	II
Killer whale (*Orcinus orca*)	8500[q]	-	DD	SC[r]	II
Short-finned pilot whale (*Globicephala macrorhynchus*)	160,200[l]	-	DD	-	II
Harbor porpoise (*Phocoena phocoena*) *	202,988[s, u]	-	LC	SC	II
Dall's porpoise (*Phocoenoides dalli*)	57,549[j, v]	-	LC	-	II
Pinnipeds					
Northern fur seal (*Callorhinus ursinus*)	721,935[t, u]	-	VU	-[w]	-
California sea lion (*Zalophus c. californianus*) *	238,000[j]	-	LC	-	-
Steller sea lion (*Eumetopias jubatus*) *	48,519–54,989[t, u] (Eastern stock, U.S.)	T	EN	SC	-
Harbor seal (*Phoca vitulina richardsi*) *	24,732[J] (OR/WA)	-	LC	-	-
Northern elephant seal (*Mirounga angustirostris*)	124,000[J] (CA)	-	LC	-	-
Mustelids					
Sea otter (*Enhydra lutris kenyoni*) *	70,658[t]	EN	EN	SC	II

'-' Data not available or species status was not assessed (CITES), species not listed (ESA), Not at Risk (Committee on the Status of Endangered Wildlife in Canada; COSEWIC), or No Status (SARA).
* Coastal species unlikely to be encountered in the offshore study area.
[a] Endangered Species Act: EN = Endangered, T = Threatened.
[b] Codes for IUCN classifications: EN = Endangered; VU = Vulnerable; LC = Least Concern; DD = Data Deficient. Classifications are from the 2008 IUCN *Red List of Threatened Species* (IUCN 2008).
[c] Species at Risk under SARA based on designations by COSEWIC (2009), but may need to be reassessed based on current information; EN = Endangered, T = Threatened, SC = Special Concern.
[d] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2009).
[e] Eastern North Pacific Ocean (Wada 1973).
[f] Calambokidis et al. (1997).
[g] Wada (1976).
[h] Tillman (1977).
[i] Ohsumi and Wada (1974).
[j] Aundance given for U.S., Eastern North Pacific, or California/Oregon/Washington Stock, whichever is included in the 2007. U.S.Pacific Marine Mammal Stock Assessments (Carretta et al. 2007), unless otherwise stated.
[k] Eastern temperate North Pacific (Whitehead 2002).
[l] Eastern Tropical Pacific (Wade and Gerrodette 1993).
[m] Western North Pacific (Reeves and Leatherwood 1994; Kasuya 2002).
[n] Combined estimate for unidentified mesoplodont whales for U.S. west coast (Carretta et al. 2007).
[o] Barlow and Forney (2007).
[p] Buckland et al. (1993).
[q] Combined estimate for Eastern Tropical Pacific (Ford 2002).
[r] Status of offshore killer whale population is *threatened* under COSEWIC and *special concern* under SARA.
[s] Eastern North Pacific Ocean (totals from Carretta et al. 2007 and Angliss and Outlaw 2008).
[t] Angliss and Outlaw (2008).
[u] Numbers are pending revision in the DRAFT 2008 Alaska Stock Assessment Report.
[v] Numbers are pending revision in the DRAFT 2008 Pacific Stock Assessment Report.
[w] Listed as *threatened* by COSEWIC and No Status by SARA.

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APPENDIX F:
VISUAL EFFORT AND SIGHTINGS

TABLE F.1. All and useable[a] visual observation effort (in km and h) from the *Langseth* in the ETOMO study area, 22 August to 19 September 2009, by airgun status.

	Effort (km)		Effort (h)	
Airgun Status	**All**	**Useable[a]**	**All**	**Useable[a]**
Total Airguns On (Seismic)	**1677.9**	**1318.2**	**209.3**	**159.5**
Ramp up	9.3	0	1.3	0
1-90 s after shut down	0	0	0	0
1 airgun	13.5	8.5	2.1	1.3
9 airguns	4.9	4.9	0.7	0.7
12 airguns	7.2	0	1.0	0
18 airguns	135.1	92.1	17.4	11.5
27 airguns	89.3	66.2	11.6	8.2
35 airguns	3.8	3.8	0.4	0.4
36 airguns	1414.7	1142.8	174.9	137.5
Total Airguns Off	**1035.8**	**606.1**	**120.5**	**51.4**
Non-seismic[b]	1018.1	606.1	118.4	51.4
Recently-exposed[c]	0	-	0	-
Potentially exposed[d]	17.5	-	2.1	-
Total Effort (Airguns On & Off)	**2713.7**	**1924.3**	**329.9**	**210.9**

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

[b] >6 h since seismic.

[c] 90 s - 2 hr after seismic; all such sightings and effort categorized as 'non-useable'.

[d] 2 - 6 hr after seismic; all such sightings and effort categorized as 'non-useable'.

TABLE F.2. All and useable[a] (shown in parentheses) visual observation effort from the *Langseth* in the ETOMO study area, 22 August to 19 September 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***	**7***	**Total**
(A) Effort in km									
Total Airguns On (Seismic)	**0**	**0**	**260.2 (235.2)**	**467.4 (415.5)**	**562.9 (510.4)**	**182.6 (157.2)**	**204.7 (0)**	**0**	**1677.9**
Ramp up	0	0	0	0	0	0	9.3 (0)	0	**9.3**
1-90 s after shut down	0	0	0	0	0	0	0.2 (0)	0	**0.2**
1 airgun	0	0	0.4 (0.4)	0	0	8.2 (8.2)	5.0 (0)	0	**13.5**
9 airguns	0	0	1.8 (1.8)	0	3.1 (3.1)	0	0	0	**4.9**
12 airguns	0	0	0	0	0	0	7.2 (0)	0	**7.2**
18 airguns	0	0	16.8 (16.8)	68.1 (37.0)	50.2 (38.3)	0	0	0	**135.1**
27 airguns	0	0	16.2 (13.9)	24.5 (24.5)	23.0 (23.0)	4.8 (4.8)	20.8 (0)	0	**89.3**
35 airguns	0	0	3.8 (3.8)	0	0	0	0	0	**3.8**
36 airguns	0	0	221.4 (198.6)	374.8 (354.0)	486.7 (446.0)	169.6 (144.2)	162.2 (0)	0	**1414.7**
Total Airguns Off	**0**	**0**	**133.4 (100.8)**	**327.0 (258.8)**	**232.0 (189.5)**	**84.7 (57.0)**	**155.8 (0)**	**102.9 (0)**	**1035.8**
Non-seismic[b]	0	0	115.9 (100.8)	327.0 (258.8)	232.0 (189.5)	84.7 (57.0)	155.6 (0)	102.9 (0)	**1018.1**
*Recently-exposed[c]	0	0	0	0	0	0	0.2 (0)	0	**0.2 (0)**
*Potentially exposed[d]	0	0	17.5 (0)	0	0	0	0	0	**17.5 (0)**
Total Effort (Airguns On & Off)	**0**	**0**	**393.6 (336.0)**	**794.4 (674.2)**	**794.9 (699.9)**	**267.3 (214.2)**	**360.5 (0)**	**102.9 (0)**	**2713.7 (1924.3)**
(B) Effort in hr									
Total Airguns On (Seismic)	**0**	**0**	**32.9 (29.5)**	**58.1 (51.0)**	**67.5 (60.7)**	**21.5 (18.3)**	**29.2 (0)**	**0**	**209.3 (159.5)**
Ramp up	0	0	0	0	0	0	1.3 (0)	0	**1.3 (0)**
1-90 s after shut down	0	0	0	0	0	0	0	0	**0**
1 airgun	0	0	0.1 (0.1)	0	0	1.2 (1.2)	0.7 (0)	0	**2.0 (1.3)**
9 airguns	0	0	0.2 (0.2)	0	0.4 (0.4)	0	0	0	**0.7 (0.7)**
12 airguns	0	0	0	0	0	0	1.0 (0)	0	**1.0 (0)**
18 airguns	0	0	2.1 (2.1)	8.9 (4.6)	6.4 (4.8)	0	0	0	**17.4 (11.5)**
27 airguns	0	0	2.1 (1.9)	2.8 (2.8)	3.0 (3.0)	0.6 (0.6)	3.1 (0)	0	**11.6 (8.2)**
35 airguns	0	0	0.4 (0.4)	0	0	0	0	0	**0.4 (0.4)**
36 airguns	0	0	28.0 (24.8)	46.4 (43.6)	57.7 (52.5)	19.7 (16.5)	23.1 (0)	0	**174.9 (137.5)**
Total Airguns Off	**0**	**0**	**16.3 (10.0)**	**37.7 (20.9)**	**31.4 (14.8)**	**9.9 (5.7)**	**14.6 (0)**	**10.6 (0)**	**120.5 (51.4)**
Non-seismic[b]	0	0	16.3 (10.0)	37.7 (20.9)	31.4 (14.8)	9.9 (5.7)	12.5 (0)	10.6 (0)	**118.4**
*Recently-exposed[c]	0	0	0	0	0	0	0	0	**0.0**
*Potentially exposed[d]	0	0	0	0	0	0	2.1 (0)	0	**2.1**
Total Effort (Airguns On & Off)	**0**	**0**	**49.2 (39.5)**	**95.8 (71.9)**	**98.9 (75.5)**	**31.4 (24.0)**	**43.8 (0)**	**10.6 (0)**	**329.8 (210.9)**

[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

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

TABLE F.3. Sightings of marine mammals and sea turtles made from the R/V *Marcus G. Langseth* during all visual effort of the ETOMO cruise, 22 August to 19 September 2009.

Species	Useable ?[a]	Group size	Date & Time	Latitude (N)	Longitude (w)	Initial Sighting Dstance (m)	CPA (m)[b]	Move-ment[c]	Initial Behavior[d]	Wind Force[e]	Water Depth (m)[f]
Pacific white-sided dolphin	Y	10	25/08/2009 13:18	47.8801	-129.057	100	121	SP	TR	3	2394
Dall's porpoise	N	6	11/09/2009 8:32	48.3555	-129.317	20	136	SP	SW	2	2077
Leatherback turtle	N	1	11/09/2009 8:32	48.3555	-129.317	10	135	SP	SW	2	2077
Dall's porpoise	Y	10	11/09/2009 11:09	48.245	-129.253	70	199	SP	SW	2	2285
Dall's porpoise	Y	4	11/09/2009 15:15	48.1891	-129.358	1535	1541	SA	SW	2	2690
Dall's porpoise	Y	5	11/09/2009 15:25	48.1617	-129.358	500	579	ST	SW	2	2649
Northern elephant seal	Y	1	13/09/2009 15:15	47.8681	-129.183	200	348	ST	LO	4	2446
Unidentified toothed whale	Y	1	14/09/2009 9:04	47.6613	-129.385	845	920	SP	DI	2	2591
Sperm whale	Y	1	14/09/2009 16:56	47.9418	-129.389	500	579	SP	SW	4	2534
Dall's porpoise	N	3	15/09/2009 10:07	47.9165	-128.771	40	184	PE	BO	5	2606

[a] Useable sighting? Y = Yes. N = No. "No" if sighting was made during periods 90 s to 6 h after airguns were turned off (post-seismic), or during nighttime observations, poor visibility conditions (visibility <3.5 km), or periods with Beaufort Wind Force >5 (>2 for cryptic species). Also excluded were periods when the *Langseth*'s speed was <3.7 km/h (2 kt) or with >60º of severe glare between 90º left and 90º right of the bow. Note, only "useable" sightings *within* the study area were used for analyses in Chapter 4.
[b] CPA is the distance at the closest observed point of approach to the nearest airgun. This is not necessarily the distance at which the individual or group was initially seen nor the closest it was observed to the vessel. * indicates that the airguns were not firing at the time of the sighting.
[c] The initial movement of the individual or group relative to the vessel. PE = swimming perpendicular to ship or across ship track; SP = swimming parallel; ST = swimming toward the vessel; SA = swimming away from vessel; UN = movement unknown; NO = no movement relative to vessel; MI = milling.
[d] The initial behavior observed. PO = porpoising; SW = swimming; SA = surface active; DI = dive; TR = traveling; SW = swimming; BL = blowing; ST = Surface Active/Traveling; DE = animal presumed to be dead; UN = behavior unknown.
[e] Beaufort Wind Force Scale.
[f] Water depth was recorded for the vessel's location at the time of the sighting.
[g] Activity of the vessel at the time of the sighting. LS = line shooting with airgun(s); DP = deploying equipment; OT = other or no seismic activity; RU = ramp up.
[h] During ramp up, the number of guns was unknown.

APPENDIX G:
ETOMO SURVEY, 22 AUGUST – 19 SEPTEMBER 2009, PAM REPORT

RIGHT WAVES sas
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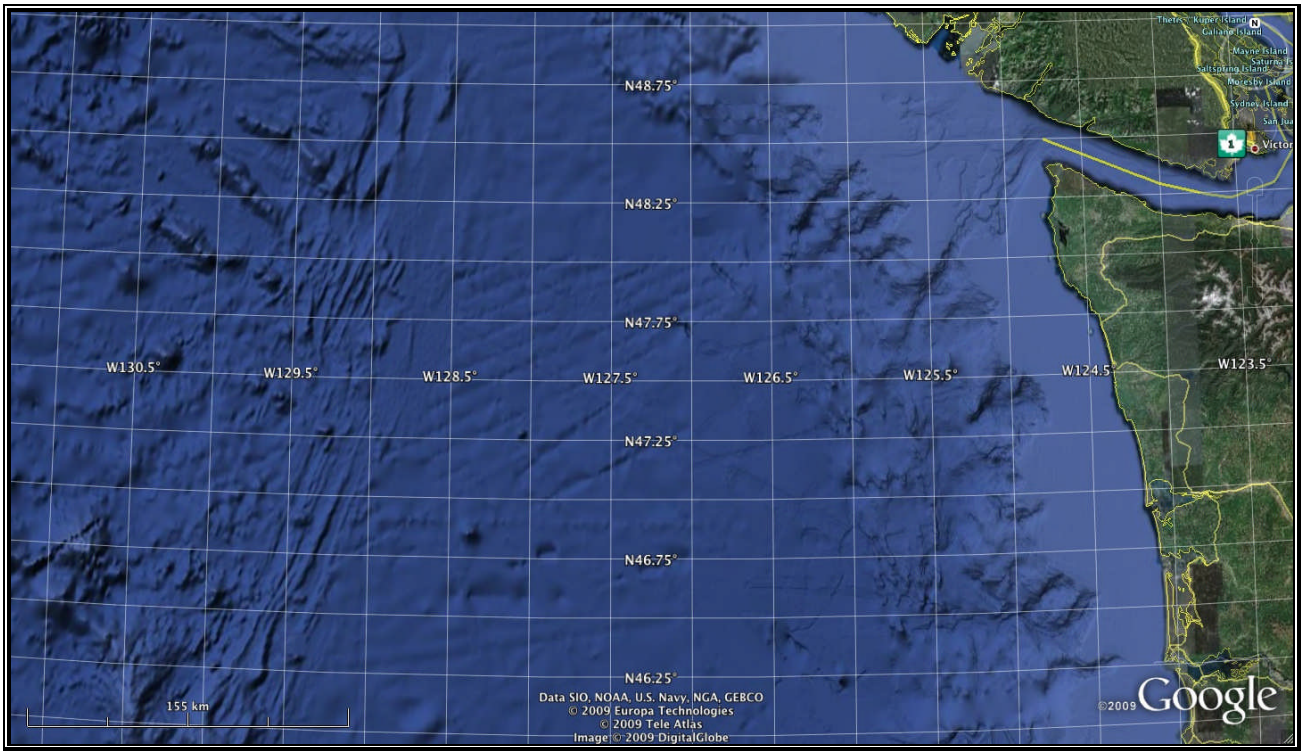
ETOMO CRUISE

Acoustic report



Prepared by Giovanni Caltavuturo, RIGHT WAVES – CIBRA

PAM hardware

There are two PAM streamers onboard, both provided by RIGHT WAVES. The main streamer consists of a Towed Digital Array, 4 channels, digital (optical and electrical) and analog output up to 96 kHz bandwidth, adjustable gain and filters (via USB), pressure gauge, 250 m lead-in coax electromechanical cable, 50 m deck lead-in, 42 m hose (15 m VIM Vibration Insulation Module + 30 m active section), OD 3 cm (Fig. 1). 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 1.

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

Fig 2A.

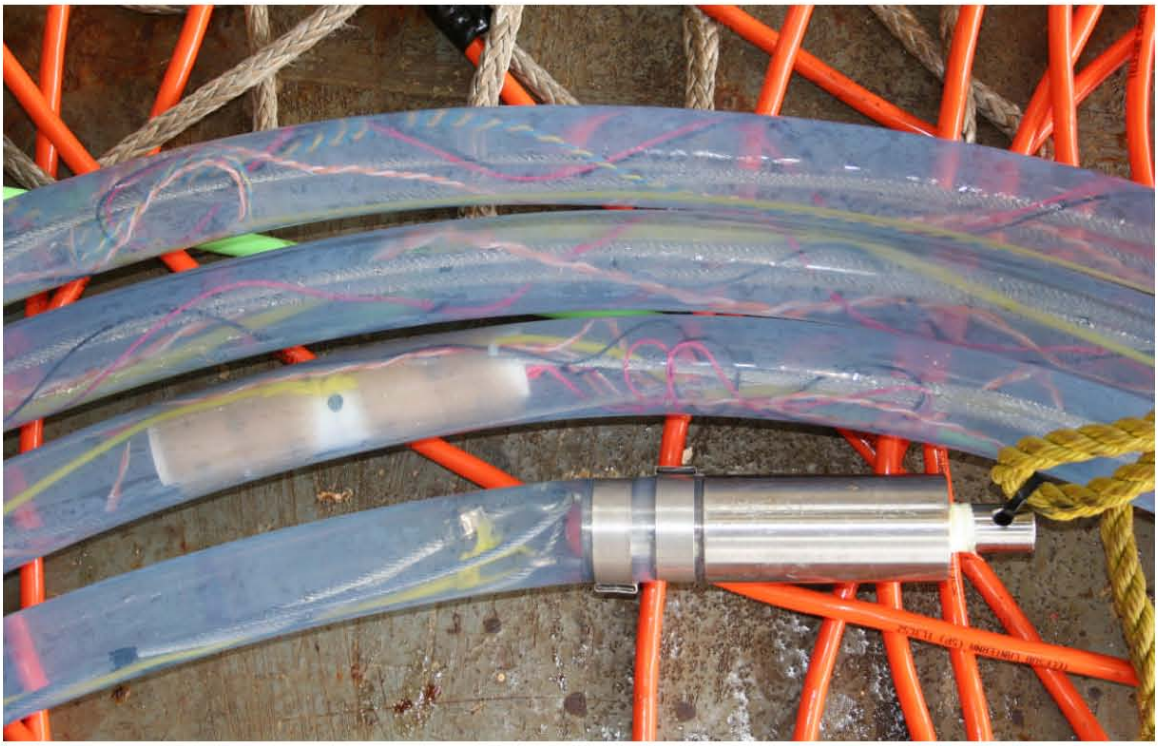


Fig 2B.

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.

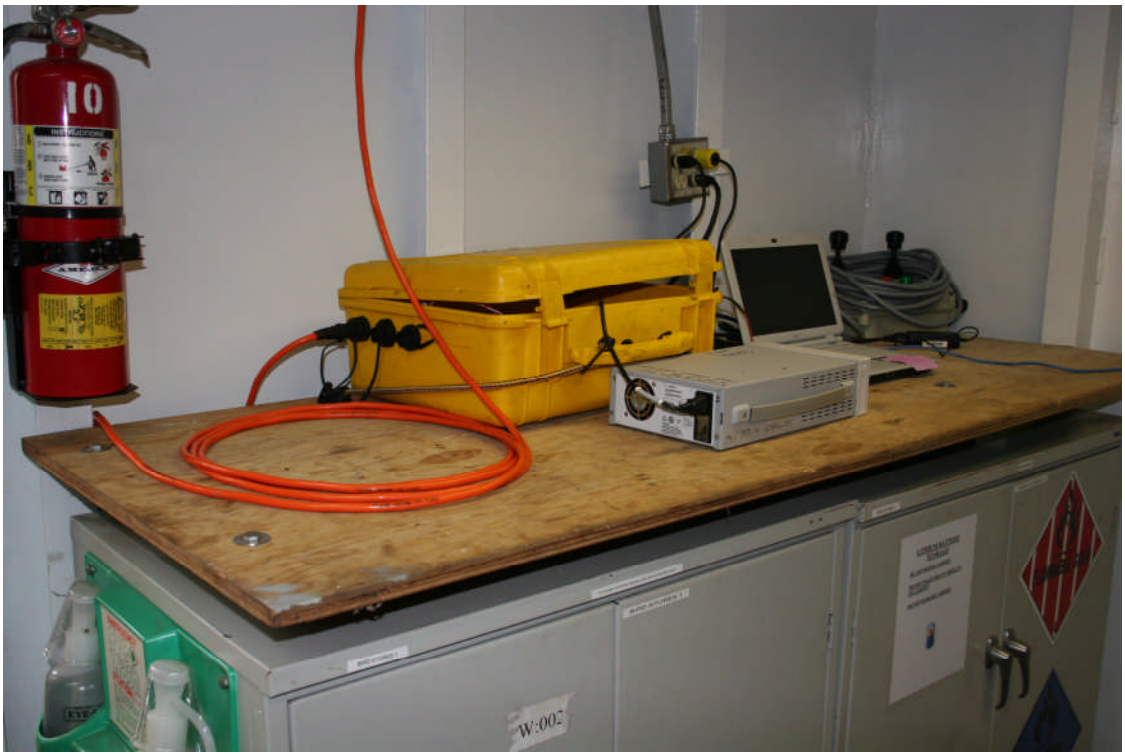


Fig 3.

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.

PAM SOFTWARE (RIGHT WAVES – CIBRA)

Software components—The SeaPro PAM Suite, based on an architecture developed by CIBRA in more than 15 years of field experience, can run either on a single (powerful) laptop computer or on a set of networked computers with distributed tasks. The PAM Suite is composed by several software components.

SeaProUltra—SeaPro is the core software developed by CIBRA for both research and mitigation purposes. The latest version, SeaProUltra 2.0, provides 2 channels sound analysis, display and recording up to 192 kHz sampling rate. It provides user sizeable data buffer for getting short audio snapshots and extended recording facilities for long recordings and for unattended recordings in user defined time cuts. Any information/data saved by SeaPro is time referenced and, when connected to a GPS data stream, georeferenced too. The program also includes a direction display mode that provides intuitive cues to the direction of incoming sound. Multiple instances of the software can be run on the same machine to monitor multiple channels or to provide multiple views of the same signals (a multiclient sound acquisition device is required for this task). The CIBRA system can be programmed to record continuously, 1 file every hour, for a set number of hours, depending on the storage space available. SeaPro can change the recording disk until all available disks are full. If connected to a network, either wired

or wireless, SeaPro can be remotely controlled by UDP commands and receive GPS information for georeferencing files.

PAMLogger—Acoustic detections logging system (on event and/or time slot logging). It reads GPS ($GPRMC string that contains all relevant data) data broadcast by the ship or broadcast by NMEAManager and reads specific UDP ports available on the ship to automatically collect and distribute additional data (Depth, Shoot Time). On user prompt ship data are collected and inserted in an Excel spreadsheet (by DDE communication) along with data provided by the operator in apposite fields. PAMLogger generates a data summary with date, time, position, speed, heading, depth (if available), PAM status, and ship operation (if set by the operator). The summary can be broadcast by UDP, for example to be displayed at the MMO laptop, and/or saved to disk continuously or every minute. The program communicates with OziExplorer (if running on the same computer) to forward GPS data ($GPRMC string) and to place WayPoints on OziExplorer map to show where acoustic detections and other relevant events happened. If a $GPRMC string is not available, it must be generated and broadcast by NMEAManager

NMEAManager—Collects NMEA navigation data either from a serial port or an UDP port and feeds SeaPro and PAMLogger. If a GPRMC string is not available, NMEAManager builds one by reading $GPGGA and any additional string that carries date and time information. If required, it can be customized to read proprietary strings generated by the ship's navigation system. **cnavNMEAManager** is the version built for the *Langseth*.

SeaPro Remote Control—The Remote Control panel allows to give commands to SeaPro (start/stop recording, save buffer, save screen snapshot) by UDP messages and logs its operations. It works either locally or on networked computers.

CatWav—File cataloguing software to provide a text catalog of all wave files with filename, size, number of channels, sample rate. The text file can be easily imported into Excel spreadsheet, for example to add comments in post-analysis.

OziExplorer—Navigation software and data mapping display; it can read GPS serial data or can be controlled by external programs, such as PAMLogger, to provide navigation and mapping facilities. It allows to import and georeference user supplied maps in lots of image format, to show the navigation context and, if available, to show planned tracks and areas of potential presence of animals. It allows to import/export shapefiles to be used by ESRI ArcView.

Microsoft Excel—Used to manage data entry driven by PAMLogger (PAMLogger and Excel communicate by DDE and must run on the same computer); an Excel spreadsheet must be open to allow PAMLogger fill in a new row every time a data record is kept. The Excel spreadsheet built this way provides easy to see history log and also allows to edit/add data and comments. If an open Excel file is not available PAMLogger saves data to a plain text file.
It is important to set Excel to AutoSave every 15 min.

ETOMO Cruise (MGL0910) Acoustic monitoring results

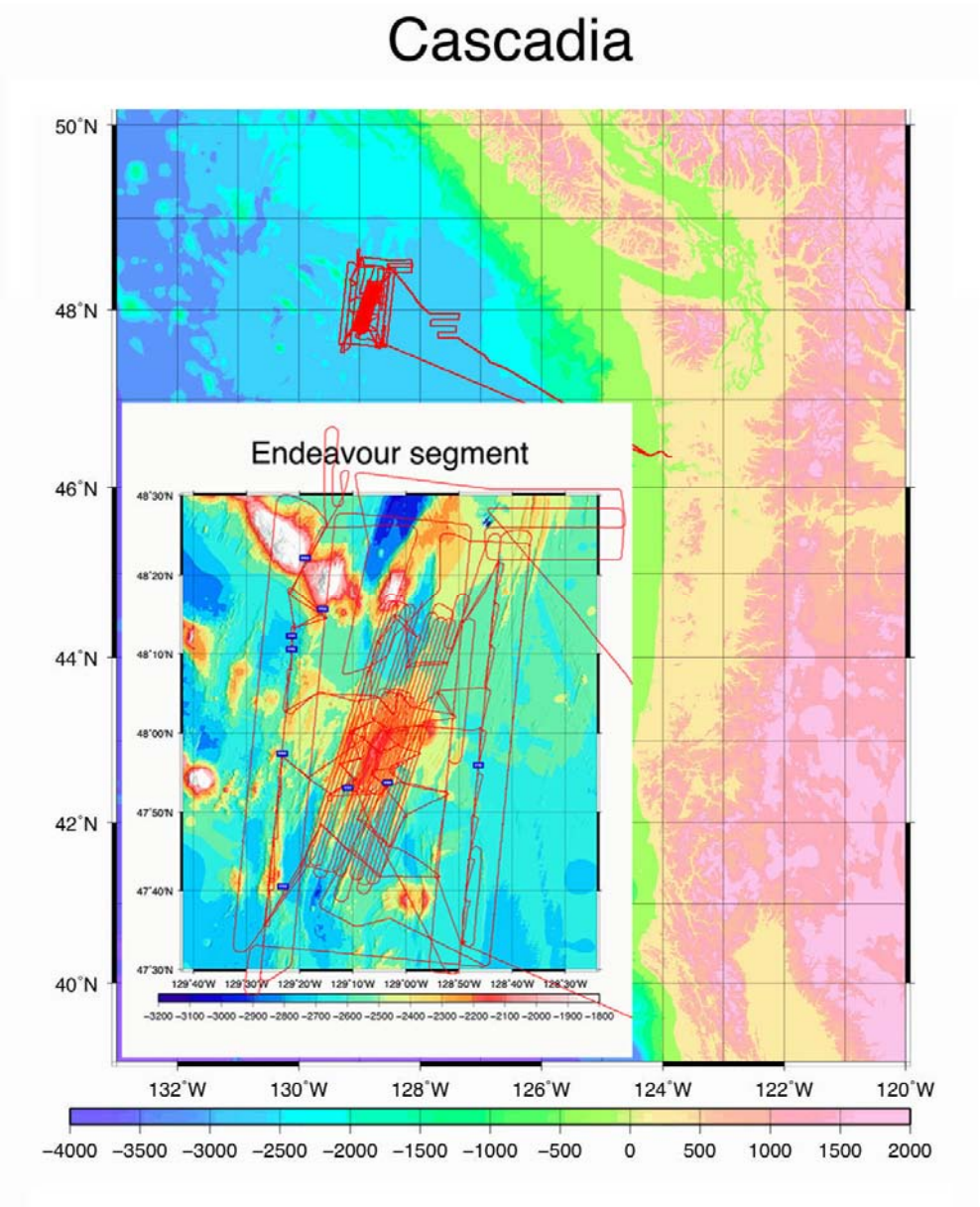


Fig. 1. The study area with the track followed (in red). Blue labels are the visual sightings, made only during Deploying/Recovering/ Transit.

The Area

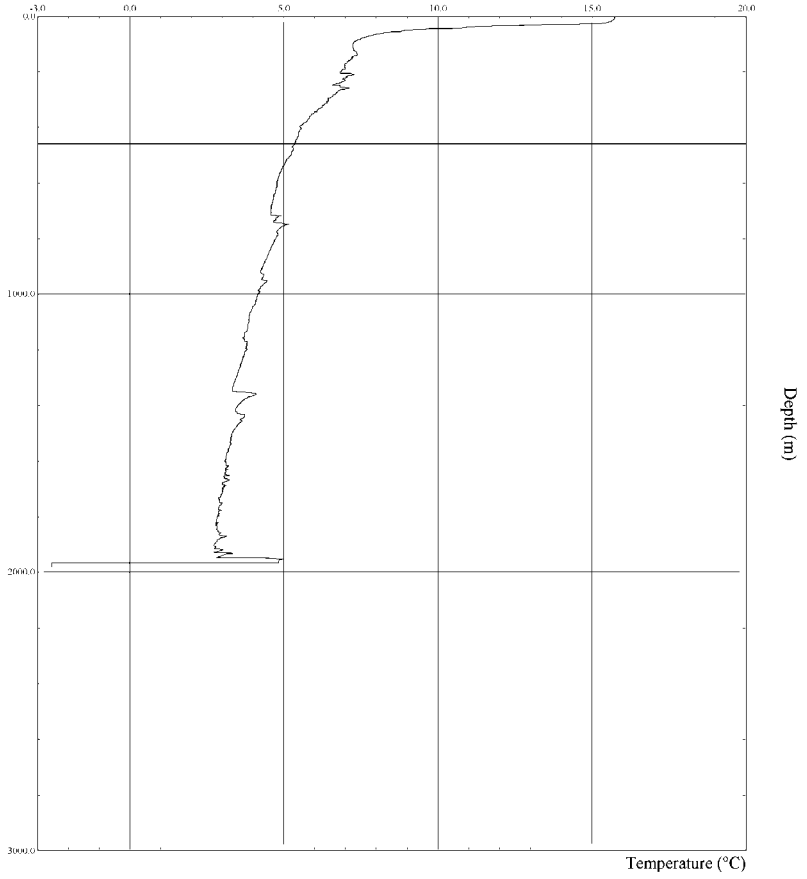
The operation was conducted in the EEZ of Canada, about 250 km southwest of Vancouver Island, British Columbia, on the Endevour segment of the Juan de Fuca Ridge. The depth ranged between **1500** and **2800** m with most of the cruise conucted in water more than 2000 m deep.

A relevant part of the time spent at sea was dedicated to deploy and recovery OBSs. No seismic streamers were used durig MGL0910.

The towing depth of the airguns was 15 m for the first part of the cruise and then 9 m for the remaining part.

Sound propagation conditions

During the cruise a number of XBTs were launched; all showed similar results. The following figure shows an almost uniform layer between 0 and 60 m depth and a steep thermocline right below. This creates a narrow surface sound channel that affects the detection capabilities of the PAM array (towing depth ~15-20 m) of vocalizing animals below 60 m and not directly under the vessel. The relatively high sea-state during most part of the cruise also affected the capabilities to detect biologic sounds decreasing the signal to noise ratio.



Probe: T-4	Data Filename: T4_00156.RDF
Terminal Depth: 1500 m (Non-Std)	Data Pathname: c:\prog...\data
Depth Eqn: Original	Sequence #: 156
Coefficient 1: 0.0	
Coefficient 2: 6.472	Latitude: 48° 14.79688N
Coefficient 3: -0.00216	Longitude: 129° 2.03711W
Coefficient 4: 0.0	
	Serial #: 00000000

PAM system

During the ETOMO cruise, the PAM system and setup was the same as during the previous cruise. The towing system and the ship itself induced low frequency noise that was canceled using a high-pass filter (low frequencies cut up to 1 kHz). Due to the bad weather on 27 August 18:00 local time while recovering the airguns, the PAM array entangled on one of the umbilicals, and the signal was lost. Because of the excessive stress caused by the entanglement, some wire inside the active section snapped. On 28 August at about 09:00, the spare array was deployed and the PAM activities restarted. On 31 August at about 09:00 the array was recovered because of the presence of continuous electrical/electronic noises due to a previous repair arranged "on the fly" during the TAIGER 4 cruise (see report).

On 1 September at 02:00, the PAM station was moved into the Dry Lab to connect the hull-mounted hydrophone HAP5050 (considered as a "better than nothing" option) to continue the PAM activities while repairs were carried out. Hull-mounted sensors for marine mammals monitoring have, in our opinion, severe limitations due to a series of reasons such as shallow depth and shipnoise. Later on the same day, at about 20:30, the repaired PAM array was deployed.

On 3 September at 21:00, the array was recovered once again due to the bad weather (Beaufort 8+) in order to avoid new damage to the only PAM array onboard; the PAM station was moved back into the Dry Lab, and PAM activities carried out with the HAP5050. On 4 September, the array was deployed at 19:00, and on 8 September, it was recovered again due to the weather. On 9 September, the array was re-deployed, and the activities were carried on until the end of the cruise. About sixty hours of acoustic monitoring were conducted with the hull-mounted hydrophone HAP5050.

Acoustic contacts

During the ETOMO cruise, **no (0) acoustic contacts** occurred.

Table 1. PAM effort and acoustic contacts (week by week) during the ETOMO cruise.

Week	**Total Effort**		**Ac. Cont.**	**No Seismic**		**Ac. Cont.**
	Hours	*Min.*		*Hours*	*Min.*	
1st (24 Aug-30 Aug)	89	48	0	1	42	0
2nd (31 Aug-06 Sep)	149	18	0	0	0	0
3rd (07 Sep-13 Sep)	100	42	0	1	16	0
TOTAL	***339***	***48***	***0***	***2***	***58***	***0***

There were **10 visual sightings**: one group of 10 Pacific white-sided dolphin (V01), five sightings of Dall's porpoises (V02, V04-V06, V10), one Sperm whale (V09), one unidentified toothed whale (V08), one northern elephant seal (V07), and one leatherback turtle (V03). All sightings took place during OBSs deployment/recovery activities or during transit when PAM was not operative. No marine mammals sightings occurred during PAM operations.

Post cruise analysis

Because of the possible presence of non-audible high-frequency (HF) sounds, we analyzed part of the recordings collected during the MGL 0910. During the previous cruises, some HF acoustic contacts were not detected by the observer but were found during this post-cruise analysis. Since these signals are not audible, it may occur that the operator, during long shifts at the PAM station, misses some weak, short HF click trains or whistles. Next year, as a further help, we will work on our software in order to assist the operator to detect the most contacts possible. The recordings from the ETOMO cruise were searched for possible missed contacts for about **80 h**. **No** acoustic contacts were found. Although it is possible that no marine mammals were present during PAM operations (there were no visual sightings during PAM), PAM performance was affected by several factors during the cruise, including unfavorable propagation conditions, severe bad weather, seismic gear interactions, damages, and presence in the area of difficult-to-detect species, such as the Dall's porpoise.