Marine Mammal Monitoring During Lamont-Doherty Earth Observatory's Marine Seismic Program In the Gulf of Alaska, September – October 2008

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and

National Marine Fisheries Service, Office of Protected Resources

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

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8 January 2009

MARINE MAMMAL MONITORING DURING LAMONT-DOHERTY EARTH OBSERVATORY'S MARINE SEISMIC PROGRAM IN THE GULF OF ALASKA, SEPTEMBER – OCTOBER 2008

by

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ACRONYMS AND ABBREVIATIONS

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

n.mi.	nautical miles
NMFS	(U.S.) National Marine Fisheries Service
No.	number
NSF	(U.S.) National Science Foundation
OBS	Ocean Bottom Seismometer
PAM	Passive Acoustic Monitoring
PD	Power down of the airguns to one operating airgun
pk-pk	peak-to-peak
psi	pounds per square inch
PTS	Permanent Threshold Shift
re	in reference to
RL	received (sound) level
rms	root-mean-square
rpm	revolutions per minute
s	seconds
SBP	Sub-bottom profiler
SD	Shut Down of all the airguns not associated with mitigation
s.d.	standard deviation
SE	Southeast
SEAMAP	SEAMAP Cetacean Monitoring System
SPL	Sound Pressure Level
STEEP	Saint Elias Erosion and Tectonics Project
SZ	Shut Down of all the airguns because of a marine mammal sighting near or within the safety radius
TTS	Temporary Threshold Shift
UNEP	United Nations Environmental Programme
U.K.	United Kingdom
U.S.	United States of America
"Useable"	Visual effort or sightings made under the following observation conditions: daylight periods within the study area, excluding periods 90 s to 6 h (for cetaceans) or 90 s to 2 h (for sea turtles) after airguns were turned off (post-seismic), nighttime observations, poor visibility conditions (visibility <3.5 km), and periods with Beaufort Wind Force >5 (>2 for cryptic species). Also excluded were periods when the *Langseth's* speed was <3.7 km/h (2 kt) or with >60º of severe glare between 90º left and 90º right of the bow. Sightings outside of the truncation distance (used for density calculations) were also considered "non-useable".
UTIG	University of Texas at Austin Institute for Geophysics

EXECUTIVE SUMMARY

Introduction

This document serves to meet reporting requirements specified in an Incidental Harassment Authorization (IHA) issued to Lamont-Doherty Earth Observatory (L-DEO) by the National Marine Fisheries Service (NMFS) on 8 September 2008. The IHA (Appendix A) authorized non-lethal takes of certain marine mammals incidental to a marine seismic survey by the R/V *Marcus G. Langseth* in the Gulf of Alaska (GOA), September–October 2008. Behavioral disturbance to marine mammals is considered to be "take by harassment" under the provisions of the U.S. Marine Mammal Protection Act (MMPA). NMFS considers that marine mammals exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} might be sufficiently disturbed to be "taken by harassment". "Taking" would also occur if marine mammals close to the seismic activity experienced a temporary or permanent reduction in their hearing sensitivity, or reacted behaviorally to the airgun sounds in a biologically significant manner.

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

Seismic Program Described

L-DEO conducted a seismic survey in the GOA offshore of the Saint Elias Mountains as part of the Saint Elias Erosion and Tectonics Project (STEEP). The purpose of the STEEP survey was to examine crustal structure, fault patterns, and tectonic-climate geohistory of the area. The seismic survey encompassed the area 58° to 60.5°N and 138° to 145°W in the GOA; the overall study area was defined as north of 53°N and east of 145°W. Water depths in the survey area ranged from 40 to 4000 m. The STEEP cruise took place from 10 September to 6 October 2008.

During the STEEP survey, a full 36-airgun array with a total discharge volume of 6600 in^3 was towed at a depth of 9 m. The acoustic receiving system consisted of one 8-km streamer containing hydrophones, which was towed behind the *Langseth*, and/or 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 operated from the *Langseth* throughout most of the study. As part of the marine mammal monitoring effort, passive acoustic monitoring (PAM) for vocalizing cetaceans also took place from the *Langseth* through the use of a towed hydrophone array or, at times, a hull-mounted hydrophone.

Monitoring and Mitigation Description and Methods

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

At least one MMO, but most often two MMOs, watched for marine mammals and sea turtles at all times while airguns operated during daylight periods, during night-time ramp ups, and whenever the vessel was underway but the airguns were not firing. The visual MMOs used 7 x 50 binoculars, 25 x 150 Big-eye binoculars, and/or the naked eye to scan the surface of the water around the vessel for marine mammals and sea turtles. The distance from the observer to the sighting was estimated using reticles on the binoculars. When a marine mammal or turtle was detected within or approaching the safety radius, the MMO called for a power down or shut down of the airguns. MMOs also conducted PAM during daytime and nighttime seismic operations when practicable. The primary purpose of the acoustic monitoring was to aid visual observers by detecting vocalizing cetaceans. The acoustic MMO listened with headphones or speakers to sounds received from the hydrophone(s) and simultaneously monitored a real-time spectrogram display.

Primary mitigation procedures, as required by the IHA, included the following: ***(A)*** Ramp ups consisting of a gradual increase in the volume of the operating airguns, whenever the airguns were started after periods without airgun operations or after prolonged operations with one airgun. ***(B)*** Immediate power downs or shut downs of the airguns whenever marine mammals or sea turtles were detected within or about to enter the safety radius. The safety radii for cetaceans, sea otters, and sea turtles during the survey were based on the distances within which the received levels of airgun sounds were expected to diminish to 180 dB re 1 μPa_{rms}, averaged over the pulse duration with no frequency weighting. The safety radius for pinnipeds was based on the distances within which the received levels of airgun sounds were expected to diminish to 190 dB re 1 μPa_{rms}.

Monitoring Results

The *Langseth* traveled a total of 5784 km (518 h) within the STEEP study area and 1636 km (101 h) during transit to and from the study area (Table ES.1). A total of 1633 km and 4151 km of seismic and non-seismic operations took place, respectively (Table ES.1). In total, 241 h of visual observations took place within the study area (Table ES.1). Nearly all (~99%) visual effort within the study area occurred during daylight periods. MMOs were on visual watch during all daylight seismic operations, including ramp ups. MMOs were also on watch for 1.5 h during periods of darkness (Table ES.1). In addition, 197 h of PAM occurred during seismic periods, but no acoustic detections of marine mammals were made (Table ES.1).

Analyses of marine mammal data focused on sightings and survey effort in the study area during "useable" survey conditions, which represented ~74% 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 >5. Also excluded from the "useable" category were periods when the *Langseth's* speed was <3.7 km/h (2 kt) or with >60º of severe glare between 90º left and right of the bow.

During the STEEP survey, 91 sightings totaling 484 cetaceans and two sightings of four sea otters were made; approximately one third of those sightings (33 groups totaling 111 individuals) were considered "useable" (Table ES.1). No pinniped or sea turtle sightings were observed. The Dall's porpoise was encountered most frequently, followed by the humpback whale. Other sightings included unidentified whales, sea otters, as well as Pacific white-sided and northern right-whale dolphins; the last two species were only sighted during transit. The four northern sea otters were seen in Yakutat Bay. All of the 33 "useable" sightings were made during non-seismic periods and consisted of cetacean sightings (n = 32) and one sea otter sighting (Table ES.1).

TABLE ES.1. Summary of *Langseth* operations, visual and passive acoustic monitoring (PAM) effort, and marine mammal sightings during the STEEP seismic survey, 10 September to 6 October 2008.

	Non-seismic					Seismic				
		Within Study Area								
			Post-Seismic[b]							
	Transit	Useable[a]	Recently Exposed	Potentially Exposed	Other Non-Useable	Useable[a]	Non-Useable	Total Useable[a]	Study Area Total	Overall Total
Operations effort in h										
Langseth Darkness	33.0	0	2.0	8.2	127.8	0	95.0	0	233.0	**266.0**
Langseth Daylight	68.3	85.7	5.0	3.8	82.3	70.2	37.8	155.8	284.7	**353.0**
***Langseth* Total**	**101.3**	**85.7**	**7.0**	**12.0**	**210.1**	**70.2**	**132.8**	**155.8**	**517.7**	**619.0**
Observer Darkness	0	0	0	0	0.4	0	1.1	0	1.5	**1.5**
Observer Daylight	22.6	85.7	4.5	3.3	38.0	70.2	37.8	155.8	239.3	**261.9**
Observer Total	**22.6**	**85.7**	**4.5**	**3.3**	**38.4**	**70.2**	**38.9**	**155.8**	**240.8**	**263.4**
PAM Total[c]			**0**			**197.0**				**197.0**
Operations effort in km										
Langseth Darkness	408.9	0	13.1	52.9	1707.9	0	755.4	0	2529.2	**2938.1**
Langseth Daylight	1226.9	1360.5	29.7	17.2	970.0	577.3	300.2	1937.8	3254.8	**4481.7**
***Langseth* Total**	**1635.8**	**1360.5**	**42.7**	**70.1**	**2677.9**	**577.3**	**1055.6**	**1937.8**	**5784.1**	**7419.9**
Observer Darkness	0	0	0	0	8.3	0	9.1	0	17.5	**17.5**
Observer Daylight	438.9	1360.5	28.6	15.3	322.1	577.3	300.2	1937.8	2604.0	**3042.9**
Observer Total	**438.9**	**1360.5**	**28.6**	**15.3**	**330.5**	**577.3**	**309.4**	**1937.8**	**2621.5**	**3060.4**
No. Cetacean Sightings (Individuals)	14 (62)	32 (110)	2 (2)	3 (7)	32 (258)	0 (0)	8 (45)	32 (110)	77 (422)	91 (484)
No. Sea Otter Sightings (Indiv.)	0	1 (1)	0	0	1 (3)	0	0	1 (1)	2 (4)	2 (4)
No. Cetacean Acoustic Detections			0			0		0	0	0
No. Power/Shut Downs (PD/SZ) for Cetaceans									5/2	5/2
No. PD/SZ for Sea Otters									0/0	0/0
PD/SZ Total									**5/2**	**5/2**

N/A means not applicable.
[a]See *Acronyms and Abbreviations* for the definition of "useable" effort. Total represents useable effort in the study area.
[b]Effort from 90 s to 6 h after airguns were turned off is considered post-seismic and non-useable; total useable effort is shown for cetaceans when Bf ≤5 is considered "useable."
[c]Effort during all non-seismic categories was combined, as was effort during all seismic activity.

For all useable sightings, the closest observed point of approach (CPA) to the non-operational airguns ranged from 163 to 4186 m with a mean of 1956 m. The mean CPA for Dall's porpoise sightings (1022 m, n = 14) was smaller than that for mysticetes (2835 m, n = 16), again considering the "useable", non-seismic sightings. Blowing and porpoising were the most frequently observed initial behaviors for humpbacks and Dall's porpoises, respectively. The greatest proportion of marine mammals had unknown or parallel movement relative to the vessel's path.

Approximately 24 marine mammal groups were detected per 1000 km of useable (non-seismic) survey effort vs. none during usable seismic effort. The marine mammal in the study area with the highest density was the Dall's porpoise. There were a total of five power downs and two shut downs for cetaceans during the STEEP survey (Table ES.1). One of the power downs resulted in a subsequent shut down.

Number of Marine Mammals Present and Potentially Affected

During the STEEP study, the "safety radii" for cetaceans and sea otters were the best estimates of the 180-dB re 1 μPa_{rms} radius for the 36-airgun array. For pinnipeds, the safety zone was based on the estimated 190-dB radius, but pinnipeds were not encountered during the survey. The airguns were powered down five times and shut down two times because of the presence of six cetacean groups, totaling 35 individuals, within or near the designated safety zone during the STEEP survey (Table ES.1).

Any large cetaceans that might have been exposed to received sound levels ≥160 dB re 1 μPa_{rms}, and delphinids and Dall's porpoises exposed to received levels ≥170 dB re 1 μPa_{rms}, were assumed to have been potentially disturbed during the seismic study. Eight groups of cetaceans (45 individuals) were sighted during seismic periods of the STEEP survey and within the ≥160 dB radius of the airgun array. Of these sightings, two groups of Dall's porpoises were likely exposed to sound levels ≥190 dB, and two groups of Dall's porpoises and a humpback whale were likely exposed to sound levels ≥180 dB before mitigation measures could be implemented. The other three groups (eight Dall's porpoises, one humpback whale, and two unidentified mysticete whales) were estimated to have received maximum levels ≥160 dB re 1 μPa_{rms} but <180 dB re 1 μPa_{rms}.

Minimum and maximum numbers of marine mammals potentially exposed to ≥160 and ≥170 dB re 1 μPa_{rms} were also estimated based on densities of marine mammals derived by line-transect procedures. These estimates allowed for animals not seen by MMOs. In the GOA, prior to the approach of the *Langseth*, a minimum of 2460 and up to 3507 cetaceans might have been in the areas later exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms}. Based on similar calculations, 1363–1820 cetaceans including 70 humpbacks, eight unidentified mysticetes, 11 unidentified whales, and 1731 Dall's porpoises, might have been present in areas that were subsequently exposed to received levels ≥170 dB re 1 μPa_{rms}. Even the maximum estimate of the number of cetaceans possibly exposed to ≥160 dB re 1 μPa_{rms} (3507) was only 51% of the authorized take.

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 STEEP survey, there were too few data to determine if the limited number of cetacean groups observed during seismic activities were avoiding the area around the seismic vessel. There were no "useable" sightings during seismic activities so no comparisons of behavior during seismic vs. non-seismic periods were possible. Given the mitigation measures that were applied, any effects were likely localized and transient, without significant impact on either individual marine mammals or their populations.

1. INTRODUCTION

Lamont-Doherty Earth Observatory (L-DEO) conducted a marine seismic program in the Gulf of Alaska (GOA) from 10 September to 6 October 2008. The marine seismic survey took place offshore of the Saint Elias Mountains as part of the Saint Elias Erosion and Tectonics Project (STEEP). The project was conducted aboard the R/V *Marcus G. Langseth*, which is owned by the National Science Foundation (NSF) and operated by L-DEO. The goal of the STEEP study was to examine crustal structure, fault patterns, and tectonic-climate geohistory of the area. The STEEP survey used a 36-airgun array as an energy source, with a maximum discharge volume of 6600 in^3. The geophysical investigation was under the direction of Drs. S. Gulick and G. Christesen of the University of Texas at Austin Institute for Geophysics (UTIG), and also included Drs. P. Mann and H. van Avendonk of UTIG.

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

Numerous species of marine mammals inhabit the waters of the GOA, including several that are listed as endangered under the ESA. The marine mammal species listed as endangered are the North Pacific right, humpback, sei, fin, blue, sperm, and Cook Inlet beluga whales, and the western stock of Steller sea lions. Those listed as threatened are the eastern stock of Steller sea lions and the northern sea otter. Two species of sea turtle, the leatherback and green turtle, occasionally occur in the GOA or southeast (SE) Alaska, but there were no sightings of either species during the STEEP survey. In the North Pacific, leatherback turtles are listed as endangered and green turtles are listed as threatened under the ESA.

On 10 April 2008, L-DEO requested that the National Marine Fisheries Service (NMFS) issue an Incidental Harassment Authorization (IHA) to authorize non-lethal "takes" of marine mammals incidental to the airgun operations in the GOA (LGL Ltd. 2008a). The IHA was requested pursuant to Section 101(a)(5)(D) of the MMPA. An Environmental Assessment (EA) was also prepared to evaluate the potential impacts of the STEEP seismic survey (LGL Ltd. 2008b). That EA was adopted by NSF, the federal agency sponsoring this seismic study. The IHA was issued by NMFS on 8 September 2008 (Appendix A).

The IHA authorized "potential take by harassment" of marine mammals during the seismic program described in this report. The *Langseth* departed from Astoria, Oregon, on 10 September 2008, for transit to the GOA study area. The vessel transited back to Astoria for arrival on 6 October.

This document serves to meet reporting requirements specified in the IHA. The primary purposes of this report are to describe the seismic program in the GOA, to describe the associated marine mammal and sea turtle monitoring and mitigation programs and their results, and to estimate the numbers of marine mammals potentially affected by the project.

Incidental Harassment Authorization

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

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

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

A notice regarding the proposed issuance of an IHA for the seismic study in the GOA was published by NMFS in the *Federal Register* on 5 August 2008, and public comments were invited (NMFS 2008a). The Marine Mammal Commission (MMC), a private citizen, and the Center for Regulatory Effectiveness (CRE) submitted comments.

On 8 September 2008, L-DEO received the IHA that had been requested for the seismic study, and on 12 September 2008 NMFS published a second notice in the *Federal Register* to announce the issuance

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

of the IHA (NMFS 2008b). The second 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 issued IHA is included in this report as Appendix A.

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

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

Mitigation and Monitoring Objectives

The objectives of the mitigation and monitoring program were described in detail in L-DEO's IHA Application (LGL Ltd. 2008a) 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 2008a,b).

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

The primary objectives of the monitoring program were as follows:

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

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

Report Organization

The primary purpose of this report is to describe the STEEP seismic study that took place in the GOA from 10 September to 6 October 2008, including the associated monitoring and mitigation program, and to present results as required by the IHA (see Appendix A). This report includes four chapters:

1. Background and introduction (this chapter);
2. Description of the seismic program;
3. Description of the marine mammal and sea turtle monitoring and mitigation requirements and

methods, including safety radii; and

4. Results of the marine mammal monitoring program, including estimated numbers of marine mammals potentially “taken by harassment.

Those chapters are followed by Acknowledgements and Literature Cited sections. No sea turtles were observed during the STEEP survey, so there are no associated sea turtle monitoring results to report.

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

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

2. SEISMIC PROGRAM DESCRIBED

The STEEP survey took place offshore of the Saint Elias Mountains in the eastern GOA (Fig. 2.1). Procedures used to obtain seismic data during the study were similar to those used during previous seismic surveys by L-DEO. A 36-airgun array was used as the energy source, and depending on the transect surveyed, the acoustic receiving system consisted of an 8-km long hydrophone streamer and/or Ocean Bottom Seismometers (OBSs).

In addition to the airgun operations, two other acoustical systems were operated during the cruise. A 12-kHz MBES and a lower energy 3.5 kHz SBP were used to map the bathymetry and sub-bottom conditions. At times, the *Langseth* towed a hydrophone array to detect calling cetaceans by PAM methods (see Chapter 3).

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

Operating Areas, Dates, and Navigation

The study encompassed the area north of 53°N and east of 145°W; however, the seismic survey took place in the GOA°, 58 to 60.5°N and 138° to 145°W in (Fig. 2.1). Water depths in the survey area ranged from 40 to 4000 m. The ship departed Astoria, Oregon, on 10 September 2008, for transit to the study area. Seismic operations took place 16–21, 25–26, and 29–30 September, and 1 October, along the gray-shaded lines ("Ship Track Exposed") shown in Figure 2.1. The vessel transited back to Astoria for arrival on 6 October. Airgun operations occurred during the day and at night. A summary of the total distances traveled by the *Langseth* during the STEEP 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 STEEP survey. The array consisted of 36 Bolt 1500LL and Bolt 1900LLX airguns with volumes ranging from 40 to 360 in^3. During firing, a brief (~0.1 s) pulse of sound was emitted. Compressed air supplied by compressors aboard the *Langseth* powered the airgun array; the firing pressure of the array was 1900 psi.

The airguns were configured as four identical linear arrays or "strings" (Fig. 2.2). Each string had ten airguns; the first and last airguns in the strings were spaced 16 m apart. Nine airguns in each string fired simultaneously, whereas the tenth was kept in reserve as a spare, to be turned on in case of failure of another airgun. The four airgun strings were distributed across an approximate area of 24×16 m behind the *Langseth*. The array was towed ~140 m behind the vessel. The airguns were suspended in the water from air-filled floats (see Appendix C). The airguns were towed at a depth of 9 m for the STEEP survey and at an average speed of ~4.4 kt. The shot spacing was 50 m (20 s) or 150 m (60 s) depending on whether the streamer or OBSs were used as the receiving system.

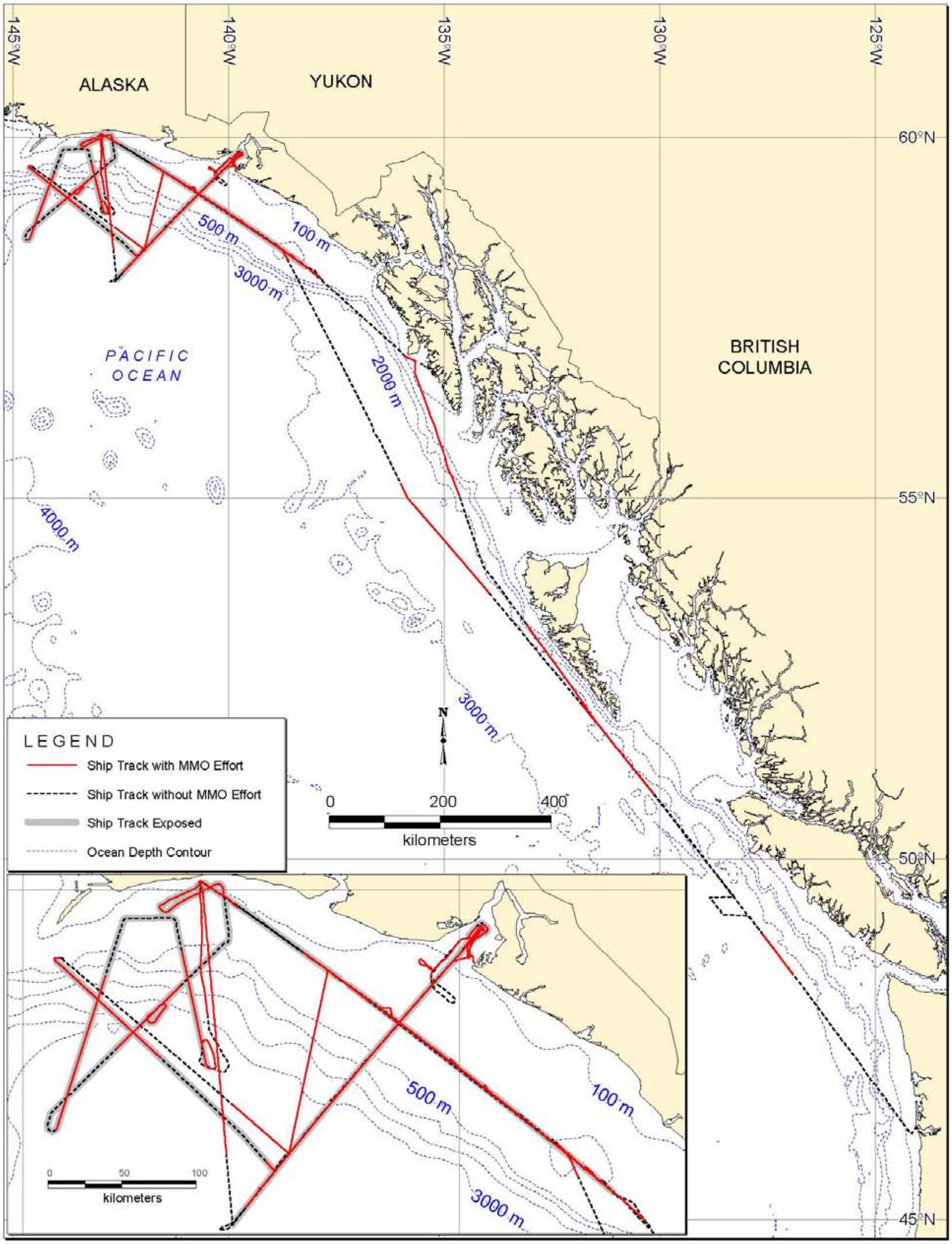

FIGURE 2.1. Map of the study area showing ship tracks with and without observer effort, plus acquired seismic lines ("Ship track exposed") during the STEEP survey, 10 September to 6 October 2008.

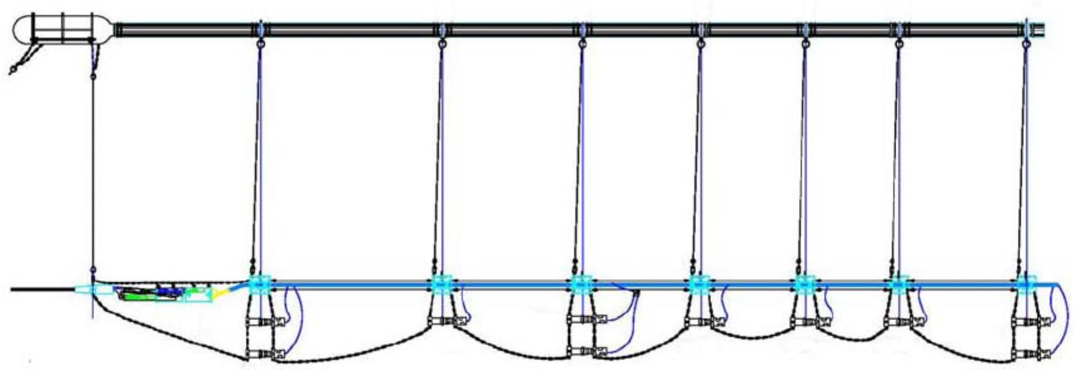

FIGURE 2.2. One of the four linear airgun arrays or strings with ten airguns. Nine airguns per string are active during seismic operations.

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

TABLE 2.1. Specification of the 36-airgun array used during L-DEO's STEEP survey, 10 September to 6 October 2008.

Energy source	Thirty-six 2000 psi Bolt airguns of 40–360 in^3
Source output (downward) [a]	0-pk is 84 bar-m (259 dB re 1 μPa·m); pk-pk is 177 bar-m (265 dB)
Total air discharge volume	~6600 in^3

[a] Source level estimates are based on a filter bandwidth of ~0–250 Hz; dominant frequency components are 2–188 Hz.

Other Airgun Operations

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

Multibeam Bathymetric Echosounder and Sub-bottom Profiler

Along with the airgun operations, two additional acoustic systems operated during the cruise. A 12-kHz Simrad EM120 MBES and a 3.5-kHz SBP operated throughout most of the cruise to map the bathymetry and sub-bottom conditions, as necessary to meet the geophysical science objectives. During seismic operations, these sources typically operated simultaneously with the airgun array. The echo-sounders are described in Appendix C.

3. MONITORING AND MITIGATION METHODS

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

Monitoring Tasks

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

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

No sea turtles were observed during the STEEP survey, and it is unlikely that any turtles were affected by the survey in the GOA.

Safety and Potential Disturbance Radii

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

Radii within which received levels from various airgun configurations were expected to diminish to certain values (i.e., 190, 180, 170, and 160 dB re 1 μPa_{rms}) were estimated by L-DEO (Table 3.1) and incorporated into the IHA (Appendix A). The 180-dB distance was used as the safety radius for cetaceans, sea otters, and sea turtles, and the 190-dB distance was used for pinnipeds. The radii depend on water depth (see Tolstoy et al. 2004a,b) as well as tow depth of the airgun array; a tow depth of ~9 m

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 shallow (<100 m), intermediate-depth (100–1000 m), and deep (>1000 m) water. Distances are estimated for the 36-airgun array and for a single airgun, as used during the seismic survey in the GOA, 2008. Predicted radii were based on L-DEO's model (see Appendix B).[a]

			Predicted RMS Radii (m)			
Source and Volume	**Tow Depth (m)**	**Water Depth**	**190 dB**	**180 dB**	**170 dB**	**160 dB**
Single Bolt airgun 40 in^3	9	Deep	12	40	120	385
		Intermediate	18	60	180	578
		Shallow	150	296	500	1050
4 strings 36 airguns 6600 in^3	9	Deep	300	950	2900	6000
		Intermediate	450	1425	4350	6667
		Shallow	2182	3694	7808	8000

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

was assumed when estimating the safety radii during the STEEP survey, and that was the actual operating depth during the project. Background on the sound modeling is provided in Appendix B.

Mitigation Measures as Implemented

The primary mitigation measures that were implemented during the present seismic study included ramp up, power down, and shut down of the airguns. These three measures are standard procedures employed during L-DEO seismic cruises and are described in detail in Appendix D. Mitigation also included those measures specifically identified in the IHA (Appendix A).

Standard mitigation measures implemented during the study included the following:

1. The configuration of the array directed more sound energy downward, and to some extent fore and aft, than to the side of the track. This reduced the exposure of marine animals, especially to the side of the track, to airgun sounds.
2. Safety radii implemented for the seismic study were based on acoustic modeling specific to the *Langseth*'s airgun configurations (see Appendix B),
3. Power-down or shut-down procedures were implemented when a marine mammal was seen within or near the applicable safety radius while the airguns were operating.
4. A change in vessel course and/or speed alteration was identified as a potential mitigation measure if a marine mammal was detected outside the safety radius and, based on its position and motion relative to the ship track, was judged likely to enter the safety radius. However, substantial alteration of vessel course or speed was not practical during the seismic study, given the length of the streamer(s) that was towed, and the design of the survey. Power downs or shut downs were the preferred and most practical mitigation measures when mammals were sighted within or about to enter the safety radii.
5. Ramp-up procedures were implemented whenever the array was powered up, to gradually increase the size of the operating source at a rate no greater than 6 dB per 5 min, the maximum

ramp-up rate authorized by NMFS in the IHA and during past L-DEO seismic cruises. Ramp up from a shut-down position could not be initiated in low-light (fog) or nighttime conditions.

6. Ramp up could not proceed if marine mammals were known to be within the safety radius, or if there had been visual detection(s) inside the safety zone within the following periods: 30 min for mysticetes and large odontocetes, including sperm whales, pygmy sperm, dwarf sperm, killer, and beaked whales, and 15 min for small odontocetes or pinnipeds.
7. PAM was conducted during most (97%) seismic operations.

Several cruise-specific mitigation measures were proposed for the STEEP study: ***(1)*** avoidance of critical habitat for Steller sea lions to the maximum extent possible, ***(2)*** shut down of airguns in the event of sightings of a North Pacific right or beluga whale at any distance from the vessel, ***(3)*** avoidance of concentrations of beaked whales, humpback whales, fin whales, or sea otters, ***(4)*** schedule seismic operations in inshore waters during daylight hours whenever possible, and ***(5)*** to the maximum extent possible, conduct inshore seismic surveys from upstream (inshore) towards the sea (offshore).

No concentrations of marine mammals were seen during the STEEP cruise, and there were no sightings of North Pacific right or beluga whales or of Steller sea lions. Yakutat Bay was surveyed from upstream towards the sea, but due to logistic reasons, seismic operations could not take place during daylight hours. However, marine mammal observations from the *Langseth* were conducted during daylight hours before seismic operations commenced within the Bay. Except for two sightings of four sea otters, no sightings of cetaceans or pinnipeds were made during the day (see Chapter 4, *Yakutat Bay*).

Visual Monitoring Methods

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

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

In summary, during the present seismic study, at least one but at most times two MMOs maintained a visual watch for marine mammals during all daylight hours from dawn to dusk. Visual observations were conducted from the *Langseth*'s observation tower. Observers focused search effort forward of the vessel but also searched aft of the vessel while it was underway. Watches were conducted with the naked eye, Fujinon 7 × 50 reticle binoculars, and mounted 25 × 150 Big-eye binoculars. Nighttime visual watches made up <1% of observation effort within the study area. Appendix D provides further details regarding visual monitoring methods.

Passive Acoustic Monitoring Methods

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

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

Two different systems were used for PAM during the STEEP study: the Right Waves hydrophone array and a hull-mounted hydrophone (see Appendix D for a description of these systems). The SEAMAP system, as used during some previous L-DEO cruises, was not available during the STEEP cruise. Acoustic monitoring software developed by CIBRA (University of Pavia, Italy) was used to record cetacean calls detected by the hydrophones (see Appendix D).

One MMO monitored the acoustic detection system by listening to the signals via headphones and by watching a real-time spectrogram display for frequency ranges produced by cetaceans. MMOs monitoring the acoustical data were usually on shift for 1–2 h. All MMOs rotated through the PAM position, although the most experienced with acoustics was on PAM duty more frequently.

During PAM as implemented from the *Langseth*, when a cetacean call is heard, the visual observer (if on duty) is immediately notified of the presence of calling marine mammals. Each acoustic "encounter" is assigned a chronological identification number. An acoustic encounter is defined as including all calls of a particular species or species-group separated by <1 h (Manghi et al. 1999).

Analyses

Categorization of Data

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

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

This categorization system was designed primarily to distinguish situations with ongoing seismic surveys from those where any seismic surveys were sufficiently far in the past that it can be assumed that they had no effect on current behavior and distribution of animals. Since the rate of recovery to "normal" behavior is unknown, the post-seismic period was defined so as to be sufficiently long (6 h for marine mammals) 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 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 outside of the study area (i.e., during transit) and outside of the truncation distance (used for density calculations) were considered non-useable. For data analysis purposes, all effort within the Alaska Downwelling Coastal Province (as defined by Longhurst 2007) was considered to be within the study area; this included waters north of 53ºN. Although "non-useable" sightings (and associated survey effort) were not considered when calculating densities of marine mammals, such sightings were taken into account when determining the need for real-time mitigation measures (power downs, shut downs).

Correction factors for missed cetaceans, i.e., *f*(0) and *g*(0), were taken from other related studies (i.e., Koski et al. 1998; Barlow 1999). This was necessary because of the low number of sightings of any individual species during the present study, and the inability to assess trackline sighting probability, during a study of this type. Densities that allow for these factors are listed here as "corrected" densities.

Densities during non-seismic periods were used to estimate the numbers of animals that presumably would have been present in the absence of seismic activities. Densities during seismic periods are generally used to estimate the numbers of animals present near the seismic operation and exposed to various sound levels. The difference between the two estimates could be taken as an estimate of the number of animals that moved in response to the operating seismic vessel, or that changed their behavior sufficiently to affect their detectability to visual observers. However, densities for seismic periods were zero for the STEEP study, as there were no useable sightings during those periods. 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 may have been exposed to sound levels ≥160 dB re 1 μPa_{rms}:

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

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

The two approaches can be interpreted as providing minimum and maximum estimates of the number of marine mammals exposed to sound levels ≥160 dB re 1 μPa_{rms}. The actual number exposed is probably somewhere between these two estimates. This approach was originally developed to estimate numbers of seals potentially affected by seismic surveys (Harris et al. 2001), and has recently been used in various L-DEO reports to NMFS (e.g., Haley and Koski 2004; Smultea et al. 2004, 2005; MacLean and Koski 2005; Holst et al. 2005a,b; Holst and Beland 2008; Holst and Smultea 2008; Hauser et al. 2008). The methodology is described in detail in these past reports and in Appendix D.

4. MONITORING RESULTS

Introduction

This chapter provides background information on the occurrence of marine mammals in the project area, and describes results of the marine mammal monitoring program. In addition, numbers of marine mammals exposed to various sound levels and potentially affected during project operations is estimated.

Status of Marine Mammals in the GOA

A total of 18 species of cetaceans are known to occur in the GOA and belong to two taxonomic groups: odontocetes (toothed cetaceans, such as dolphins and porpoises) and mysticetes (baleen whales). Three species of pinnipeds could occur in the eastern GOA, including the Steller sea lion, northern fur seal, and harbor seal. However, no pinnipeds were sighted during the STEEP survey. Additionally, the northern sea otter is found in coastal regions of the GOA. There is limited information on the distribution and abundance of marine mammals inhabiting the waters offshore SE Alaska and in the eastern GOA, although a few reports are available (e.g., Buckland et al. 1993; Hobbs and Lerczak 1993; Straley et al. 1995; Calambokidis et al. 1997; MacLean and Koski 2005; Angliss and Outlaw 2008). Several of the species are listed as endangered under the ESA, including the humpback, sei, fin, blue, North Pacific right, sperm, and Cook Inlet beluga whales, and the western stock of Steller sea lions. The eastern stock of Steller sea lions and the northern sea otter are listed as threatened. Additional information on the occurrence, distribution, population size, and conservation status for each of the 22 marine mammal species known to occur in the eastern GOA is presented in Appendix E.

Visual Monitoring Effort and Sightings

This section summarizes the visual monitoring effort and sightings from the *Langseth* during the STEEP seismic survey, 10 September to 6 October 2008. Summaries of the monitoring results are presented here, with detailed data summaries presented in Appendix F, including visual survey effort subdivided by seismic activity and Beaufort wind force. A general summary of effort and sightings is shown in Table ES.1.

Visual Survey Effort

Just under half of all seismic operations (47%) occurred in water >1000 m deep, 44% took place in water 100–1000 m deep, and ~9% occurred in shallow water <100 m. During the STEEP survey, 410 km of a total of 577 “useable” seismic km were surveyed with the 36-airgun array (see Appendix F). The remaining “useable” operations (167 km) occurred during ramp up, power down, or seismic testing with fewer airguns.

The *Langseth* traveled a total of ~7420 km (619 h) during the STEEP cruise (Table ES.1). Visual observations were obtained for a total of ~2622 km (241 h) within the study area and 439 km (23 h) during transit (Table ES.1). Observers were on watch during all daytime airgun operations and during most daytime periods when the vessel was underway but not firing the airguns. A total of ~18 km (1.5 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.

Approximately one third (~34%) of all visual effort within the study area took place during seismic periods (Fig. 4.1). Survey conditions were considered “useable” for systematic analysis during ~74% 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 for most marine mammal species and Bf >2 for cryptic species, and ship speed <3.7 km/h (2 kt). Also, sightings whose lateral distances from the trackline were outside the truncation distance (used to determine densities) were considered "non-useable". Beaufort wind force during observations aboard the *Langseth* ranged from zero to seven, and the majority (~69%) of "useable" observations took place during Bf 2-3 (Fig. 4.2; Appendix F). Sightings and survey effort during "non-useable" conditions were excluded when calculating densities, but were included when determining when power downs or shut downs were necessary because of marine mammals within the safety zone.

Sightings of Marine Mammals

A total of 488 marine mammals in 93 groups were recorded during the STEEP survey, including periods of transit to and from the survey area (Fig. 4.3; Table 4.1; Appendix F). Odontocete sightings included Dall's porpoises and Pacific white-sided and northern right-whale dolphins; however, dolphins were only seen during transit. Mysticete sightings included humpback and unidentified baleen whales. Two sightings of four northern sea otters and three sightings of four unidentified whales were also made. No pinnipeds or sea turtles were observed. Dall's porpoise, followed by the humpback whale, was the most frequently identified species (50 and 26 of 93 sightings, respectively; Table 4.1).

Just over a third of all sightings (~35% or 33 groups totaling 111 individuals) were made during "useable" observation effort within the study area (Table 4.1). Of the "useable" sightings, Dall's porpoise and the humpback whale each accounted for 42% of the sightings (14 sightings of each). The rest of the sightings included two groups of unidentified mysticetes, two groups of unidentified whales, and one sighting of a sea otter (Table 4.1). Only "useable" sightings, along with the corresponding effort data, are considered in the ensuing analyses of behavior, detection rates, and densities of marine mammals seen during the study. "Useable" sightings do not include sightings made during transit.

Sightings by Seismic State

All of the 33 "useable" sightings during the STEEP survey were made during non-seismic periods (Table 4.1). Since no "useable" sightings were made during seismic periods, no comparisons between seismic and non-seismic periods could be made for behavior or movement of marine mammals seen during the survey. Eight groups totaling 45 individuals were observed during seismic periods but were not "useable" for systematic analysis due to environmental conditions (Table 4.1). Five power downs and two shut downs had to be implemented due to marine mammals being observed within the applicable safety radii around the active airgun array. One of the shut downs followed an initial power down, and the other shut down of the then-operating single airgun was precautionary. Further details on these encounters are provided later in this chapter (see Table 4.4 under *Mitigation Measures Implemented*).

Detection Rate

The detection rates (number of cetacean groups sighted per 1000 km of "useable" effort) were based on ~1938 km of useable effort, of which 1361 km was non-seismic and 577 km was seismic. Considering useable sightings and effort during all activities, ~17 marine mammal groups were detected per 1000 km (n = 33). The detection rate was 24 groups/1000 km during non-seismic and zero groups/ 1000 km during seismic. Overall detection rates were highest during Bf 2 and lower during other Bf values (Fig. 4.4). Detection rates are typically lower in higher Bf conditions, as rougher sea conditions make it more difficult for observers to detect animals.

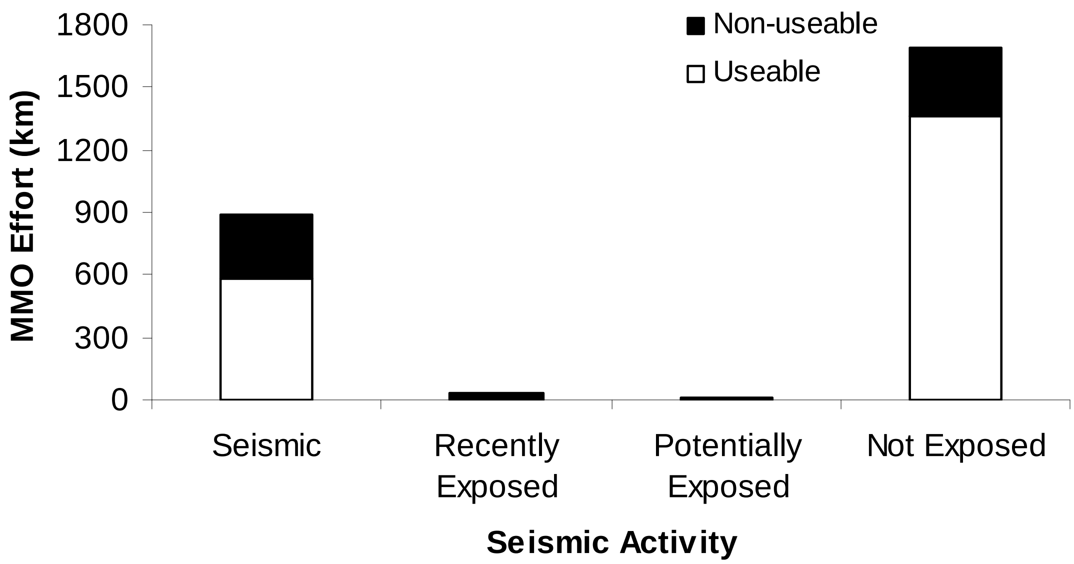

FIGURE 4.1. Total observer effort, categorized by seismic activity, during operations of the *Langseth* in the STEEP study area, 10 September to 6 October 2008. Recently Exposed includes periods 90 s to 2 h after airguns were turned off. Potentially Exposed includes periods 2−6 h after airguns were turned off.

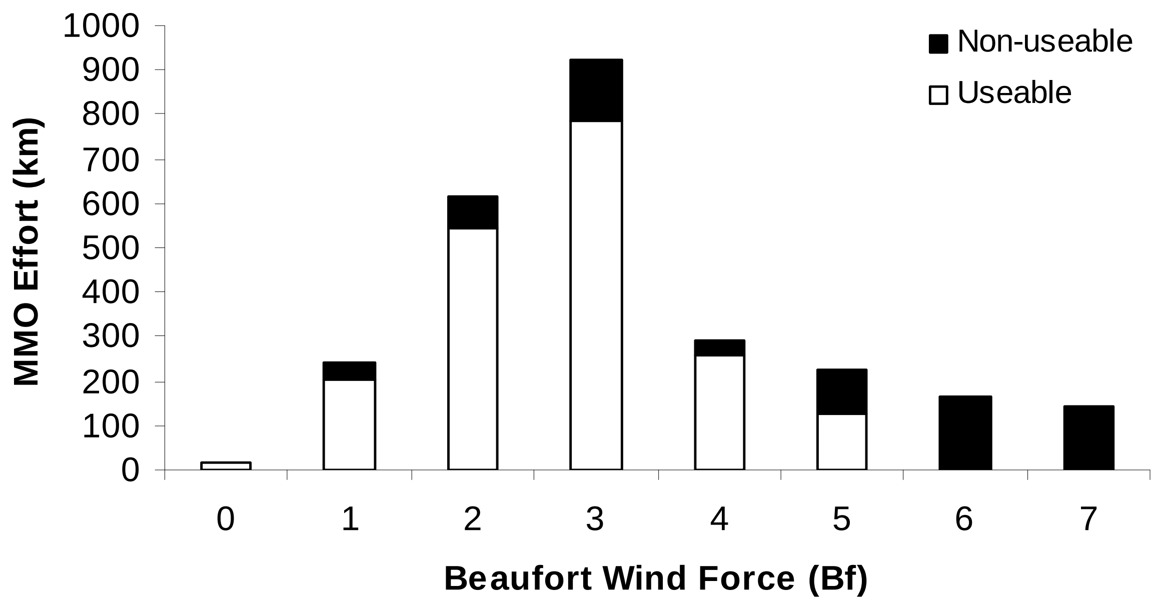

FIGURE 4.2. Total observer effort, categorized by Beaufort wind force, during operations of the *Langseth* in the STEEP study area, 10 September to 6 October 2008.

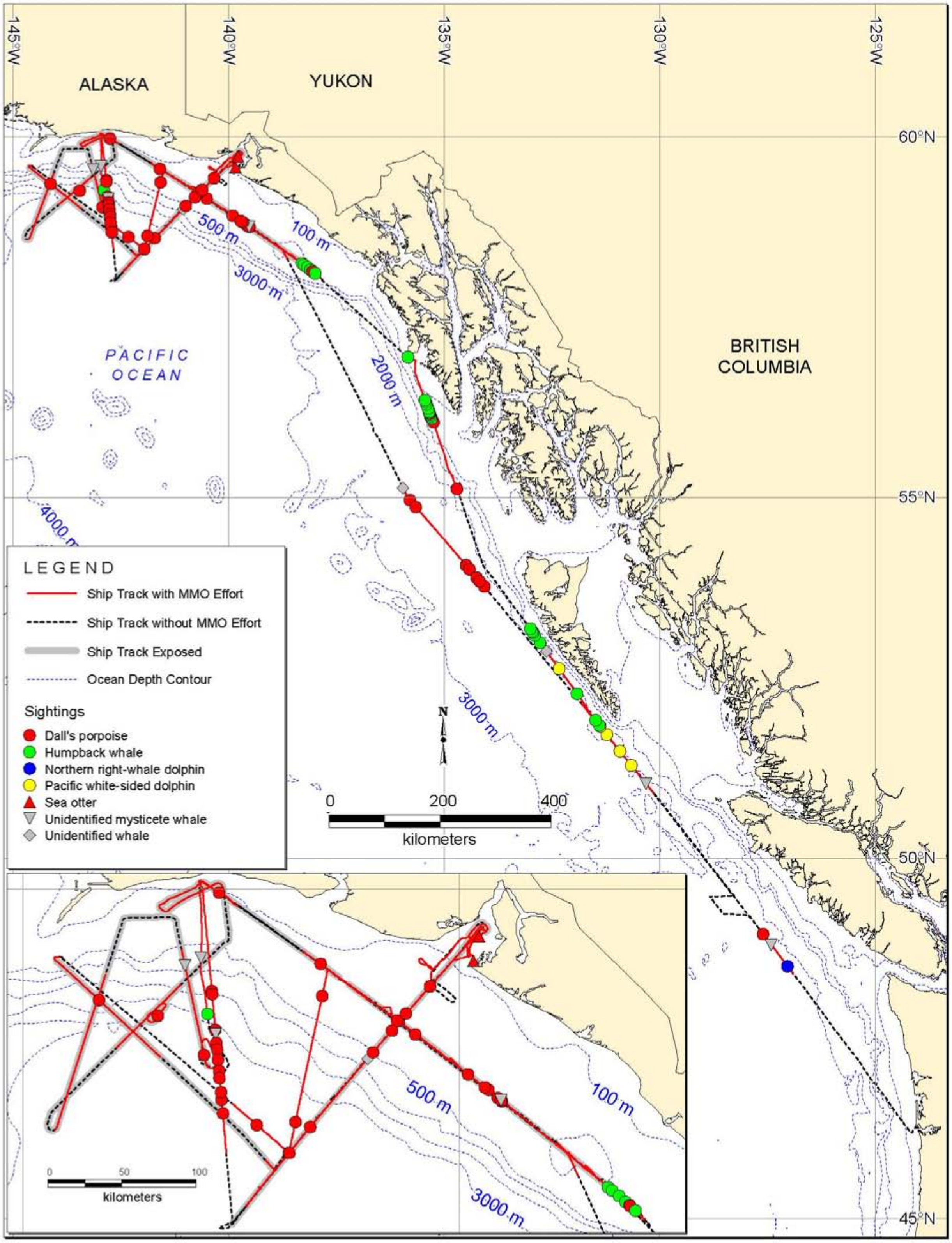

FIGURE 4.3. The STEEP survey showing the ship track, seismic lines, and sightings of cetaceans and sea otters, 10 September to 6 October 2008. Airguns operated along the shaded lines ("Ship track exposed"). The "study area" for analysis purposes was defined as north of 53ºN within the Alaska Downwelling Coastal Province (as defined by Longhurst 2007).

TABLE 4.1. Numbers of marine mammals observed from the *Langseth* during the STEEP seismic survey, 10 September to 6 October 2008.

	Species	Seismic		Recently Exposed[b]		Potentially Exposed[c]		Non-seismic		Transit		Total	
		Groups	Indiv.	Groups	Indiv.	Groups	Indiv.	Groups	Indiv.	Groups	Indiv.	Groups	Indiv.
All Sightings													
Odontocete	Dall's porpoise	5	41	0	0	1	5	43	339	1	4	**50**	**389**
	Northern right-whale dolphin	0	0	0	0	0	0	0	0	1	6	**1**	**6**
	Pacific white-sided dolphin	0	0	0	0	0	0	0	0	5	43	**5**	**43**
Mysticete	Humpback whale	2	2	2	2	2	2	16	23	4	6	**26**	**35**
	Unidentified mysticete whale	1	2	0	0	0	0	3	3	2	2	**6**	**7**
Unidentified whale		0	0	0	0	0	0	2	3	1	1	**3**	**4**
Marine Fissiped	Sea Otter	0	0	0	0	0	0	2	4	0	0	**2**	**4**
Total		***8***	***45***	***2***	***2***	***3***	***7***	***66***	***372***	***14***	***62***	***93***	***488***
Useable Sightings[a]													
Odontocete	Dall's porpoise	0	0	-	-	-	-	14	85	-	-	**14**	**85**
Mysticete	Humpback whale	0	0	-	-	-	-	14	20	-	-	**14**	**20**
	Unidentified mysticete whale	0	0	-	-	-	-	2	2	-	-	**2**	**2**
Unidentified whale		0	0	-	-	-	-	2	3	-	-	**2**	**3**
Marine Fissiped	Sea Otter	0	0	-	-	-	-	1	1	-	-	**1**	**1**
Total		***0***	***0***	**-**	**-**	**-**	**-**	***33***	***111***	**-**	**-**	***33***	***111***

[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 and during transit.

[b]Recently Exposed is defined as 90 s - 2 h after seismic stopped.

[c]Potentially Exposed is defined as 2 - 6 h after seismic stopped.

[d]Non-useable sightings during transit and during Recently or Potentially Exposed periods not shown.

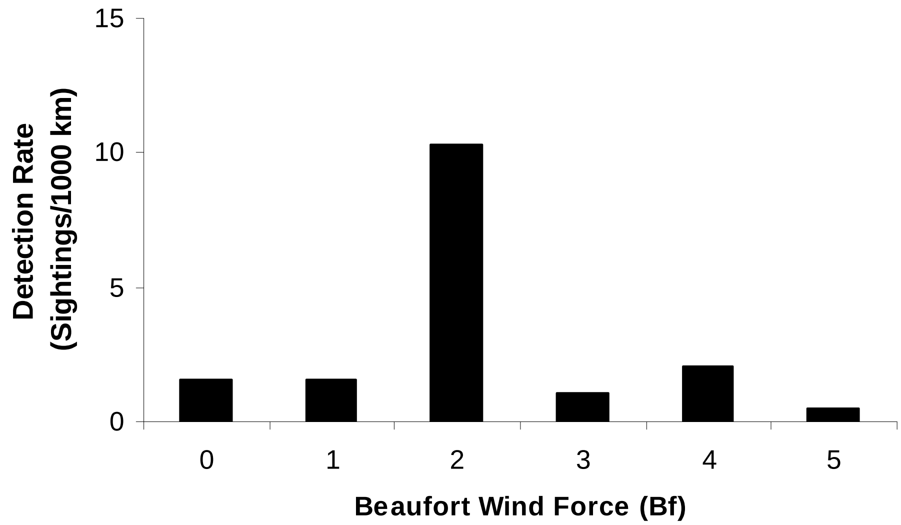

FIGURE 4.4. Marine mammal detection rates (based on useable sightings and effort) from the *Langseth* during different Beaufort wind force conditions during the STEEP seismic survey. All "useable" sightings were during non-seismic periods.

Density

Calculated densities were based on the number of "useable" sightings made during non-seismic periods of the STEEP survey. As no "useable" sightings were made during seismic periods, densities for those periods were zero (Table 4.2). Densities of each species were calculated by water depth category. Overall cetacean density was higher in deep (>1000 m) water compared with intermediate-depth (100–1000 m) water, even though less than half (39% or 534 of 1361 km) of non-seismic "useable" effort occurred in deep water (Appendix F). The density of Dall's porpoise was ~2.5× greater in deep compared with intermediate-depth water. However, humpback whale density was ~4× higher in intermediate water compared with deep water. A single sea otter was observed during the "useable" non-seismic period; thus, density could not be accurately calculated for sea otters. Sea otters are usually observed at a considerable distance from large vessels (>1 km in this case) and occur in nearshore habitat, invalidating assumptions associated with the calculation of $f(0)$; additionally, there are no reliable $g(0)$ values available for sea otters in the literature to account for detection probability.

Other Vessels

The numbers and characteristics of other vessels near the *Langseth* were also recorded during the STEEP survey. Tugs and barges were observed near the *Langseth* during the study, and other vessels were observed in conjunction with two humpback whale sightings. ***(1)*** On 13 September at 22:50 GMT, a fishing vessel was recorded over 15 km away and heading towards the *Langseth* while a humpback was seen milling about 4 km from the *Langseth*; no airguns were active at the time. ***(2)*** On 21 September at 23:04 GMT, two fishing vessels were observed during a sighting of a humpback lobtailing. Seismic gear was being recovered at the time of the sighting, so no airguns were active. The MMOs estimated that the fishing vessels were more than 5 km from the whale.

TABLE 4.2. Sightings and densities of cetaceans in water depths ***(A)*** <100 m, ***(B)*** 100–1000 m, and ***(C)*** >1000 m during "useable" survey effort in the STEEP study area, 10 September to 6 October 2008. Cetacean densities were corrected for *f*(0) and *g*(0) using values from Koski et al. (1998) and Barlow (1999).

Activity	Species	Number of Sightings	Mean group size	Average corrected density (#/km) Density	CV[a]
Non-seismic					
	(A) <100 m (83 km effort)				
	Sea otter[b]	***1***		-	-
	Total Cetaceans	***0***		***0***	-
	(B) 100-1000 m (744 km effort)				
	Mysticetes				
	Humpback whale	12	1.4	0.009	0.54
	Unidentified mysticete whale	1	1	0.001	0.94
	Total Mysticetes	**13**		**0.010**	**0.52**
	Odontocetes				
	Dall's Porpoise	9	6.2	0.098	0.58
	Unidentified Whale	**1**	**1**	**0.001**	**0.94**
	Total Cetaceans	***23***		***0.108***	***0.43***
	(C) >1000 m (534 km effort)				
	Mysticetes				
	Humpback whale	2	1.5	0.002	0.83
	Unidentified mysticete whale	1	1	0.001	0.94
	Total Mysticetes	3		0.003	0.76
	Odontocetes				
	Dall's Porpoise	5	5.8	0.250	0.68
	Unidentified Whale	1	2	0.001	0.94
	Total Cetaceans	***9***		***0.254***	***0.58***
Seismic					
	(A) <100 m (70 km effort)				
	Total Cetaceans	***0***		***0***	-
	(B) 100-1000 m (204 km effort)				
	Total Cetaceans	***0***		***0***	-
	(C) >1000 m (304 km effort)				
	Total Cetaceans	***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.

[b] One sea otter sighting was made, but density was not calculated because appropriate correction factors were unavailable.

Distribution and Behavior

The data collected during visual observations normally 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). In this project, there were no "useable" sightings during periods when airguns were operating. Thus, behavior with and without airgun operations cannot be compared.

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 (94% of "useable") initial sightings were of animals located in the forward 180º relative to the orientation of the vessel.

Closest Point of Approach

There were no "useable" sightings during seismic periods. During non-seismic periods, the mean CPA for odontocetes (all Dall's porpoises, n = 14) was closer (1022 m) than that for mysticetes (2835 m, n = 16) (Table 4.3). The CPA for one sea otter was 1106 m (Table 4.3).

First Observed Behavior

First observed behavior was recorded for all 33 "useable" marine mammal sightings during the STEEP survey. Dall's porpoises were most frequently observed porpoising (79% of 14 sightings), and mysticetes were most frequently observed blowing (94% of 16 sightings). Overall, blowing and porpoising were the most commonly observed first behaviors (48 and 33%, respectively), although swimming and traveling also occurred (15 and 3% of sightings, respectively; Fig. 4.5). One sea otter was observed swimming, and unidentified whales were seen blowing or traveling (Fig. 4.5). All sightings during seismic periods were "non-useable" for systematic analysis, but the first observed behaviors were blowing for all mysticetes, and porpoising, traveling or swimming for Dall's porpoises.

Movement

Of the 33 "useable" marine mammal sightings during the STEEP survey, the greatest proportion of animals had unknown or parallel movement relative to the vessel's path (33 and 30%, respectively; Fig. 4.6). Animal movement was also categorized as milling, swimming away, towards, and perpendicular to the path of the vessel, in that order of frequency (Fig. 4.6). Mysticetes were most often recorded has having unknown movement (50% of 16 sightings), although moving parallel to the vessel was also common (31%); mysticetes were also observed milling and swimming away from the vessel (Fig. 4.6). Dall's porpoises were most frequently seen swimming parallel to the vessel (29% of 14 sightings), but also swam towards, away, and perpendicular to the vessel, had unknown movement, or milled (Fig. 4.6). The movement of one sea otter was recorded as unknown, as was one unidentified whale observation; one unidentified whale swam parallel to the vessel (Fig. 4.6). Again, movement could not be compared for seismic vs. non-seismic periods because of the lack of "useable" sightings during seismic periods. However, movement types recorded for non-useable "seismic" sightings were swimming away, swimming towards, and unknown for three mysticete sightings, and swimming away or towards or across the vessel path for five Dall's porpoise sightings.

TABLE 4.3. Summary of closest observed point of approach (CPA) distances of marine mammals to the airgun array during non-seismic periods in the STEEP study area, 10 September to 6 October 2008.

Marine Mammal Group	Mean CPA (m)	s.d.	*n*[a]	Range (m)
Odontocete	1022	771	14	163 - 2644
Mysticete	2835	1338	16	657 - 4186
Unknown whale	1892	370	2	1630 - 2153
Sea Otter	1106	N/A	1	1106
Cetacean Total	***1983***	***1383***	***32***	***163 - 4186***
Marine Mammal Total	***1956***	***1369***	***33***	***163 - 4186***

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

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

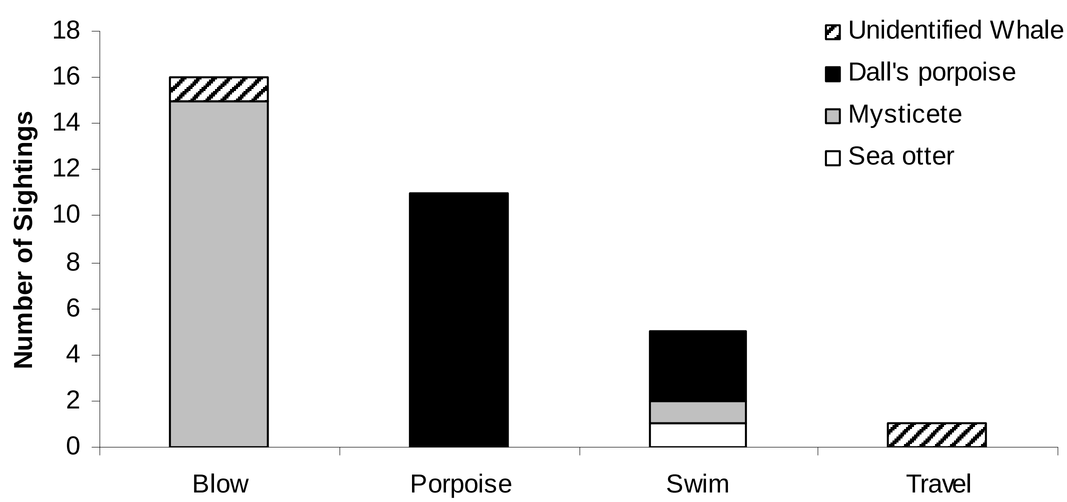

FIGURE 4.5. First observed behavior of "useable" sightings for each species sighted from the *Langseth* during the STEEP survey, 10 September to 6 October 2008. All "useable" sightings were in "non-seismic" conditions.

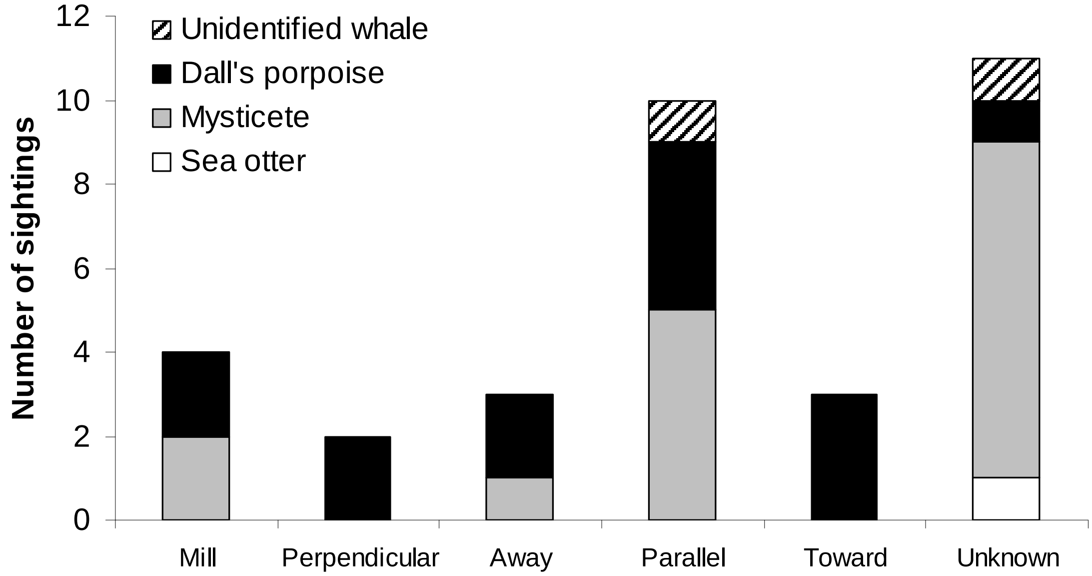

FIGURE 4.6. Movement categories relative to the *Langseth* for “useable” sightings during the STEEP survey, 10 September to 6 October 2008. All “useable” sightings were in “non-seismic” conditions.

Occurrence

Sightings during the STEEP cruise were made in shallow (<100 m), intermediate (100–1000 m), and deep (>1000 m) water. Sea otters were only seen in shallow water; no other marine mammal species were encountered in shallow water. Sea otters occur in nearshore waters, are benthic foragers, and would be expected in the somewhat protected coastal waters of Yakutat Bay where they were encountered during the STEEP cruise. Dall’s porpoises were seen in intermediate and deep water of the study area, as were humpback whales and unidentified whales. Pacific white-sided and northern right whale dolphins were only seen during transit to and from the study area in deep water. Most sightings during transit occurred between ~50ºN and 53ºN.

Acoustic Monitoring Effort and Detections

This section summarizes the PAM effort and detections from the *Langseth* during the STEEP seismic survey, 10 September to 6 October 2008. A short summary of the monitoring results is presented here, with a more detailed summary presented in Appendix G.

Passive Acoustic Monitoring Effort

During the STEEP survey, 197 h of PAM took place during most (97%) seismic operations; technical difficulties with PAM occurred during the remainder of seismic operations (see Appendix G).

Acoustic Detections of Cetaceans

During the STEEP survey, there were no acoustic detections of marine mammals during seismic operations; PAM did not occur during non-seismic periods (Appendix G). The lack of detections was presumably related to equipment difficulties and the fact that the equipment was not designed to detect high-frequency clicks from species such as the Dall’s porpoise (Appendix G).

Yakutat Bay

Seismic Survey

Seismic operations in Yakutat Bay took place in the evening (local time) of 24 and 28 September. On both dates, the vessel entered the Bay and MMOs watched for marine mammals. No marine mammals were sighted on 24 September; thus, a ramp up was initiated just before nightfall. On 28 September, two sightings of four sea otters were made in Yakutat Bay before seismic operations commenced. After all sea otters were well outside of the safety radius, the airgun array was ramped up just before nightfall. No other marine mammals were seen in Yakutat Bay on either date. However, opportunistic aerial surveys (see below) noted the presence of belugas at Turner Point, located ~30 km from the seismic survey and well outside the estimated 160-dB distance.

In order to meet the science objectives, it was necessary to start ramping up the array on both dates as the vessel was heading into the Bay, so that the entire transect line could be surveyed with the full 36-airgun array while the vessel headed out of the Bay. The full 36-airgun array was not operating when the vessel was heading into the Bay.

Aerial Survey

In support of the marine mammal and mitigation objectives, opportunistic aerial surveys were flown in Yakutat Bay. Aerial surveys were not required by the IHA for the STEEP study, but were initiated by L-DEO as additional monitoring. In total, four aerial surveys were flown: two surveys over the beach to locate stranded animals and two surveys over Yakutat Bay to look for belugas. The beach surveys took place on 21 and 22 September 2008. The surveys of Yakutat Bay took place on 24 and 28 September 2008 before seismic operations commenced. Two observers scanned for marine mammals during each of the surveys, and sightings were communicated to MMOs onboard the *Langseth*.

One large mysticete carcass was seen on the beach at 60º03.433N and 142º17.562W (Table 4.4). This carcass was first sighted on 21 September. It was suspected that the animal was a gray whale and had been deceased for an extended period, because it was partially decayed to the stage of having exposed rib bones.

On 24 September, there were a total of 12 marine mammal sightings (27 individuals) including: two beluga whale sightings totaling 10 individuals, four groups of 7 harbor porpoises, three groups of 7 harbor seals, and three sea otter sightings (Table 4.4). None of these animals were observed simultaneously by MMOs aboard the *Langseth*. One sighting of five harbor porpoises was made during overflights on 28 September.

Mitigation Measures Implemented

Ramp ups, power downs, and shut downs of the airgun array were implemented as mitigation measures during the STEEP study (associated visual and acoustic monitoring procedures are outlined in Chapter 3). Ramp ups were conducted during daylight whenever the airguns were started up after a prolonged period of inactivity (7 min) or during the day or night when there was a requirement to increase the number of operating airguns by a factor exceeding 2× (e.g., from 1 to 36 airguns). The latter occurred subsequent to a power down or shut down for a marine mammal seen within the relevant safety radius. In addition, ramp-up procedures were delayed twice due to the presence of a sea otter and a group of eight Dall's porpoises within or near the safety radius.

TABLE 4.4. Sightings of marine mammals in Yakutat Bay during aerial surveys conducted in support of marine mammal monitoring objectives during the STEEP survey, 10 September to 6 October 2008.

	Beach survey		Bay survey	
	21-Sep	22-Sep	24-Sep	28-Sep
Beluga whale	0 (0)	0 (0)	2 (10)	0 (0)
Harbor Porpoise	0 (0)	0 (0)	4 (7)	1 (5)
Harbor Seal	0 (0)	0 (0)	3 (7)	0 (0)
Sea Otter	0 (0)	0 (0)	3 (3)	0 (0)
Total	***0 (0)***	***0 (0)***	***12 (27)***	***1 (5)***
Whale Carcass	1 (1)	0 (0)	0 (0)	0 (0)

There were a total of five power downs and two shut downs of the airgun array due to marine mammals observed within or about to enter the relevant safety radius (Table 4.5). Power downs reduced the operating airgun array to a single airgun (40 in^3) and were implemented for five different cetacean sightings within or near the nominal 180 dB re 1 μPa_{rms} (flat-weighted) safety radius (Table 4.5). Four of the five power downs occurred for Dall's porpoise groups, and one of those power downs was followed by a subsequent shut down (Table 4.5). The remaining power down and shut down were implemented for two different humpback whales.

- A group of 12 Dall's porpoises was seen on 16 September at 19:36 GMT while 36 airguns were operating in deep water. The porpoises were seen swimming away from the vessel at a distance of 100 m from the observers and 241 m from the airguns; the array was powered down immediately. All porpoises were well within the nominal safety radius for the 36-airgun array; thus, all 12 porpoises were likely exposed to sound levels ≥190 dB re 1 μPa_{rms} (on a flat-weighted basis) when they dove. The airgun array was ramped up again after the animals had not been seen for 15 min.
- A group of eight Dall's porpoises was sighted in water 145 m deep on 20 September at 16:58 GMT while 36 airguns were firing. The group was first seen porpoising 50 m from the observers or 182 m from the airguns, and proceeded to ride the bow wave. The airgun array was powered down immediately. When the porpoises were sighted again 7 min later at a distance of 1535 m from the observers, the airgun array was ramped up again. As the group of porpoises was seen well within the safety radius of the full array, it is likely that some, if not all, of the porpoises were (when below the surface) exposed to sound levels ≥190 dB re 1 μPa_{rms} (flat-weighted).
- One humpback whale was seen on 21 September at 21:52 GMT in water 145 m deep while 36 airguns were operating. This animal was first seen blowing and swimming away from the *Langseth* at a distance of 760 m from the observers and 916 m from the airguns. A power down was implemented immediately. The humpback whale was seen for ~18 min during which time it fluked several times and breached. After 18 min, it was seen well outside the safety radius at a distance of 2.6 km from the observers, but the array remained powered down for another 8 min, and was subsequently shut down due to another humpback while sighting (see below). As this animal was within the nominal safety radius around the airgun array, it is likely that it was exposed to sound levels ≥180 dB re 1 μPa_{rms} when it dove.

TABLE 4.5. List of power downs (PD) and shut downs (SZ) of the airguns implemented for cetaceans sighted in or near the safety radius during the STEEP survey, 10 September to 6 October.

Species	Group size	Date	Water depth (m)	Movement[a]	First Behavior[b]	No. airguns on (in^3) prior to SZ or PD[c]	CPA (m)[d]	Mitigation (PD or SZ)	Est. received sound level (dB re 1μPa$_{rms}$)
Dall's porpoise	12	16-Sep	3374	SA	TR	36 (6600)	241	PD	≥190
Dall's porpoise	8	20-Sep	145	ST	PO	36 (6600)	182	PD	≥190
Dall's porpoise	6	29-Sep	3479	PE	SW	35 (6480)	411	PD	≥180
Dall's porpoise	7	30-Sep	2970	ST	SW	33 (5270)	425	PD/SZ[e]	≥180
Humpback whale	1	21-Sep	145	SA	BL	36 (6600)	916	PD	≥180
Humpback whale	1	21-Sep	151	ST	BL	1 (40)	174	SZ[f]	≥170

[a]Initial movement of animal(s) relative to the vessel: PE = swimming perpindicular to or across the vessel track, SA = swimming away from the vessel track, ST = swimming toward the vessel.
[b]First observed behavior of animal(s): TR = travel, PO = porpoise, BL = blow, SW = swim.
[c]SZ = shut down, PD = power down.
[d]The closest (observed) point of approach (CPA) of the animal(s) to the airguns before mitigation.
[e]A SZ was implemented following an earlier PD for this same group.
[f]A precautionary shut down was implemented for this animal prior to entering the 180 dB safety radius of the then operating single airgun.

- Another humpback whale was seen during the power down (1 airgun operating) noted above at 22:18 GMT on 21 September. This individual was seen swimming towards the *Langseth* in water 151 m deep at a distance of 302 m from the observer and 174 m from the airguns. The humpback was seen blowing and fluking. Because the vessel was approaching the end of the transect line, the single airgun was shut down even though the whale had not yet entered the 180-dB safety radius of the single airgun then in operation. Thus, the humpback whale was likely exposed to sound levels <180 dB (or ~170 dB re 1 μPa$_{rms}$) when it dove.
- A group of six Dall's porpoises was first sighted in deep water on 29 September at 22:18 GMT while 35 airguns were firing. The group was seen swimming across the vessel path at a distance of ~250 m from the observer or 411 m from the airguns. The airgun array was powered down immediately. When the porpoises were sighted again 4 min later outside of the safety radius, all 35 airguns were started again. As the group of porpoises was seen within the safety radius of the full array and some were seen to dive, it is likely that several, if not all, of the porpoises were exposed to sound levels ≥180 dB re 1 μPa$_{rms}$ (flat-weighted) when they dove.
- A group of six Dall's porpoises was first sighted in deep water on 30 September at 22:21 GMT while 33 airguns were firing. The group was seen swimming across the vessel path at a distance of ~2614 m from the observers. Nineteen minutes later, a group of seven Dall's porpoises (assumed to be the same group) was seen swimming towards the *Langseth* at a distance of 250 m from the observers and 425 m from the airguns. The airgun array was powered down immediately. After 3 min, the array was shut down when the porpoises were about to enter the 180-dB safety radius of the single airgun. Within another 3 min, the porpoises had left the safety radius, and all 33 airguns were started up again. As the group of porpoises was seen within the safety radius of the array and some were seen to dive, it is likely that several, if not all, of the porpoises were exposed to sound levels ≥180 dB re 1 μPa$_{rms}$ (flat-weighted).

In summary, mitigation measures were implemented for six cetacean groups totaling 35 individuals. Five of those groups, totaling 34 individuals, were likely exposed to sound levels ≥180 dB re 1 μPa$_{rms}$ during the STEEP survey (Table 4.5). Only one or a few shots were fired between the initial detection and the time when the airguns were powered down. Two groups (20 individuals) of Dall's porpoises were inside the nominal 190-dB radius prior to mitigation, and two groups (13 animals) of Dall's porpoise and one humpback whale were detected within the nominal 180-dB radius prior to mitigation; these animals were presumably exposed to strong airgun pulses. The sound levels received by these cetacean groups were likely ≥190 or 180 dB re 1 μPa_{rms}, respectively, for some of the airgun pulses prior to the power down or shut down. This assumes that the animals, while inside the safety radius, were at some point well below the surface when one or more of the airgun pulses were received. Received levels when the animals were at or near the surface would have been substantially lower. Effective received levels for the Dall's porpoises, which comprised most of the animals exposed to ≥180 dB re 1 μPa_{rms}, would also have been lower given that they are high-frequency specialists with reduced sensitivity to the predominant low-frequency components of airgun sound (Southall et al. 2007).

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

In order to minimize the incidental 'taking' of ESA-listed marine mammals, L-DEO implemented the above-mentioned mitigation measures for marine mammals sighted near or within the safety radius. Sperm, blue, fin, sei, and North Pacific right whales were not encountered during the survey and were therefore not affected. Similarly, no Steller sea lions, Cook Inlet beluga whales, or leatherback turtles were seen during the STEEP survey.

In addition to the typical monitoring and mitigation measures such as ramp ups, power downs, and shut downs (see Chapter 3), the Biological Opinion also specified the following mitigation measures: ***(1)*** avoidance of critical habitat for Steller sea lions to the maximum extent possible, ***(2)*** emergency shut-down of airguns in the event a North Pacific right whale is sighted at any distance from the vessel, and ***(3)*** avoidance of concentrations of humpback whales and fin whales. No Steller sea lions, North Pacific right whales or fin whales were sighted during the STEEP survey; thus, it is very unlikely that the seismic operations had any effects on any of these species. Although concentrations of humpbacks were not encountered, two sightings of individual humpback whales were made during seismic operations. Although it is likely that both of these individuals were exposed to received sound levels >160 dB, the humpback whales did not appear to react to the airgun sounds in a biologically significant manner.

For listed Pacific salmon or steelhead, NMFS specified vessel-based monitoring as well as ramp-up and emergency shut-down procedures for injuries or mortality. No injured fish or fish-kills were observed during the STEEP seismic survey.

Estimated Number of Marine Mammals Potentially Affected

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

Disturbance and Safety Criteria

Any cetacean that might have been exposed to airgun pulses with received sound levels ≥160 dB re 1 μPa_{rms} (flat-weighted) was assumed to have been potentially disturbed. Such disturbance was authorized by the IHA issued to L-DEO. However, the 160-dB criterion was developed by NMFS from studies of baleen whale reactions to seismic pulses (Richardson et al. 1995). That criterion likely is not appropriate for delphinids and some porpoises. The hearing of small odontocetes is relatively insensitive to low frequencies, and behavioral reactions of most small odontocetes (including Dall's porpoises) to airgun sounds indicate that they are usually less responsive than are some baleen whales (Richardson et al. 1995; Gordon et al. 2004). Probable exposure to rms received levels ≥170 dB was used as an alternative criterion in estimating potential disturbance of delphinids and Dall's porpoises.

Table 3.1 shows the predicted received sound levels at various distances from the airgun(s) deployed from the *Langseth*. The ≥160-dB radius is an assumed behavioral disturbance criterion. As discussed above, the 170 dB-radius was used as an alternative criterion in estimating potential disturbance of delphinids and Dall's porpoises. The ≥180 dB-radius is a safety radius, used in determining when mitigation measures are required. During this and other recent L-DEO projects, NMFS has required that mitigation measures be applied to avoid, or minimize, the exposure of cetaceans to impulse sounds with received levels ≥180 dB re 1 μPa_{rms}. During this study, five power downs and one subsequent shut down, as well as a precautionary shut down, were required (as described above) due to marine mammals being sighted within or near the applicable safety radii around the operating airguns. However, additional estimates of the numbers of marine mammals potentially exposed to various received sound levels were also derived based on observed densities and the assumed 160- and 170-dB radii.

This section applies two methods to estimate the number of marine mammals possibly exposed to seismic sound levels strong enough that they might have caused disturbance or other potential impacts. The procedures include ***(A)*** minimum estimates based on the direct observations of marine mammals by MMOs, and ***(B)*** estimates based on marine mammal densities obtained during this study. The actual numbers of individual marine mammals exposed to, and potentially affected by, seismic survey sounds likely were between the minimum and maximum estimates provided in the following sections. The estimates provided here are based on observations during this project. In contrast, the estimates provided in the IHA Application and EA for this project (LGL Ltd. 2008a,b) were based on survey and other information available prior to the fieldwork.

Estimates from Direct Observations

The number of marine mammals observed close to the *Langseth* during the seismic study provides a minimum estimate of the number potentially affected by seismic sounds. This is likely an underestimate of the actual number potentially affected. Some animals probably moved away before coming within visual range of MMOs, and it is unlikely that MMOs were able to detect all of the marine mammals near the vessel trackline. During daylight, animals are missed if they are below the surface when the ship is nearby. Some other marine mammals, even if they surface near the vessel, are missed because of limited visibility (e.g., fog), glare, or other factors limiting sightability. Also, sound levels were estimated to be ≥160 dB re 1 μPa_{rms} out to ~6, 6.7, and 8 km when the 36-airgun array was in use in deep, intermediate, and shallow water, respectively (see Table 3.1); thus, some smaller, less conspicuous cetaceans may have been missed. Furthermore, marine mammals cannot be seen effectively during periods of darkness. However, a very limited amount (<2 h) of marine mammal survey effort occurred at night during the STEEP survey.

Animals may have avoided the area near the seismic vessel while the airguns were firing (see Richardson et al. 1995, 1999; Gordon et al. 2004; Smultea et al. 2004; Stone and Tasker 2006; Weir 2008). Within the assumed ≥160–170 dB radii around the source (i.e., up to 8 km with the 36-airgun array), and perhaps farther away in the case of the more sensitive species and individuals, the distribution and behavior of cetaceans may have been altered as a result of the seismic survey. This could occur as a result of reactions to the airguns or as a result of reactions to the *Langseth* itself. The extent to which the distribution and behavior of cetaceans might be affected by the airguns beyond the distance at which they are detectable by MMOs is impossible to determine from shipboard MMO data.

Cetaceans Potentially Exposed to Sounds ≥180 dB re 1 μPa$_{rms}$.—During the STEEP survey, six cetacean groups totaling 35 individuals were sighted within or about to enter the safety radius around the airguns; a power down and/or shut down was implemented on each of those occasions (Table 4.5). All of these animals, other than an individual humpback whale, were estimated to have received sound levels ≥180 dB (flat-weighted), based on the distance of their CPA to the airgun array. The sound levels received by these cetacean groups were likely ≥180 dB re 1 μPa$_{rms}$ for some of the airgun shots prior to the power down. This assumes that the animals, while inside the safety radius, were well below the surface when one or more of the airgun pulses were received.

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

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

Airgun operations occurred at night as well as during daytime, but MMOs were generally not on duty at night (and had much reduced ability to sight mammals on occasions when they were on duty at night). During the STEEP study, ~47% of the airgun operations occurred at night. If cetaceans were encountered at similar rates by night as by day, then the total numbers exposed to various sound levels were presumably about twice the numbers estimated by direct observation in daytime. However, in the absence of the nighttime sighting data that would be needed as a basis for initiating power downs and shut downs at night, on a per-encounter basis, the frequency of exposure to high sound levels would be somewhat higher by night than by day. In addition, <1% of daytime observation effort during seismic occurred during periods of poor visibility (≤500 m visibility).

Cetaceans Potentially Exposed to Sounds ≥160 dB re 1 μPa$_{rms}$.—Eight groups of cetaceans totaling 45 individuals were sighted during the STEEP survey when the airguns were operating (Table 4.1; Appendix F). These included five groups of Dall's porpoises, two sightings of individual humpbacks, one group of two unidentified mysticetes. All of these sightings occurred within the ≥160-dB radius of the then-operating airgun array. No sea otters were observed during seismic periods; pinnipeds and sea turtles were not seen at all during the STEEP survey.

Because the 160-dB radii of the 36-airgun array were estimated to be ≥6 km, some smaller, less conspicuous cetaceans that were exposed to that sound level in daytime probably occurred at the surface without being seen by observers. Additional cetaceans would be exposed during airgun operations at night and in periods of poor visibility. These missed animals are accounted for in estimates presented later in this section based on densities of animals during "useable" non-seismic periods (there were no "useable" sightings during seismic periods).

Dolphins and Dall's Porpoise Potentially Exposed to Sounds ≥170 dB 1 μPa$_{rms}$.—For delphinids and some porpoises, exposure to airgun sounds with received levels ≥170 dB may be a more appropriate criterion of disturbance than exposure to ≥160 dB, as discussed above. During the STEEP survey, there were no sightings of dolphins within the study area or during seismic periods. However, four groups totaling 33 Dall's porpoises were observed where received levels of airgun sounds below the surface were estimated to be ≥170 dB re 1 μPa$_{rms}$ (flat-weighted).

Estimates Extrapolated from Marine Mammal Density

The methodology used to estimate the areas exposed to received levels ≥160 dB and ≥170 dB re 1 μPa$_{rms}$ and to estimate corrected marine mammal densities, was described briefly in Chapter 3 *Analyses* and in further detail in Appendix D. Densities were based on the number of "useable" sightings during the survey and were calculated for non-seismic periods; densities for seismic periods could not be calculated (see Table 4.2). The former represent the densities of mammals expected to occur "naturally" within the area (assuming that, during non-seismic periods, there was little bias associated with avoidance of or attraction to the ship). Densities calculated from useable sightings and effort during seismic periods represent the densities of mammals that apparently remain within the area exposed to strong airgun pulses. During the STEEP survey, there were no "useable" sightings during seismic, resulting in densities of zero. As there were eight non-useable sightings during seismic periods, the actual density in seismic conditions was non-zero but not determinable.

The corrected densities were used to estimate the number of marine mammals 'normally' present in the area before the ship approached and thus potentially affected by the seismic survey. The actual number of exposures or individuals exposed to 160 and 170 dB will be lower than estimated as many marine mammals are expected to move away from the operating airgun array before those levels are reached. Because no pinnipeds or sea turtles were seen during the STEEP seismic survey, the estimated number of pinnipeds and sea turtles exposed were zero. As discussed above, sea otter densities were not estimated for the STEEP survey (see *Density* and Table 4.2). Thus, the estimated number of sea otters exposed was also zero.

Table 4.6 summarizes the estimated numbers of cetaceans exposed to airgun sounds with received levels ≥160 dB and ≥170 dB re 1 µPa_{rms}. The data used to calculate these numbers include the densities presented in Table 4.2 and the extent of ensonified areas presented in Table 4.7.

***Estimated Numbers of Cetaceans Exposed to ≥160 or ≥170 dB*.—**For all types of marine mammals sighted, Table 4.6 shows the estimated numbers of animals in the area prior to the arrival of the seismic vessel and thus potentially exposed to ≥160 and ≥170 dB re 1 µPa_{rms} if they did not avoid the operating airgun array. It is assumed that baleen 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 small odontocetes (dolphins and Dall's porpoises) are unlikely to be disturbed appreciably unless exposed to received levels ≥170 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.

Estimates Based on Densities during Non-seismic Periods: "Corrected" estimates of the densities of cetaceans present during non-seismic periods are given in Table 4.2; densities during seismic periods were zero. The corrected densities were used to estimate the number of cetaceans that were present in the area and thus potentially exposed to ≥160 and ≥170 dB if they did not avoid the seismic vessel (Table 4.6).

(A) 160 dB re 1 µPa_{rms}: During the STEEP survey, we estimate that there would have been ~3507 exposures of ~2460 different individual cetaceans to ≥160 dB during the survey if no cetaceans moved out of the ≥160-dB zone in response to the approaching airguns (Table 4.6). The "exposures" estimate would be reasonable if cetaceans did not react to the approaching seismic vessel; the "individuals" estimate would be reasonable if there was no reaction and if cetaceans remained largely stationary throughout the study. Both of these assumptions are unlikely. The actual numbers of individuals that were exposed to ≥160 dB re 1 µPa_{rms}, or that moved away in response to the approaching seismic vessel before levels reached 160 dB, are expected to be somewhere between the "exposures" and "individuals" estimates shown in Table 4.6.

(B) 170 dB re 1 µPa_{rms}: On average, small odontocetes (Dall's porpoises in this case) 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 Dall's porpoise exposed during the STEEP survey, if they did not avoid the vessel, would be ~52% of the corresponding estimates for ≥160 dB, based on the proportionally smaller area exposed to ≥170 dB (Table 4.8), or 1731 exposures of 1299 individual Dall's porpoises (Table 4.6),

***Summary of Exposure Estimates*.—**Estimates of the numbers of exposures to received sound levels ≥160 dB re 1 µPa_{rms} (flat weighted) are considered *maximum* estimates of the number of mammals exposed. In this method, repeated exposures of some of the same animals are counted separately, with no allowance for overlapping survey lines. This method, when based on densities during non-seismic periods, also assumes that no mammals move away before received sound levels reach the level in question. For the STEEP survey, ~3507 potential marine mammal exposures of 2460 individuals to received levels ≥160 dB re 1 µPa might have occurred based on densities during non-seismic periods (Table 4.6).

The highest overall estimate of exposures to ≥160 dB for the STEEP survey (3507) is ~51% of the authorized 'take' in the IHA (see Appendix A). There were no cases where the calculated exposure estimate for a species, based on actual densities in the study area during non-seismic periods, exceeded the requested or authorized take for that species (Table 4.6).

TABLE 4.6. Estimated numbers of exposures and minimum number of individual marine mammals potentially exposed to airgun sounds with flat-weighted received levels ≥160 dB re 1 μPa_{rms} and ≥170 dB based on observed densities during non-seismic periods of the STEEP survey, 10 September to 6 October 2008 (no useable sightings were made during seismic periods). These estimates would apply if no mammals move away from (or toward) the approaching ship before received levels of airgun pulses reach 160 or 170 dB re 1 μPa_{rms}. The numbers of exposures are shown for water depths 100–1000 and >1000 m (there were no density estimates for water <100 m deep). The requested and authorized takes are also shown (see Appendix A; LGL Ltd. 2008a,b).

	Number of Exposures						Number of Individuals						Requested /
	100–1000 m		>1000 m		Total		100–1000 m		>1000 m		Total		Authorized
Species	≥160 dB	≥170 dB	≥160 dB	≥170 dB	≥160 dB	≥170 dB	≥160 dB	≥170 dB	≥160 dB	≥170 dB	≥160 dB	≥170 dB	Take
Odontocetes													
Sperm whale	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**	**74 / 49**
Cuvier's beaked whale	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**	**47 / 35**
Baird's beaked whale	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**	**11 / 8**
Stejneger's beaked whale	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**	**3 / 3**
Beluga whale	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**	**5 / 0**
Pacific white-sided dolphin	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**	**203 / 56**
Risso's dolphin	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**	**5 / 0**
Killer whale	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**	**285 / 116**
Short-finned pilot whale	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**	**20 / 0**
Harbor porpoise	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**	**548 / 346**
Dall's porpoise	1001	643	2360	1088	**3361**	**1731**	701	456	1656	843	**2357**	**1299**	**7329 / 5379**
Mysticetes													
North Pacific right whale	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**	**2 / 0**
Gray whale	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**	**6 / 6**
Humpback whale	92	60	21	10	**113**	**70**	65	42	15	8	**80**	**50**	**424 / 246**
Minke whale	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**	**41 / 9**
Fin whale	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**	**178 / 89**
Blue whale	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**	**2 / 2**
Sei whale	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**	**0 / 0**
Unidentified mysticete	6	4	7	4	**13**	**8**	4	3	5	3	**9**	**6**	-
Unidentified Whale[a]	6	4	14	7	**20**	**11**	4	3	10	5	**14**	**8**	-
Pinnipeds													
Northern fur seal	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**	**5 / 5**
Harbor seal	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**	**403 / 269**
Steller sea lion	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**	**110 / 74**
Marine Fissiped													
Sea otter[b]	0	0	0	0	**0**	**0**	0	0	0	0	**0**	**0**	**240 / 0**
Total Marine Mammals	**1105**	**711**	**2402**	**1109**	**3507**	**1820**	**774**	**504**	**1686**	**859**	**2460**	**1363**	**9941 / 6872**

Note: species in italics are listed as endangered under the ESA [Cook Inlet beluga and western stock Steller sea lions are endangered].

[a] Baleen or toothed whale. Take is based on direct observations of 2 groups of 3 individuals.

[b] There was a single "useable" sea otter sighting during non-seismic periods of the STEEP survey, but takes were not estimated. Accurate and appropriate *f*(0) and *g*(0) correction factors were not available.

TABLE 4.7. Estimated ensonified area and effort for 160 and 170 dB re 1 μPa_{rms} (averaged over pulse duration) received sound levels in the STEEP study area, with and without overlapping areas, for water ***(A)*** 100−1000 m deep and ***(B)*** >1000 m.

dB re 1 μPa_{rms} Criteria	Ensonified Area (km^2)	
	With overlap	No Overlap
(A) Water Depth 100-1000 m (744 km effort)		
160	10205	7146
170	6556	4648
(B) Water Depth >1000 m (534 km effort)		
160	9448	6628
170	4354	3372

Note: Overlapping ensonified area was used for estimating the number of exposures, and non-overlapping ensonified area was used for estimating the number of individuals exposed.

The requested and authorized takes were higher than the calculated numbers exposed to ≥160 dB, because 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 2008 study period at times when airgun operations were not ongoing. Note that the estimates *do* include approximate allowance for animals missed by the observers during daytime. That allowance is based on application of "best available" correction factors for missed animals [i.e., $f(0)$ and $g(0)$ factors] during daytime. The estimates also include an allowance for animals encountered during seismic operations at night.

Summary and Discussion

The seismic program included 156 h of "useable" visual observation effort and 197 h of PAM effort. Density and behavioral analyses for the STEEP cruise considered only "useable" survey effort and "useable" sightings, consisting of 110 cetaceans in 32 groups and a single sea otter. In general, Dall's porpoises and humpback whales were the most commonly observed cetacean species during the STEEP study. Similarly, those two species were also the most frequently sighted cetaceans during seismic surveys in the GOA in 2004 (MacLean and Koski 2005). Sightings of unidentified whales and sea otters were also made within the STEEP study area; two sightings of four sea otters were made in Yakutat Bay. A sea otter sighting was also made in Yakutat Bay during surveys in 2004 (MacLean and Koski 2005). Pacific white-sided and northern right-whale dolphins were encountered during transit to or from the STEEP study area but not during the seismic survey. No pinnipeds or sea turtles were observed during the STEEP study.

Considering all "useable" survey effort and sightings, ~17 marine mammal groups were detected per 1000 km. Based on "useable" data during non-seismic periods, Dall's porpoise had the highest density, whereas densities during "useable" seismic periods were zero for all species. Dall's porpoise densities during the STEEP study were higher than those for non-seismic periods during surveys in the GOA in 2004, whereas humpback whale densities were lower (see MacLean and Koski 2005). During the 2004 surveys, the density of Dall's porpoises in intermediate water depths was nearly 2× greater during seismic compared with non-seismic periods; however, only a small source (two Generator Injector guns) was used during the survey (MacLean and Koski 2005). The density of humpback whales in intermediate water depths during the 2004 surveys was lower during seismic than during non-seismic periods (MacLean and Koski 2005).

During the STEEP study, blowing and porpoising were the most frequently observed behaviors of humpbacks and Dall's porpoises, respectively, and movement was most frequently recorded as unknown or parallel relative to the vessel's path. Behavior and movement of marine mammals could not be compared during seismic and non-seismic periods since there were no "useable" sightings during seismic periods.

Based on direct observations during the STEEP survey, a total of eight groups of 45 individual cetaceans were observed during seismic periods. All of these animals were estimated to have received sound levels ≥160 dB re 1 μPa_{rms} (flat-weighted). Six cetacean groups totaling 35 individuals were seen about to enter or within the safety radii. A power down was initiated in five cases, followed by a subsequent shut down for one group. A precautionary shut down of a single operating airgun was also implemented for one humpback whale. Five of the six groups (34 individuals) were estimated to have been exposed to received sound levels ≥180 dB re 1 μPa_{rms} (flat-weighted), based on their final approach distance before mitigation could be initiated. The highest overall estimate of exposures to ≥160 dB for the STEEP survey (3507) is ~51% of the authorized "takes".

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APPENDIX A:[2]
Incidental Harassment Authorization Issued to L-DEO for the STEEP 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 Gulf of Alaska, September, 2008:

1. This Authorization is valid from September 10 through October 31, 2008.

2. This Authorization is valid only for the R/V *Marcus G. Langseth*'s (*Langseth*) seismic survey in the Gulf of Alaska (see Table 2 for authorized take numbers).

3. (a) The incidental taking of marine mammals, by Level B harassment only, is limited to the following species in the Gulf of Alaska (see Table 2 for authorized take numbers):

(i) <u>Odontocetes</u>—sperm whale (*Physeter macrocephalus*), Cuvier's beaked whale (*Ziphius cavirostris*), Baird's beaked whale (*Berardius bairdii*), Stejneger's beaked whale (*Mesopoldon stejnegeri*), Pacific white-sided dolphin (*Lagenorhynchus obliquidens*), killer whale (*Orcinus orca*), Dall's porpoise (*Phocoenoides dalli*), and harbor porpoise (*Phocoena phocoena*).

(ii) <u>Mysticetes</u>—gray whale (*Eschrichtius robustus*), humpback whale (*Megaptera novaeangliae*), minke whale (*Balaenoptera acutorostrata*), fin whale (*Balaenoptera physalus*), and blue whale (*Balaenoptera musculus*).

(iii) <u>Pinnipeds</u>—northern fur seal (*Callorhinus ursinus*), Steller sea lion (*Eumetopias jubatus*), and Pacific harbor seal (*Phoca vitulina richardsi*).

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

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

(i) A 36 Bolt airgun array with a total capacity of 6,600 in^3 (or smaller);
(ii) A multi-beam echosounder; and

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

(iii) A sub-bottom profiler.

4. The taking of any marine mammal in a manner prohibited under this Authorization must be reported immediately to the 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. <u>Monitoring and Mitigation</u>

The Holder of this Authorization is required to:

(a) Utilize at least one, and two (when practical), NMFS-qualified, vessel-based marine mammal visual observers (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. Vessel crew will also assist in detecting marine mammals, when practical. Observers will have access to reticle binoculars (7 X 50 Fujinon), big-eye binoculars (25 X 150), and night vision devices. MMVO shifts will last no longer than 4 hours 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.

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

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

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

(iii) the data listed under 6(b)(ii) will also be recorded at the start and end of each observation watch and during a watch whenever there is a change in one or more of the variables.

(c) Visually observe the entire extent of the safety radius (190 dB for pinnipeds, 180 dB for cetaceans; see Table 2 for distances, attached) using NMFS-qualified MMVOs, for at least 30 minutes prior to starting the airgun (day or night). If for any reason the entire radius cannot be seen for the entire 30 minutes (i.e., rough seas, fog, darkness), or if the marine mammals are near, approaching, or in the safety radius, the airguns may not be started up. If one airgun is already running at a source level of at least 180 dB, L-DEO may start the second gun without observing the entire safety radius for 30 minutes prior, provided no marine mammals are known to be near the safety radius (in accordance with condition 6(f) below).

(d) Utilize the passive acoustic monitoring (PAM) system, to the maximum extent practicable, to detect and allow some localization of marine mammals around the *Langseth* during all airgun operations and during most periods when airguns are not operating. One NMFS-qualified marine mammal observer and/or bioacoustician will monitor the PAM at all times in shifts of 1-6 hours. A bioacoustician shall design and set up the PAM system and be present to operate or oversee PAM, and available when technical issues occur during the survey.

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

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

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

(f) Implement a "ramp-up" procedure when starting up at the beginning of seismic operations or anytime after the entire array has been shutdown for more than 7 minutes, which means start the smallest gun first and add airguns in a sequence such that the source level of the array will increase in steps not exceeding approximately 6 dB per 5-min period. During ramp-up, the MMVOs will monitor the safety radius, and if marine mammals are sighted, a course/speed alteration, power-down, or shut-down will be implemented as though the full array were operational.

(g) 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.

(h) Shutdown or power-down the airguns if a marine mammal is detected within, approaches, or enters the relevant safety radius (as defined in Table 2, attached). A shutdown means all operating airguns are shut down. A power-down means shutting down one or more airguns and reducing the safety radius to the degree that the animal is outside of it. Following a power-down, if the marine mammal approaches the smaller designated safety radius, the airguns must then be completely shut down. Airgun activity will not resume until the marine mammal has cleared the safety radius, which means it was visually observed to have left the safety radius, or has not been seen within the radius for 15 min (small odontocetes and pinnipeds) or 30 min (mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, killer, and beaked whales).

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

(j) If concentrations of humpback whales, fin whales, and/or sea otters (*Enhydra lutris kenyoni*) are observed (by visual observers or passive acoustic detection) prior to or during the airgun operations, those operations will be powered/shut down and/or moved to another location based on recommendations by the on-duty MMO aboard the *Langseth*.

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

(l) If a beluga whale (*Delphinapterus leucas*) is visually sighted, the airgun array will be shut-down regardless of the distance of the whale to the sound source. The array will not resume firing until 15 min after the last documented beluga whale visual sighting.

(m) Emergency shut-down. If observations are made or credible reports are received that one or more marine mammals are within the general operating area of this activity in an injured or mortal state, or are indicating acute distress, the seismic airguns will be immediately shut down and the Chief of the Permits, Conservation and Education Division, Office of Protected Resources or a staff member contacted. The airgun array will not be restarted until review and approval has been given by the Director, Office of Protected Resources or his designee.

(n) Schedule seismic operations in inshore waters during daylight hours and ocean bottom seismometer (OBS) operations to nighttime hours whenever possible.

(o) To the maximum extent possible, inshore seismic surveys will be conducted from upstream (inshore) and proceed towards the sea (offshore) in order to avoid trapping marine mammals in shallow water.

(p) To the maximum extent possible, avoid encroaching upon critical habitat around Steller sea lion rookeries and haul-outs.

(q) To the maximum extent possible, coordinate activities and communicate with natives and villages to avoid areas where and when subsistence collectors are hunting marine mammals and/or fishing.

7. <u>Reporting</u>

The Holder of this Authorization is required to submit a report on all activities and monitoring results to the Office of Protected Resources, NMFS, within 90 days of the completion of the *Langseth's* cruise. This report must contain and summarize the following information:

(a) Dates, times, locations, heading, speed, weather during (including Beaufort Sea State), and associated activities during all seismic operations and marine mammal sightings;

(b) 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.

(c) 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.

(d) 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.

8. In the unanticipated event that any taking of a marine mammal in a manner prohibited by this Authorization occurs, such as 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 Alaska Regional Stranding Department, Protected Resources Division, Alaska Region, NMFS, at 1-800-853-1964 (24 Hour Hotline), 907-271-5006 (Anchorage), 907-586-7235 (Juneau), and the Chief of the Permits, Conservation, and Education Division, Office of Protected Resources, NMFS, at 301-713-2289. Research activities will then be postponed until NMFS is able to review the circumstances of the take, worked with L-DEO to determine whether modifications in the activities are appropriate and necessary, and notified the permit holder that they may resume sound source operations.

9. 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. L-DEO is required to abide by the Terms and Conditions of the Incidental Take Statement corresponding to NMFS' Biological Opinion.

10. 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).

SEP 08 2008

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

Date

Attachment

Table 1. Safety Radii for Triggering Mitigation.

Source and Volume	Tow Depth (m)	Water Depth	Predicted RMS Distances (m)		
			Shut-down zone for pinnipeds 190 dB	Shut-down zone for cetaceans 180 dB	160 dB
Single Bolt airgun 40 in^3	9	Deep Intermediate Shallow	12 18 150	40 60 296	385 578 1,050
4 strings 36 airguns 6600 in^3	9	Deep Intermediate Shallow	300 450 2,182	950 1,425 3,694	6,000 6,667 8,000

Table 2. Authorized Take Numbers for Each Species in the Gulf of Alaska.

Species	Authorized Take in the Gulf of Alaska
Sperm whale (*Physeter macrocephalus*)	49
Cuvier's beaked whale (*Ziphius cavirostris*)	35
Baird's beaked whale (*Berardius bairdii*)	8
Stejneger's beaked whale (*Mesoplodon stejnegeri*)	3
Beluga whale (*Delphinapterus leucas*)	0
Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)	56
Risso's dolphin (*Grampus griseus*)	0
Killer whale (*Orcinus orca*)	116
Short-finned pilot whale (*Globicephala macrorhynchus*)	0
Harbor porpoise (*Phocoena phocoena*)	346
Dall's porpoise (*Phocoenoides dalli*)	5,379
North Pacific right whale (*Eubalaena japonica*)	0
Gray whale (*Eschrichtius robustus*)	6
Humpback whale (*Megaptera novaeangliae*)	246
Minke whale (*Balaenoptera acutorostrata*)	9
Fin whale (*B. physalus*)	89
Blue whale (*B. musculus*)	2
Sei whale (*B. borealis*)	0
Northern fur seal (*Callorhinus ursinus*)	5
Steller sea lion (*Eumetopias jubatus*)	74
Pacific harbor seal (*Phoca vitulina richardsi*)	269

APPENDIX B:
DEVELOPMENT AND IMPLEMENTATION OF SAFETY RADII

This appendix provides additional background information on the development and implementation of safety radii as relevant to L-DEO seismic studies. Additional information on L-DEO's 2003 calibration study conducted with various configurations of the *Ewing*'s airgun arrays is also provided. Further information on these topics can be found in Smultea et al. (2003) and Tolstoy (2004a,b).

There has been considerable speculation about the potential for strong pulses of low-frequency underwater sound from marine seismic exploration to injure marine mammals (e.g., Richardson et al. 1995), based initially on what was known about hearing impairment to humans and other terrestrial mammals exposed to impulsive low-frequency airborne sounds (e.g., artillery noise). It is not known whether exposure to a sequence of airgun pulses can, under practical field conditions, cause hearing impairment or non-auditory injuries in marine mammals. However, studies on captive odontocetes and pinnipeds suggest that, as a minimum, temporary threshold shift (TTS) is a possibility (Finneran et al. 2002; Kastak et al. 2005; Southall et al. 2007). The 180-dB "do not exceed" criterion for cetaceans was established by NMFS (1995) before any data were available on TTS in marine mammals. NMFS (1995, 2000) concluded that there are unlikely to be any physically-injurious effects on cetaceans exposed to received levels of seismic pulses up to 180 dB re 1 μPa_{rms}. The corresponding NMFS "do not exceed" criterion for pinnipeds is 190 dB re 1 μPa (rms). For sea turtles, NMFS specified a criterion of 180 dB re 1 μPa (rms) for most other L-DEO surveys from 2003–2005 (e.g., Smultea et al. 2004, 2005; Holst et al. 2005) and in 2008 (Holst and Beland 2008; Holst and Smultea 2008).

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

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

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

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.

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 depend mainly on pulse energy (Southall et al. 2007). However, we consider rms pressure because current NMFS criteria are based on that method. NMFS is developing new noise exposure criteria for marine mammals that account for the now-available scientific data on TTS, the expected offset between the TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors.

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

Figure B.1 shows the predicted sound fields for the 4-string array used during L-DEO's 2008 STEEP seismic survey, and Figure B.2 shows the sound fields for a single airgun used during power downs. The predicted sound contours are shown as SEL. We assumed that rms pressure levels of received seismic pulses will be 10 dB higher than the SEL values predicted by L-DEO's model (e.g., 170 dB SEL ≈ 180 dB rms). A maximum relevant depth of 2000 m was applied when predicting safety radii.

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

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

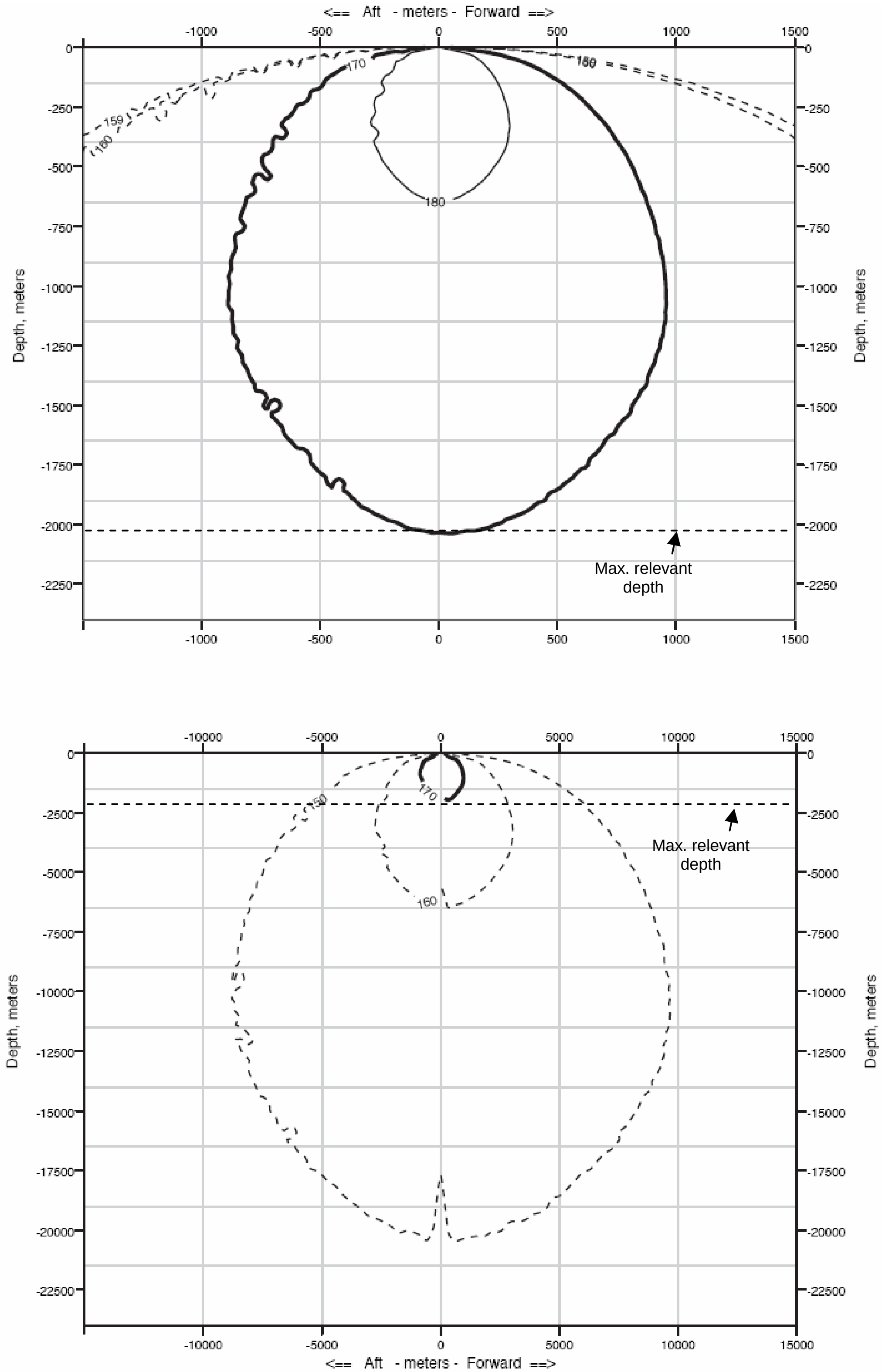

FIGURE B.1. Modeled received sound levels (SELs) from the 36-airgun array operated at a tow depth of ~9 m during the STEEP survey, 10 September to 6 October 2008. Received rms levels (SPLs) are expected to be ~10 dB higher. Maximum relevant depth as applicable to marine mammals is indicated.

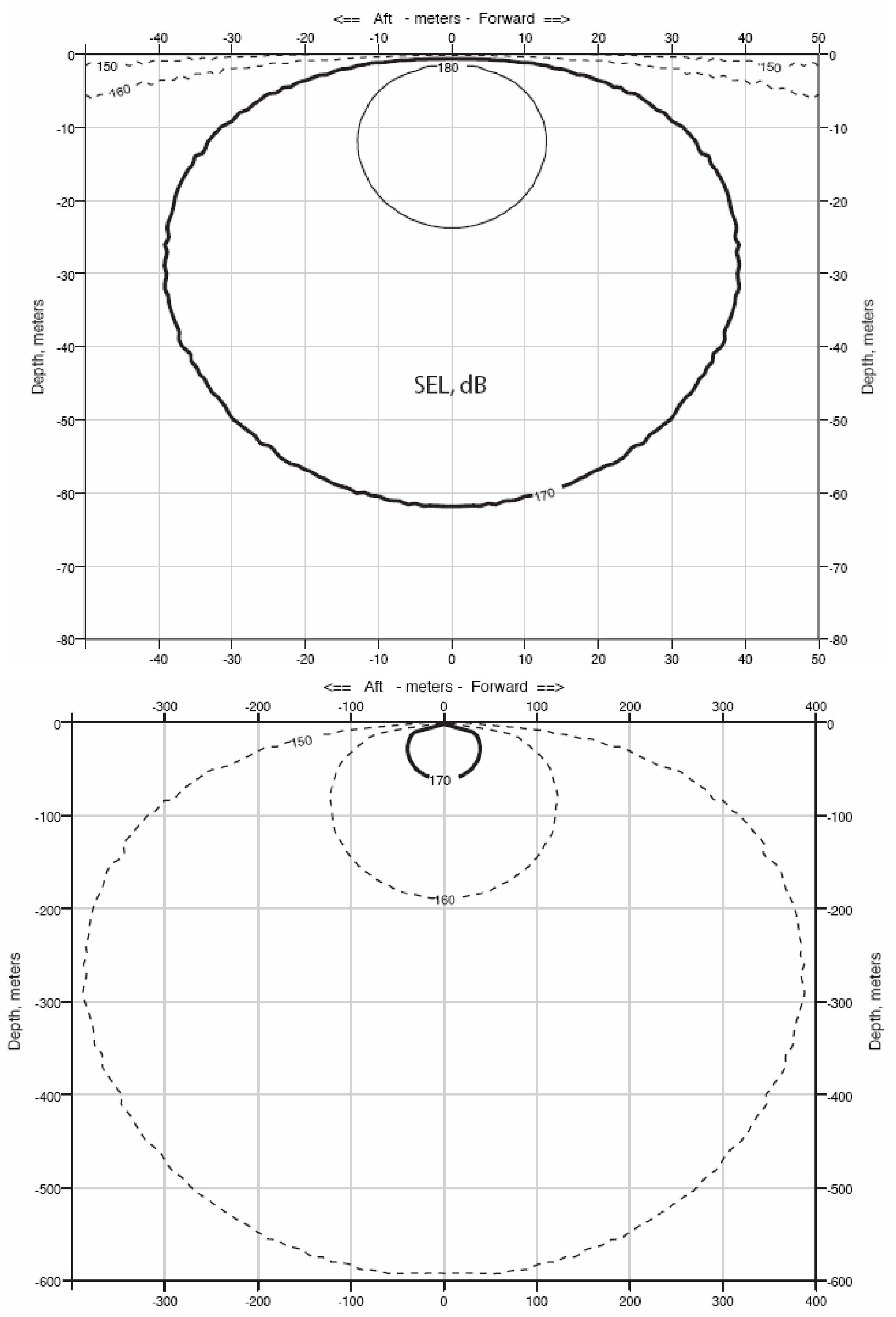

FIGURE B.2. Modeled received sound exposure levels (SELs) from a single 40 in^3 airgun, at a tow depth of ~ 9 m, used during power down operations during the STEEP survey, 10 September to 6 October 2008. Otherwise same as above.

- Empirical measurements were not conducted for ***intermediate depths*** (100–1000 m). On the expectation that results would be intermediate between those from shallow and deep water, 1.1× to 1.5× correction factors have been applied to the estimates provided by the model for deep water situations. The 1.5× factor was applied to model estimates during L-DEO cruises in 2003, and 1.1× to 1.5× factors were applied to estimates for intermediate-depth water during all subsequent cruises.
- For ***shallow*** water (<100 m deep), the radii are based on the empirical data of Tolstoy et al. (2004a,b) for 160, 170 and 180 dB, and are extrapolated to estimate the radii for 190 dB. The safety radii were typically based on measured values in shallow water, and ranged from 3× to 15× higher than the modeled values depending on the sound level measured (Tolstoy et al. 2004b).

The depth at which the source is towed has a major effect on the maximum near-field output and on the shape of its frequency spectrum. If the source is towed at a relatively deep depth, the effective source level for sound propagating in near-horizontal directions is substantially greater than if the array is towed at shallower depths.

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

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

Other details of the *Langseth* include the following:

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

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

Multibeam Bathymetric Echosounder and Sub-bottom Profiler

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

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

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

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

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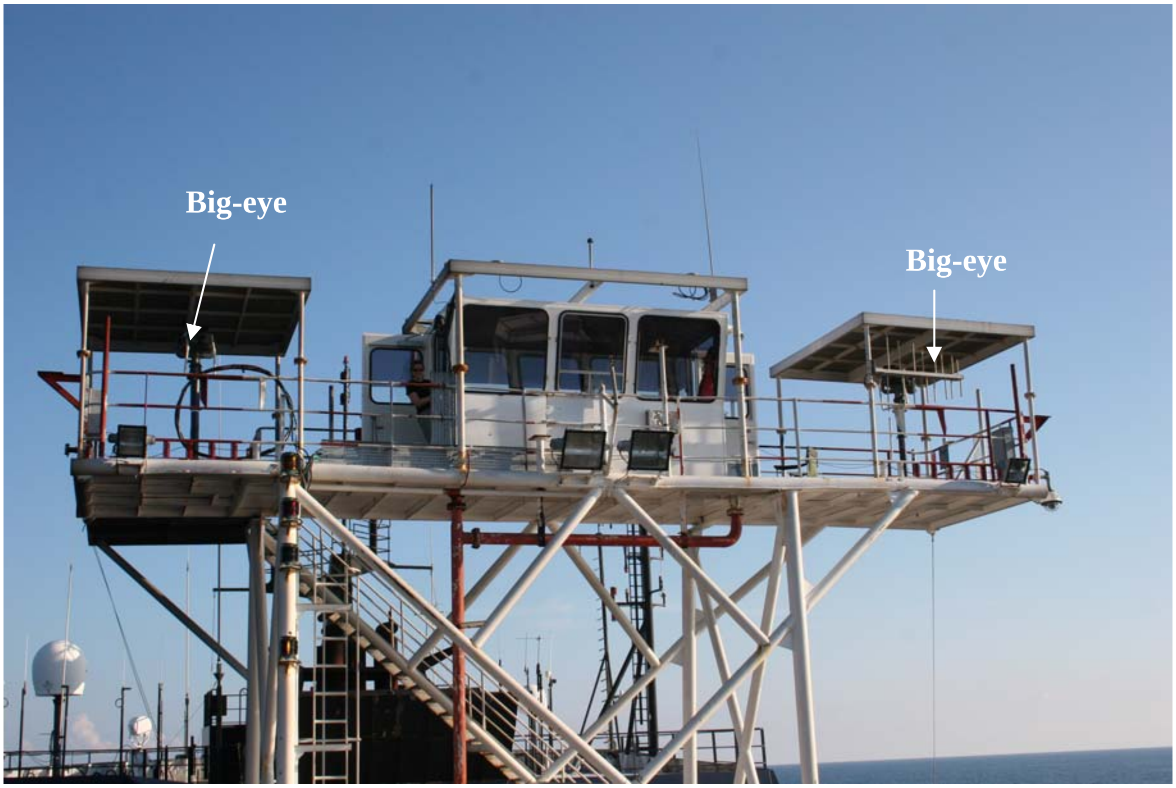

FIGURE C.3. The observation tower and booth on the R/V *Marcus G. Langseth* from which visual observations for marine mammals and sea turtles were made. The locations of two mounted 25x150 "Big-eye" binoculars used during the study is shown.

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

Langseth Sub-bottom Profiler Specifications

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

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

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

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

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

Visual Monitoring Methods

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

Visual observations were generally made from the *Langseth's* observation tower (Fig. C.1, C.3), which is the highest suitable vantage point on the *Langseth*. When stationed on the observation tower, the eye level is ~18.9 m above sea level (asl), and the observer has a good view around the entire vessel. Other observation platforms aboard the *Langseth* include the helideck or stern (13.7 m asl), the bridge (12.8 m asl), and the catwalk around the bridge (12.3 m asl).

Five observers trained in marine mammal identification and observation methods were present on the *Langseth*. Visual watches aboard the *Langseth* were usually conducted in 1–2 h shifts (max. 4 h), alternating with PAM shifts and/or 1–4 h breaks, for a total of ~8 h per day per MMO. Daytime watches were conducted from dawn until dusk. MMO(s) scanned around the vessel, alternating between unaided eyes and 7×50 Fujinon binoculars. Scans were also made using the 25×150 Big-eye binoculars, to detect animals and to identify species or group size during sightings. Both the Fujinon and Big-eye binoculars were equipped with reticles on the ocular lens to measure depression angles relative to the horizon, an indicator of distance. During the day, at least one and (if possible) two MMOs were on duty, especially during the 30 min before and during ramp ups.

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

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

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

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

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

Passive Acoustic Monitoring Methods

Passive acoustic monitoring was conducted from aboard the *Langseth* to detect calling cetaceans and to alert visual MMOs to the presence of these animals. Although the SEAMAP array is typically used during L-DEO cruises, the Right Waves hydrophone array and/or a hull-mounted hydrophone is used when the SEAMAP array is unavailable (see Appendix G).

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

WS	Watch Start
WE	Watch End

LINE

Enter Line ID or leave blank

SEISMIC ACTIVITY

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

 # GUNS

Enter Number of Operating Airguns, or

X	Unknown

ARRAY VOLUME

Enter operating volume, or

X	Unknown

(BEAUFORT) SEA STATE

See Beaufort Scale sheet.

LIGHT OR DARK

L	Light (day)
D	Darkness

GLARE AMOUNT

NO	None
LI	Little
MO	Moderate
SE	Severe

POSITION

Clock Position, or

V	Variable (vessel turning)

WATER DEPTH

In meters

MARINE MAMMAL SPECIES

Baleen Whales

BLW	Blue Whale
BRW	Bryde's Whale
FW	Fin Whale
SW	Sei Whale
HW	Humpback Whale
MW	Minke Whale
UMW	Unidentified Mysticete Whale
UW	Unidentified Whale

Large Toothed Whales

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

Beaked Whales

BBW	Blainville's Beaked Whale
CBW	Cuvier's Beaked Whale
GBW	Gervais' Beaked Whale
SBW	Sowerby's Beaked Whale
UBW	Unidentified Beaked Whale

Dolphins

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

Porpoises

DP	Dall's Porpoise
HP	Harbor Porpoise

Mustelids

SO	Sea Otter

Pinnipeds

HS	Harbor Seal
NFS	Northern Fur Seal
SSL	Steller Sea Lion

TURTLE SPECIES

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

MOVEMENT

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

INDIVIDUAL BEHAVIOR

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

GROUP BEHAVIOR (BEHAVIORAL STATES)

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

 # RETICLES or ESTIMATE

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

0 to 16	Number of reticles
E	Estimate, by eye

SIGHTING CUE

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

IDENTIFICATION RELIABILITY

MA	Maybe
PR	Probably
PO	Positive

BEHAVIOR PACE

SE	Sedate
MO	Moderate
VI	Vigorous

WITH ABOVE RECORD?

Y	Yes
(blank)	not with above record

SEAMAP

The SEAMAP system consists of hardware (i.e., the hydrophone) and a software program. The "wet end" of the system consists of a towed hydrophone array that is connected to the vessel by a "hairy" faired cable (Fig. D.1). The array is deployed from a winch located on the back deck. A deck cable is connected from the winch to the main computer lab where the signal conditioning and processing system are located.

The hydrophone array is 56 m in length and consists of an active section of four hydrophones; only two hydrophones are monitored simultaneously with the SEAMAP system. The distance between the outer hydrophones is ~50 m. The length of the lead-in cable to the array is ~400 m and is generally fully deployed when the system is in use. Thus, the hydrophones are typically 400–450 m behind the stern of the ship. The depth at which the hydrophone array is towed can be adjusted by adding or removing weights; it is generally towed at a depth of ~30 m.

Due to numerous problems with the SEAMAP software, a back-up software and recording system (SeaProUltra designed by CIBRA, University of Pavia, Italy) was used during the cruise. Details of the SEAMAP system and monitoring protocol are given below, followed by details about the CIBRA back-up system that is mainly used for recording of vocalizations. The SEAMAP system (as well as the CIBRA system) is used to display the incoming signals on the monitor, but it cannot be used to record or localize vocalizations. The CIBRA system can be used to record vocalizations, but it is not capable of localizing vocalizations.

SEAMAP software (version 1.525, Houston, TX) can be used for real-time processing of two channels of acoustic data from the array. GPS position is recorded automatically by SEAMAP software every minute. Integrated plotting software automatically displays the ship location, as well as a user-defined safety radius, graphically depicted as a colored ring centered on the airgun array. Waveform, spectral density, and a sound spectrogram are displayed using the SEAMAP software. Cross-correlation techniques are used to calculate the time delay between the signals arriving at two hydrophones in the SEAMAP array. A signal of interest (e.g., any signal believed to be a cetacean call) can be selected by the operator with a mouse using a "windowing" feature. The speed of sound, the time delay, and the distance between the two hydrophones are used to calculate the bearing to the selected signal. The bearing to the signal is graphically displayed on the plot display in SEAMAP.

For each bearing, there is also a "mirror-image" complementary bearing on the opposite side of the ship's trackline. When only one call is detected, it is not possible to distinguish reliably, from acoustic data alone, which of the two complementary bearings is the true bearing to the mammal.

With SEAMAP and similar systems, multiple bearings are necessary to obtain an animal location. This is accomplished, at least in theory, by repeatedly obtaining bearings to an animal as the ship moves along a straight-line. The animal's location is determined by triangulating from two or more bearings; the point at which the bearing lines intersect is the estimated location of the animal. When only one call is detected, it is not possible to determine the animal's location. Also, if the animal is moving, there is some degree of error in the estimated location. When there are successive bearings to repeated calls by the same individual cetacean or group, SEAMAP can theoretically provide information on the distance of the vocalizing cetacean(s) from the hydrophone array. However, in practice, it is generally not possible to localize vocalizing cetaceans based on SEAMAP alone, for a number of reasons:

FIGURE D.1. Deployment of the PAM hydrophone streamer from the stern of the R/V *Marcus G. Langseth*.

- The SEAMAP software manual recommends that the monitoring vessel change its heading by ~10º between successive acoustic "fixes" in order to resolve the mirror-image ambiguity and to obtain distance information on vocalizing marine mammals. This is not possible during most L-DEO cruises, as it is important for the primary purpose of the seismic survey to maintain the planned transect lines.
- When the calls are from a spread-out group of individuals, it is impossible to ascertain whether successive acoustic bearings are to the same animal or subgroup. With widespread groups, successive calls can originate from varying locations. The resultant sequence of bearings does not necessarily provide successive bearings to any one particular animal or subgroup.

The SEAMAP system is able to monitor broadband signals between ~8 Hz and 24 kHz. There are interference effects from ship noise and airgun sounds, although problems from ship noise appeared to be minimal. Hardware was used that filtered out sounds from airguns as they were fired (to make listening to the received signals more comfortable while using headphones). This filtering procedure filtered out all sounds for ~1–2 s so no other sounds could be heard during that interval. It is doubtful that any sequences of marine mammal vocalizations were missed as a result of the brief periods of "blanking" during the airgun shots. However, it appeared that the SEAMAP system has limited ability to detect low frequencies (<100 Hz) such as those that are typically produced by some baleen whales.

Detailed instructions on the PAM protocol followed when using SEAMAP aboard the *Langseth* are described in a user manual written specifically for L-DEO seismic cruises (Stoltz et al. 2004).

Right Waves Hydrophone Array and SeaProUltra

When the SEAMAP array is unavailable for use, the Right Waves array is used. This array consists of two hydrophones; the active portion of the array is ~50 m long. The array is attached to a cable, which is typically 50 to 100 m long. The array can detect signals at frequencies up to 20 kHz. The array is deployed and used as described above for the SEAMAP array.

The CIBRA software, SeaProUltra, is also used to monitor for vocalizing cetaceans detected via the hydrophone array. SeaProUltra was initially used as a back-up system, but because of technical problems with the SEAMAP software, SeaProUltra was subsequently used as the main monitoring system. The CIBRA system functions include real-time spectrographic display, continuous and event audio recordings, navigation display, semi-automated data logging, and data logging display. These functions are similar to those of the SEAMAP system; however, the data logging capabilities are unique to the CIBRA system and are described briefly below. A document with detailed explanations of the CIBRA system is available from CIBRA (Pavan 2005).

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

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

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

Hull-mounted Hydrophone

When a towed hydrophone array is not available (i.e., if it is damaged or deemed ineffective), then the hull-mounted hydrophone, HAP-5050, is used. This single-channel hydrophone is made by Harrys Acoustics and can detect frequencies up to 50 kHz and greater.

Mitigation

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

Ramp-up Procedures

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

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

Power-down and Shut-down Procedures

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

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

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

The MMOs were stationed on the observation tower, which is located ~35 m ahead of the stern. The closest airgun was located ~140 m behind the *Langseth's* stern during the STEEP survey. The decision to initiate a power down was based on the distance from the observers rather than from the array, unless the animals were sighted close to the array. This was another precautionary measure, given that most sightings were ahead of the vessel.

Analyses

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

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

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

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

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

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

Number of Marine Mammal Exposures

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

- area assumed to be ensonified to ≥160 dB (depending on the airgun(s) in use at the time; Table 3.1; Table 4.8), and
- "corrected" densities of marine mammals estimated by line transect methods as summarized above.

Number of Individuals Exposed

The estimated number of individual exposures to levels ≥160 dB obtained by the method described above likely overestimates the number of different *individual* mammals exposed to the airgun sounds at received levels ≥160 dB. This occurs because some exposure incidents may have involved the same individuals previously exposed, 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 and Dall's porpoise, 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 GULF OF ALASKA

TABLE E.1. The habitat, abundance, and conservation status of marine mammals that occur in the GOA (taken from the EA/IHA Application; LGL Ltd. 2008a,b). Regional abundance estimates are also given, usually for the Northeastern Pacific Ocean or the U.S. West Coast.

Species	Habitat	Abundance (Alaska)	Regional Abundance	ESA[1]	IUCN[2]	CITES[3]
Odontocetes						
Sperm whale (*Physeter macrocephalus*)	Pelagic	159 [4]	24,000 [5]	EN	VU	I
Cuvier's beaked whale (*Ziphius cavirostris*)	Pelagic	N.A.	20,000 [6]	N.L.	DD	II
Baird's beaked whale (*Berardius bairdii*)	Pelagic	N.A.	6000 [7]	N.L.	LR-cd	I
Stejneger's beaked whale (*Mesoplodon stejnegeri*)	Likely pelagic	N.A	N.A	N.L.	DD	II
Beluga whale (*Delphinapterus leucas*)	Coastal & ice edges	366 [8]	N.A.	N.L.	VU	II
Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)	Pelagic, shelf, coastal	26,880 [9]	931,000 [10]	N.L.	LR-lc	II
Risso's dolphin (*Grampus griseus*)	Pelagic, shelf, coastal	N.A.	16,066 [11]	N.L.	DD	II
Killer whale (*Orcinus orca*)	Pelagic, shelf, coastal	1975 [12]	8500 [13]	N.L.	LR-cd	II
Short-finned pilot whale (*Globicephala macrorhynchus*)	Pelagic, shelf, coastal	N.A.	160,200 [6]	N.L.	LR-cd	II
Harbor Porpoise (*Phocoena phocoena*)	Coastal	17,076 [14] 41,854 [15]	202,988 [16]	N.L.	VU	II
Dall's Porpoise (*Phocoenoides dalli*)	Pelagic, shelf	83,400 [17]	1,186,000 [18]	N.L.	LR-cd	II
Mysticetes						
North Pacific right whale (*Eubalaena japonica)*	Coastal, shelf	N.A.	100-200 [19]	EN	EN	I
Gray whale (*Eschrichtius robustus*)	Coastal	N.A.	18,813 [20]	N.L.	LR-cd	I
Humpback whale (*Megaptera novaeangliae*)	Coastal, banks	2644 [21]	>6000 [22]	EN	VU	I
Minke whale (*Balaenoptera acutorostrata*)	Coastal, shelf	1232 [21]	9000 [23]	N.L.	LR-cd	I
Sei whale (*Balaenoptera borealis*)	Pelagic	N.A.	7260–12,620 [22]	EN	EN	I
Fin whale (*Balaenoptera physalus*)	Pelagic	1652 [24]	13,620–18,680 [22]	EN	EN	I
Blue whale (*Balaenoptera musculus*)	Pelagic, shelf, coastal	N.A.	1744 [11]	EN	EN	I
Pinnipeds						
Northern fur seal (*Callorhinus ursinus*)	Pelagic, breeds coastally	N.A.	721,935 [25]	N.L.	VU	NL
Steller sea lion (*Eumetopias jubatus*)	Coastal	47,885 [26] 44,780 [27]	N.A.	T [†] EN [‡]	EN	NL
Harbor seal (*Phoca vitulina richardsi*)	Coastal	180,017 [28]	N.A.	NL	NL	NL

Species	Habitat	Abundance (Alaska)	Regional Abundance	ESA[1]	IUCN[2]	CITES[3]
Mustelids Sea otter (*Enhydra lutris*)	Coastal	12,632 [29] 16,552 [30] 41,474 [31]	N.A.	T [‡]	EN	II

Note: N.A. means data not available. Cook Inlet beluga whales are now listed as endangered under the ESA.
[1] U.S. Endangered Species Act. EN = Endangered; T = Threatened; N.L. = Not listed.
[2] IUCN Red List of Threatened Species (2007). Codes for IUCN classifications: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; LR = Lower Risk (-cd = Conservation Dependent; -nt = Near Threatened; -lc = Least Concern); DD = Data Deficient; NL = Not Listed.
[3] Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (UNEP-WCMC 2007). I and II are CITES Appendices; NL = Not Listed.
[4] Western GOA and eastern Aleutians (Zerbini et al. 2003).
[5] Eastern temperate North Pacific (Whitehead 2002).
[6] Eastern Tropical Pacific (Wade and Gerrodette 1993).
[7] Western North Pacific (Reeves and Leatherwood 1994; Kasuya 2002).
[8] Cook Inlet stock (Rugh et al. 2005).
[9] GOA (Angliss and Outlaw 2007).
[10] North Pacific Ocean (Buckland et al. 1993).
[11] California/Oregon/Washington (Carretta et al. 2007).
[12] Minimum abundance in Alaskan waters, includes 1339 resident and 636 transient (Angliss and Outlaw 2007).
[13] Eastern Tropical Pacific (Ford 2002).
[14] SE Alaska stock (Angliss and Outlaw 2007).
[15] GOA stock (Angliss and Outlaw 2007).
[16] Western North Pacific Ocean (totals from Carretta et al. 2007 and Angliss and Outlaw 2007).
[17] Alaska stock (Angliss and Outlaw 2007).
[18] North Pacific Ocean and Bering Sea (Houck and Jefferson 1999).
[19] Eastern North Pacific (Wada 1973).
[20] Mean of 2000–2001 and 2001–2002 abundance estimates for eastern North Pacific (Angliss and Outlaw 2007).
[21] Western GOA and eastern Aleutians (Zerbini et al. 2006).
[22] North Pacific Ocean (Carretta et al. 2007).
[23] North Pacific Ocean (Wada 1976).
[24] Central waters of western Alaska and eastern and central Aleutian Islands (Angliss and Outlaw 2007)
[25] Abundance for Eastern Pacific Stock (Angliss and Outlaw 2007).
[26] Eastern U.S. Stock (Angliss and Outlaw 2007).
[27] Western U.S. Stock (Angliss and Outlaw 2007).
[28] Alaska statewide (Angliss and Outlaw 2007)
[29] Abundance estimate for SE Alaska stock (USFWS 2002 *in* Angliss and Outlaw 2007).
[30] Abundance estimate Southcentral Alaska (USFWS 2002 *in* Angliss and Outlaw 2007).
[31] SW Alaska stock (USFWS 2002 *in* Angliss and Outlaw 2007).
[†] Eastern stock; listed as a strategic stock under the MMPA.
[‡] Western stock of Steller sea lions; listed as a strategic stock under the MMPA.

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APPENDIX F:
VISUAL EFFORT AND SIGHTINGS

TABLE F.1. All and useable[a] visual observation effort from the *Langseth* in the STEEP study area, during the STEEP study, 10 September to 6 October, in **(A)** kilometers and **(B)** hours, subdivided by water depth and airgun status.

Airgun Status	All Effort by Water Depth				Useable[a] Effort by Water Depth			
	<100m	100-1000 m	>1000 m	Total	<100m	100-1000 m	>1000 m	Total
(A) Effort in km								
Total Airguns On (Seismic)	**88.3**	**274.4**	**524.0**	**886.7**	**69.7**	**203.6**	**304.0**	**577.3**
Ramp up	6.7	11.0	21.0	38.7	3.8	11.0	0.0	14.8
1-90 s after shut down	0.0	0.9	0.2	1.2	0.0	0.6	0.2	0.9
1 airgun	11.0	10.9	30.5	52.4	11.0	7.2	1.6	19.8
18 airguns	0.0	22.0	0.0	22.0	0.0	18.1	0.0	18.1
27 airguns	1.1	44.7	9.1	54.8	0.0	11.9	9.1	21.0
30 airguns	0.0	2.6	0.0	2.6	0.0	2.6	0.0	2.6
33 airguns	0.0	11.0	48.1	59.1	0.0	11.0	39.2	50.2
35 airguns	0.0	0.0	79.9	79.9	0.0	0.0	40.1	40.1
36 airguns	69.5	171.3	335.2	576.0	54.9	141.2	213.8	409.8
Total Airguns Off	**215.2**	**901.9**	**617.7**	**1519.6**	**82.9**	**744.0**	**533.6**	**1360.5**
Non-seismic[b]	215.2	858.3	617.5	1475.7	82.9	744.0	533.6	1360.5
Recently-exposed[c]	0.0	28.3	0.2	28.6	-	-	-	-
Potentially exposed[d]	0.0	15.3	0.0	15.3	-	-	-	-
Total Effort (Airguns On&Off)	**303.5**	**1176.3**	**1141.7**	**2621.5**	**152.6**	**947.5**	**837.6**	**1937.8**
(B) Effort in hr								
Total Airguns On (Seismic)	**10.9**	**34.6**	**63.6**	**109.0**	**8.9**	**25.6**	**35.7**	**70.2**
Ramp up	0.9	1.4	2.6	4.8	0.5	1.4	0.0	1.9
1-90 s after shut down	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1
1 airgun	1.5	1.4	4.5	7.4	1.5	1.0	0.2	2.7
18 airguns	0.0	2.5	0.0	2.5	0.0	2.1	0.0	2.1
27 airguns	0.1	5.9	1.0	7.0	0.0	2.0	1.0	3.0
30 airguns	0.0	0.4	0.0	0.4	0.0	0.4	0.0	0.4
33 airguns	0.0	1.2	5.2	6.4	0.0	1.2	4.2	5.4
35 airguns	0.0	0.0	9.9	9.9	0.0	0.0	5.1	5.1
36 airguns	8.4	21.7	40.4	70.4	6.9	17.5	25.1	49.5
Total Airguns Off	**18.9**	**71.0**	**41.9**	**131.8**	**5.8**	**48.7**	**31.2**	**85.7**
Non-seismic[b]	18.9	63.3	41.8	124.1	5.8	48.7	31.2	85.7
Recently-exposed[c]	0.0	4.5	0.0	4.5	-	-	-	0.0
Potentially exposed[d]	0.0	3.3	0.0	3.3	-	-	-	0.0
Total Effort (Airguns On&Off)	**29.8**	**105.6**	**105.5**	**240.9**	**14.6**	**74.3**	**66.9**	**155.8**

[a] See "useable" definition in *Acronyms and Abbreviations*.
[b] >6 h since seismic
[c] 90 s - 2 hr after seismic
[d] 2 - 6 hr after seismic

TABLE F.2. All and useable[a] (shown in parentheses) visual observation effort from the *Langseth* in the STEEP study area, during the STEEP study, 10 September to 6 October, in **(A)** kilometers and **(B)** hours, subdivided by Beaufort Wind Force (Bf) and airgun status.

Airgun Status	Beaufort Wind Force 0	1	2	3	4	5	6*	7*	Total
(A) Effort in km									
Total Airguns On (Seismic)	**0 (0)**	**48.7 (40.9)**	**136.3 (123.2)**	**200.6 (195.9)**	**132.7 (125.3)**	**140.9 (92.1)**	**96.1**	**131.4**	**886.7 (577.3)**
Ramp up	0 (0)	5.8 (2.9)	4.1 (4.1)	7.8 (7.8)	0 (0)	3.7 (0)	6.7	10.6	38.7 (14.8)
1-90 s after shut down	0 (0)	0 (0)	0.3 (0.0)	0.9 (0.9)	0 (0)	0 (0)	0	0	1.2 (0.9)
1 airgun	0 (0)	11.0 (11.0)	5.7 (2.1)	6.7 (6.7)	0 (0)	2.9 (0)	0	26.0	52.4 (19.8)
18 airguns	0 (0)	0 (0)	0 (0)	0 (0)	22.0 (18.1)	0 (0)	0	0	22 (18.1)
27 airguns	0 (0)	0 (0)	0 (0)	0 (0)	9.9 (9.9)	11.1 (11.1)	11.8	22.1	54.8 (21.0)
30 airguns	0 (0)	0 (0)	0 (0)	2.6 (2.6)	0 (0)	0 (0)	0	0	2.6 (2.6)
33 airguns	0 (0)	0 (0)	0 (0)	40.7 (40.7)	4.8 (4.8)	4.7 (4.7)	8.9	0	59.1 (50.2)
35 airguns	0 (0)	0 (0)	5.4 (5.4)	19.2 (19.2)	19.1 (15.5)	6.9 (0)	29.3	0	79.9 (40.1)
36 airguns	0 (0)	31.8 (27.0)	120.8 (111.6)	122.7 (118.0)	76.9 (76.9)	111.6 (76.4)	39.5	72.7	576 (409.8)
Total Airguns Off	**15.5 (15.5)**	**194.3 (162.5)**	**478.9 (423.2)**	**720.2 (587.2)**	**157.8 (135.6)**	**87.1 (36.4)**	**70.8**	**10.4**	**1734.8 (1360.5)**
Non-seismic[b]	15.5 (15.5)	194.3 (162.5)	449.9 (423.2)	705.3 (587.2)	157.8 (135.6)	87.1 (36.4)	70.8	10.4	1690.9 (1360.5)
Recently-exposed[c]	0 (0)	0 (0)	13.7 (0)	14.9 (0)	0 (0)	0 (0)	0	0	28.6 (0)
Potentially exposed[d]	0 (0)	0 (0)	15.3 (0)	0 (0)	0 (0)	0 (0)	0	0	15.3 (0)
Total Effort (Airguns On&Off)	**15.5 (15.5)**	**242.9 (203.4)**	**615.2 (546.3)**	**920.7 (783.1)**	**290.5 (260.9)**	**227.9 (128.6)**	**166.9**	**141.8**	**2621.5 (1937.8)**
(B) Effort in hr									
Total Airguns On (Seismic)	**0 (0)**	**5.8 (4.9**	**15.8 (14.3**	**24.4 (23.9)**	**16.6 (15.6)**	**16.9 (11.5)**	**12.5**	**17.0**	**109.0 (70.2)**
Ramp up	0 (0)	0.8 (0.4)	0.4 (0.4)	1.1 (1.1)	0 (0)	0.4 (0)	0.7	1.4	4.8 (1.9)
1-90 s after shut down	0 (0)	0 (0)	0 (0)	0.1 (0.1)	0 (0)	0 (0)	0.0	0.0	0.1 (0.1)
1 airgun	0 (0)	1.5 (1.5)	0.7 (0.3)	0.9 (0.9)	0 (0)	0.3 (0)	0.0	4.0	7.4 (2.7)
18 airguns	0 (0)	0 (0)	0 (0)	0 (0)	2.5 (2.1)	0 (0)	0.0	0.0	2.5 (2.1)
27 airguns	0 (0)	0 (0)	0 (0)	0 (0)	1.5 (1.5)	1.6 (1.6)	1.5	2.5	7.0 (3.0)
30 airguns	0 (0)	0 (0)	0 (0)	0.4 (0.4)	0 (0)	0 (0)	0.0	0.0	0.4 (0.4)
33 airguns	0 (0)	0 (0)	0 (0)	4.4 (4.4)	0.5 (0.5)	0.5 (0.5)	1.0	0.0	6.4 (5.4)
35 airguns	0 (0)	0 (0)	0.7 (0.7)	2.4 (2.4)	2.4 (2.0)	0.8 (0)	3.5	0.0	9.9 (5.1)
36 airguns	0 (0)	3.5 (3.0)	14.0 (12.9)	15.1 (14.6)	9.7 (9.7)	13.3 (9.4)	5.7	9.1	70.4 (49.5)
Total Airguns Off	**0.8 (0.8)**	**12.7 (9.8)**	**33.0 (23.7)**	**57.4 (39.5)**	**11.1 (8.7)**	**7.2 (3.1)**	**8.1**	**0.8**	**131.8 (85.7)**
Non-seismic[b]	0.8 (0.8)	12.7 (9.8)	28.7 (23.7)	54.9 (39.5)	11.1 (8.7)	7.2 (3.1)	8.1	0.8	124.1 (85.7)
Recently-exposed[c]	0 (0)	0 (0)	2.0 (0)	2.5 (0)	0 (0)	0 (0)	0.0	0.0	4.5 (0)
Potentially exposed[d]	0 (0)	0 (0)	3.3 (0)	0 (0)	0 (0)	0 (0)	0.0	0.0	3.3 (0)
Total Effort (Airguns On&Off)	**0.8 (0.8)**	**18.5 (14.7)**	**49.7 (38.0)**	**81.7 (63.4)**	**27.7 (24.4)**	**24.1 (14.6)**	**20.5**	**17.5**	**240.9 (155.8)**

[a] See "useable" definition in *Acronyms and Abbreviations*.
[b] >6 h since seismic
[c] 90 s - 2 hr after seismic
[d] 2 - 6 hr after seismic
*Effort in these categories is not considered "useable".

TABLE F.3. Sightings of marine mammals made from the R/V *Marcus G. Langseth* during all visual effort of the STEEP cruise, 10 September to 6 October 2008.

Species	Useable? [a]	Group size	Date & Time	Latitude	Longitude	CPA (m)[b]	Movement[c]	Initial Behavior[d]	Bf[e]	Water Depth (m)[f]	Vessel Activity[g]	Number of guns on	Mitigation[h]
Transit to Study Area													
Humpback whale	Y	1	12/09/2008 16:40:50	51.8433	-131.404	1595	SP	BL	3	2050	OT	0	None
Humpback whale	Y	2	12/09/2008 17:09:25	51.9121	-131.493	3206	PE	BL	3	1983	OT	0	None
Humpback whale	Y	1	12/09/2008 19:42:33	52.2781	-131.92	189	SP	FS	3	2187	OT	0	None
Humpback whale	Y	2	13/09/2008 01:01:20	52.9857	-132.777	4090	SP	BL	4	1225	OT	0	None
Pacific white-sided dolphin	Y	25	12/09/2008 15:44:00	51.7114	-131.229	802	ST	SW	3	2039	OT	0	None
Pacific white-sided dolphin	Y	1	12/09/2008 16:32:44	51.8247	-131.378	1186	SP	SW	3	2025	OT	0	None
Pacific white-sided dolphin	Y	8	12/09/2008 22:20:23	52.6266	-132.337	534	SP	PO	4	1766	OT	0	None
Unidentified whale	Y	1	13/09/2008 00:08:31	52.8694	-132.633	1098	MI	BL	4	1211	OT	0	None
Transit from Study Area													
Dall's porpoise	N	4	05/10/2008 14:51	48.9433	-127.603	241	ST	SA	4	2417	OT	0	None
Northern right-whale dolphin	Y	6	05/10/2008 18:11:35	48.4966	-127.037	152	SP	PO	2	2570	OT	0	None
Pacific white-sided dolphin	Y	6	04/10/2008 19:36:05	51.4799	-130.922	241	ST	PO	5	2035	OT	0	None
Pacific white-sided dolphin	Y	3	04/10/2008 20:59:39	51.2837	-130.659	225	UN	BO	5	2004	OT	0	None
Unidentified mysticete whale	Y	1	04/10/2008 22:51:25	51.0277	-130.317	4271	UN	BL	5	2157	OT	0	None
Unidentified mysticete whale	Y	1	05/10/2008 15:57:34	48.794	-127.414	2093	X	X	3	2217	OT	0	None
Within Study Area													
Dall's porpoise	Y	4	13/09/2008 15:28:32	55.1155	-134.704	202	SP	PO	1	1423	OT	0	None
Dall's porpoise	Y	30	13/09/2008 20:56:56	56.0402	-135.249	757	MI	PO	2	374	OT	0	None
Dall's porpoise	Y	4	13/09/2008 21:17:55	56.0943	-135.293	1098	SP	PO	2	340	OT	0	None
Dall's porpoise	Y	6	13/09/2008 21:42:56	56.1614	-135.335	861	SA	PO	2	260	OT	0	None
Dall's porpoise	N	2	14/09/2008 21:28	58.7491	-139.515	182	ST	SW	3	173	DP	0	None
Dall's porpoise	N	8	14/09/2008 21:48	58.7675	-139.56	198	ST	PO	3	173	TR	0	None
Dall's porpoise	N	1	14/09/2008 23:37	58.9056	-139.901	282	ST	PO	3	161	TR	0	None
Dall's porpoise	N	12	16/09/2008 19:36	59.0214	-142.923	241	SA	TR	5	3374	LS	36	PD
Dall's porpoise	N	8	18/09/2008 21:55	59.2515	-143.451	234	ST	PO	7	3724	SH	1	None
Dall's porpoise	N	8	20/09/2008 16:58	59.5571	-141.59	182	ST	PO	3	145	LS	36	PD
Dall's porpoise	N	5	22/09/2008 0:37	58.1307	-138.043	3184	ST	PO	2	161	RC	0	None
Dall's porpoise	N	20	22/09/2008 17:12	58.7539	-139.518	4248	SA	PO	2	100-1000	RC	0	None
Dall's porpoise	Y	1	22/09/2008 18:08:57	58.8146	-139.666	558	ST	PO	2	100-1000	TR	0	None
Dall's porpoise	N	30	22/09/2008 18:26	58.8319	-139.711	1630	MI	PO	2	100-1000	RC	0	None
Dall's porpoise	N	10	22/09/2008 23:30	59.143	-140.502	266	ST	SW	2	100-1000	RC	0	None
Dall's porpoise	N	5	23/09/2008 0:21	59.2192	-140.692	440	MI	RE	3	100-1000	TR	0	None
Dall's porpoise	N	3	23/09/2008 1:23	59.2252	-140.712	359	SP	ST	3	100-1000	TR	0	None
Dall's porpoise	Y	1	23/09/2008 16:29:33	59.9774	-142.751	2644	MI	SW	2	100-1000	TR	0	None
Dall's porpoise	N	15	23/09/2008 22:01	59.3985	-142.835	1705	ST	SW	3	1411	TR	0	None
Dall's porpoise	N	9	23/09/2008 22:07	59.3806	-142.832	3122	ST	SW	3	1214	TR	0	None
Dall's porpoise	N	18	23/09/2008 23:20	59.1701	-142.795	1000	ST	SW	3	2999	TR	0	None
Dall's porpoise	N	9	23/09/2008 23:47	59.0909	-142.781	621	SP	PO	3	3274	TR	0	None
Dall's porpoise	N	6	24/09/2008 0:01	59.0527	-142.774	4186	UN	PO	3	3244	TR	0	None
Dall's porpoise	N	12	24/09/2008 0:21	58.9931	-142.764	1103	SP	PO	3	3242	TR	0	None
Dall's porpoise	Y	5	24/09/2008 00:44:28	58.927	-142.753	1244	SP	PO	0	3342	TR	0	None

TABLE F.3 continued.

Dall's porpoise	Y	7	24/09/2008 00:44:28	58.927	-142.753	2506	UN	PO	0	3342	TR	0	None
Dall's porpoise	Y	10	24/09/2008 00:59:14	58.8843	-142.745	1630	PE	PO	0	3320	TR	0	None
Dall's porpoise	Y	3	24/09/2008 01:28:03	58.8014	-142.731	248	ST	PO	2	3271	TR	0	None
Dall's porpoise	N	5	24/09/2008 1:44	58.7552	-142.723	4248	ST	PO	2	3259	TR	0	None
Dall's porpoise	N	20	24/09/2008 2:11	58.6748	-142.709	2706	PE	SW	3	3257	TR	0	None
Dall's porpoise	Y	1	24/09/2008 16:02:37	59.0375	-140.988	740	PE	SW	2	193	TR	0	None
Dall's porpoise	Y	3	24/09/2008 17:20:29	59.1658	-140.772	163	SP	PO	1	165	TR	0	None
Dall's porpoise	Y	5	24/09/2008 19:51:16	59.425	-140.334	865	ST	PO	1	220	TR	0	None
Dall's porpoise	N	15	27/09/2008 16:09	59.2656	-140.61	657	PE	SW	3	100-1000	RC	0	None
Dall's porpoise	N	6	29/09/2008 22:18	58.5963	-141.707	411	PE	SW	3	3479	SH	35	PD
Dall's porpoise	N	7	30/09/2008 22:02	59.3455	-144.127	425	PE	TR	3	2965	LS	33	PD/SZ
Dall's porpoise	N	2	01/10/2008 16:14	58.6084	-142.32	1186	ST	SW	3	3291	TR	0	None
Dall's porpoise	N	4	01/10/2008 17:47	58.4436	-141.95	792	SA	PO	3	3496	RC	0	None
Dall's porpoise	N	2	01/10/2008 17:51	58.443	-141.948	205	ST	PO	3	3495	RC	0	None
Dall's porpoise	N	8	01/10/2008 19:55	58.6248	-141.877	2767	ST	SW	3	3451	TR	0	None
Dall's porpoise	Y	5	02/10/2008 00:19:44	59.3692	-141.572	792	SA	SW	2	190	TR	0	None
Dall's porpoise	N	12	03/10/2008 16:58	54.9608	-135.793	1595	SA	PO	4	2674	OT	0	None
Dall's porpoise	N	10	03/10/2008 17:43	54.8671	-135.656	609	ST	TR	4	2695	OT	0	None
Dall's porpoise	N	3	04/10/2008 0:01	54.0616	-134.496	370	SP	PO	3	2789	OT	0	None
Dall's porpoise	N	6	04/10/2008 0:03	54.0555	-134.487	190	SP	PO	3	2789	OT	0	None
Dall's porpoise	N	5	04/10/2008 0:30	54.0007	-134.409	153	ST	PO	3	2797	OT	0	None
Dall's porpoise	N	6	04/10/2008 1:23	53.8879	-134.249	657	ST	PO	3	2834	OT	0	None
Dall's porpoise	N	2	04/10/2008 1:47	53.8358	-134.174	325	SP	PO	3	2843	OT	0	None
Dall's porpoise	N	6	04/10/2008 2:20	53.7623	-134.071	193	ST	BO	3	2846	OT	0	None
Humpback whale	Y	1	13/09/2008 01:46:57	53.0873	-132.898	4152	UN	BL	4	1160	OT	0	None
Humpback whale	Y	2	13/09/2008 02:02:58	53.1235	-132.94	3653	SP	BL	4	1040	OT	0	None
Humpback whale	Y	3	13/09/2008 02:11:53	53.1433	-132.964	3653	SP	BL	4	895	OT	0	None
Humpback whale	Y	1	13/09/2008 02:26:35	53.1766	-133.004	2366	SA	BL	4	851	OT	0	None
Humpback whale	N	1	13/09/2008 20:56	56.0402	-135.249	6011	SP	BL	2	374	OT	0	None
Humpback whale	Y	1	13/09/2008 21:17:55	56.0943	-135.293	3091	SP	BL	2	340	OT	0	None
Humpback whale	Y	1	13/09/2008 21:26:00	56.1156	-135.308	3153	UN	BL	2	333	OT	0	None
Humpback whale	Y	1	13/09/2008 21:35:36	56.1414	-135.323	722	MI	BL	2	325	OT	0	None
Humpback whale	Y	1	13/09/2008 21:48:24	56.1762	-135.343	704	SP	SW	2	260	OT	0	None
Humpback whale	Y	1	13/09/2008 21:52:41	56.1878	-135.35	900	UN	BL	2	228	OT	0	None
Humpback whale	Y	1	13/09/2008 22:09:42	56.2338	-135.376	3504	UN	BL	2	205	OT	0	None
Humpback whale	Y	2	13/09/2008 22:28:53	56.2868	-135.405	3091	UN	BL	2	197	OT	0	None
Humpback whale	Y	1	13/09/2008 22:41:36	56.3224	-135.426	3267	UN	BL	2	191	OT	0	None
Humpback whale	Y	1	13/09/2008 22:50:11	56.3465	-135.441	4074	MI	BL	2	191	OT	0	None
Humpback whale	Y	3	14/09/2008 02:44:27	56.9421	-135.841	657	SP	BL	3	123	OT	0	None
Humpback whale	N	2	16/09/2008 3:42	59.2624	-142.885	1013	UN	BL	5	2688	DP	0	None
Humpback whale	N	1	21/09/2008 21:52	58.2423	-138.296	916	SA	BL	2	145	LS	36	PD
Humpback whale	N	1	21/09/2008 22:18	58.2216	-138.247	174	ST	BL	2	151	SH	1	SZ
Humpback whale	N	1	21/09/2008 23:04	58.189	-138.17	5948	NO	LT	2	149	RC	0	None
Humpback whale	N	1	21/09/2008 23:54	58.1552	-138.096	4186	SP	BL	2	153	RC	0	None
Humpback whale	N	1	22/09/2008 0:30	58.1347	-138.051	2506	SP	BL	2	159	RC	0	None
Humpback whale	N	1	22/09/2008 1:34	58.1033	-137.984	1428	PE	BL	2	169	RC	0	None

TABLE F.3 concluded

Sea otter	N	3	27/09/2008 22:50	59.5771	-139.838	325	MI	LO	2	<100	OT	0	None
Sea otter	Y	1	29/09/2008 00:16:50	59.7198	-139.774	1106	UN	SW	2	95	TR	0	None
Unidentified mysticete whale	N	1	15/09/2008 21:56	59.5949	-142.961	9231	SA	BL	3	474	DP	0	None
Unidentified mysticete whale	N	2	17/09/2008 2:31	59.5487	-143.142	1630	UN	BL	6	469	LS	36	None
Unidentified mysticete whale	Y	1	22/09/2008 17:34:47	58.7547	-139.522	4186	UN	BL	2	100-1000	TR	0	None
Unidentified mysticete whale	Y	1	23/09/2008 23:28:52	59.1465	-142.791	4186	UN	BL	3	3172	TR	0	None
Unidentified whale	Y	1	24/09/2008 15:45:32	58.9989	-141.052	1630	SP	TR	2	222	TR	0	None
Unidentified whale	Y	2	03/10/2008 15:43:34	55.1284	-135.954	2153	UN	BL	5	2759	OT	0	None

[a] Useable or non-useable sighting. Y = Yes. N = No. Sighting made during periods 90 s to 6 h 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. 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.
[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; X = movement not recorded.
[d] The initial behavior observed. PO = porpoising; SA = surface active; FS = flipper slap; TR = traveling; SW = swimming; BL = blowing; ST = Surface Active/Traveling; X = behavior not recorded.
[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. TR = transiting; RC = recovering equipment; LS = line shooting with airgun(s); DP = deploying equipment; SH = shooting between or off lines; OT = other or no seismic activity.
[h] Mitigation measures. PD = power down to a single airgun; SZ = safety zone shut down.

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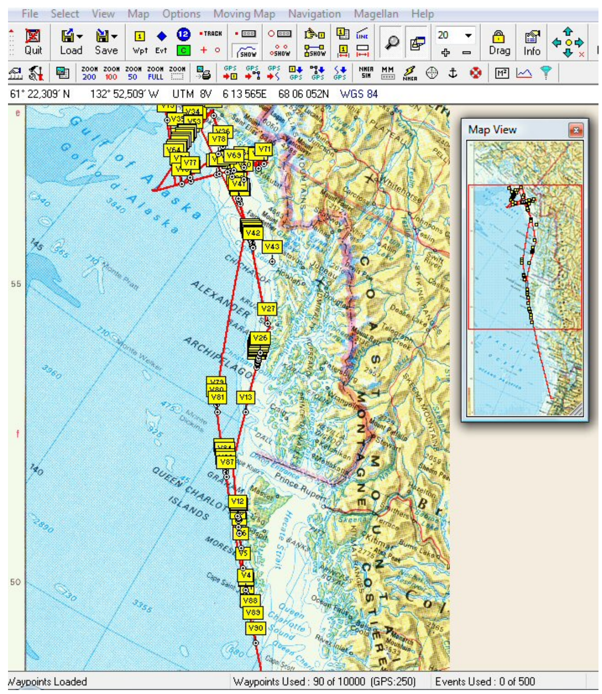
APPENDIX G:
STEEP SURVEY, GULF OF ALASKA, 10 SEPT – 6 OCT 2008
PAM REPORT

PAM operations on the *Langseth* during 2008 cruises faced a series of difficulties as stated in the previous PAM reports.
As a result, all the streamers in use were damaged. The Seamap has been discontinued and the RW/CIBRA's backup was destroyed as well during the Mutter cruise. RW managed to rebuild a new backup on the fly in Astoria, during the port call before the STEEP survey. A new dipole was then made, based on the design of the previous one, and using scrap components and last minute solutions. This guaranteed PAM for that cruise. Unfortunately, the main problem, how to safely deploy and tow the PAM streamer, was not solved yet.
In Astoria we bought a depressor with the idea to use it as a deep towing point, but due to schedule constrains, it was not possible to do the preliminary necessary tests.

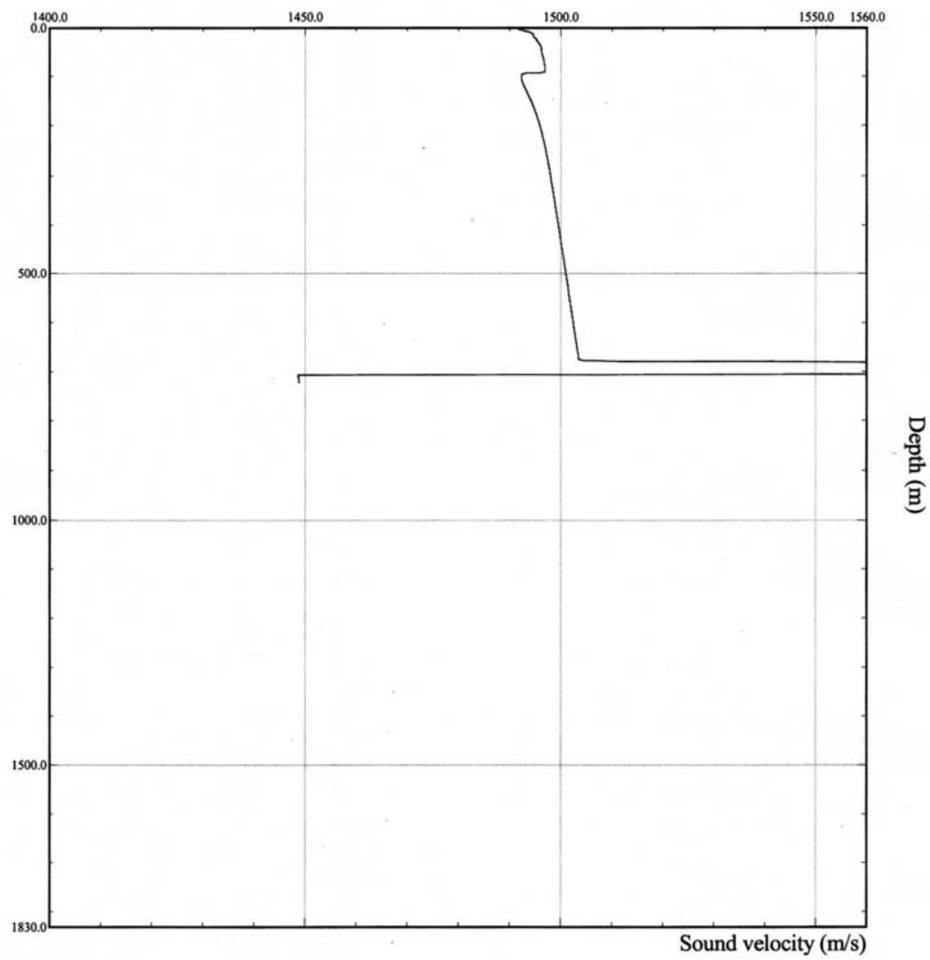


Once in the operation area, PAM streamer was deployed by hand and secured to the starboard Paravane boom, at the moment not in use for seismic since the cruise was 2D. A minimal length of tow cable was deployed in order to maintain the active section before the airguns strings. In this way the PAM streamer was clear of other seismic gear, being towed on one side. The bad part was the towing depth, which was too shallow. This solution worked as long as the weather was relatively good and the ship course was straight. But after few days we experienced strong wind from the starboard beam, and the *Langseth* started to crab. Different types of gear have different drag properties, and the PAM streamer, despite our attempts, got entangled with the airgun umbilical. This broke the tow cable but we did not lose the instrument because it was tied to an extra stress-line. Acoustic monitoring was temporally performed with a hull mounted sensor (HAP- 5050).

The PAM streamer was then retrieved and the tow cable was repaired during a couple of days dedicated to OBS operations. It was re-deployed for the final active seismic leg and towed even closer and shallower than before.

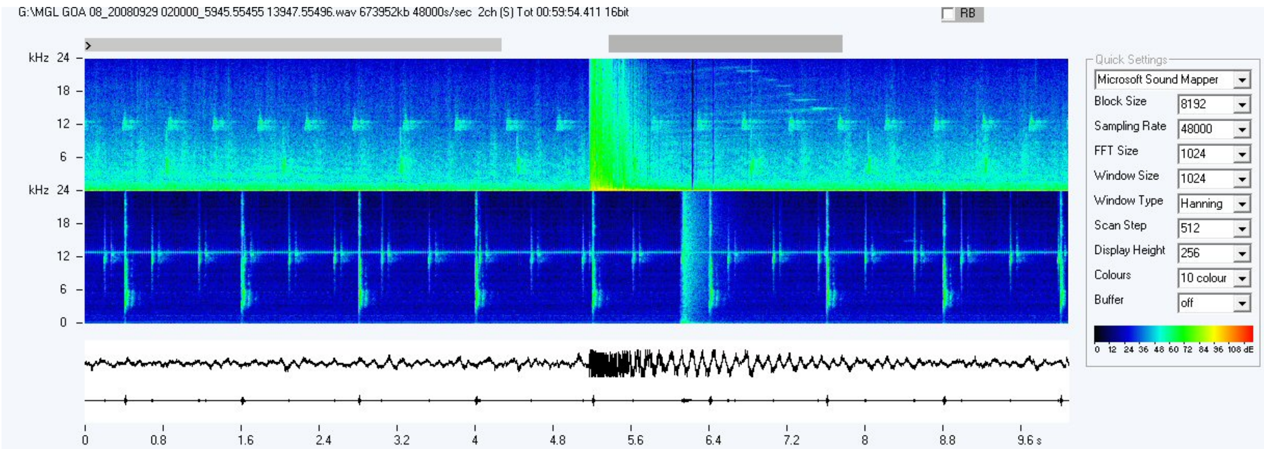
As software, we used the CIBRA/RW programs already described in previous reports.

No acoustic contacts were detected during the cruise. This was very likely due to a combination of facts. The streamer was towed too shallow, where the sound propagation is not optimal even in cold waters like the ones in the Gulf of Alaska, as shown in the xbt profile.



Other than oceanographic conditions and, mainly, the streamer's depth, animals seen during PAM operation were Dall's porpoises, which produce clicks at too high a frequency for the sensors used, and humpbacks, which vocalize mostly during the winter breeding season. When possible, we recorded data from the PAM streamer on ch1 and the hull sensor on ch2, to get a comparison of the two.

Though not a definitive judgment, since the sensors and acquisition chain were not calibrated, it appears clear that the hull mounted sensor is much less sensitive than the towed one and it's directionality is bottom oriented. This limits its usefulness to emergencies rather than being intended as a main PAM system.



The image above represents the SeaPro spectrographic display. Recordings were made in Yakutat Bay, shallow water. On the upper channel there is the RW streamer; on the lower the *Langseth* hull sensor (HAP 5050). Both channels were digitized via Edirol UA-25. This acquisition box has two options for signal input: jack and XLR. The latter has a preset level of amplification. The HAP 5050 was connected via XLR with a 50% extra gain on the control knob. The RW streamer in was a jack, and the gain knob was set on 0. Nevertheless, the upper channel looks more "noisy". In the middle of the spectrogram there is a shot (36 airguns), clearly visible on both channels, but stronger on the streamer by far. The delay between channels does not correspond to the travel time between the 2 sensors but is due to the non synchronous clocks of the acquisition PCs. Sensors were separated by about 70 m, which corresponds to 40-50 milliseconds—not enough to justify this amplitude difference.

The three following tables summarize the attended PAM effort (172 h) during the cruise. In addition, there were 25 h of unattended PAM recordings which were reviewed at a later date. PAM occurred during nearly all (97%) of seismic operations. Due to technical difficulties, it was not possible to deploy and monitor PAM during the remainder of seismic operations. The PAM array could not be deployed during non-seismic periods due to logistic reasons. Poor results (no contacts) stimulated us to improve the general characteristics of the "wet" hardware as well as the ATD converters. It remains of fundamental importance to find a proper way to deploy and tow the PAM gear to avoid interactions with other instruments and to maximize detection chance.

Date 2008 GMT	Visual effort (hrs)	PAM* effort (hrs)
10 September	Transit to study area – 0	Transit to study area – no PAM
11 September	Transit to study area – 0	Transit to study area – no PAM
12 September	Transit to study area – 11.25	Transit to study area – no PAM
13 September	Transit to study area – 12	Transit to study area – no PAM
14 September	OBS deployment – 12	No seismic – no PAM
15 September	OBS deployment – 12.75	No seismic – no PAM
16 September	Seismic – 9.25; No seismic – 4	Seismic – 13.25 PAM array
17 September	Seismic – 13	Seismic – 24 PAM array
18 September	Seismic – 13	Seismic – 13.5 PAM array
19 September	Seismic – 13	Seismic – 1 hr with hull-mounted hydrophone
Total	**100.25**	**51.75**

Date 2008 GMT	Visual effort (hrs)	PAM* effort (hrs)
20 September	Seismic – 12; No seismic – 1	Hull-mounted hydrophone – 24
21 September	Seismic – 7.5; No seismic – 5.25	Hull-mounted hydrophone – 15.25
22 September	OBS recovery – 12.25	No PAM
23 September	OBS recovery – 12.5	No PAM
24 September	Seismic – 2.25; No seismic – 10.75	Hull hydrophone + PAM array – 3.75
25 September	Seismic – 12.75	Hull hydrophone + PAM array – 24
26 September	OBS recovery – 4.25	Hull hydrophone + PAM array – 1
Total	**80.5**	**68**

Date 2008 GMT	Visual effort (hrs)	PAM* effort (hrs)
27 September	OBS recovery – 10	No PAM
28 September	Seismic – 2.75; No seismic – 9.75	10.5
29 September	Seismic – 12.75	24
30 September	Seismic – 9.75; No seismic – 1.5	18
1 October	OBS recovery – 12.25	No PAM
2 October	Transit – 1.75	No PAM
3 October	Transit – 11.75	No PAM
4 October	Transit – 9	No PAM
5 October	Transit – 4.25	No PAM
Total	**85.5**	**52.5**

Tables from the LGL weekly MMO reports.

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