MARINE MAMMAL MONITORING DURING A UNIVERSITY OF TEXAS INSTITUTE FOR GEOPHYSICS SEISMIC SURVEY IN THE NORTHEAST PACIFIC OCEAN, JULY 2008

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and

National Marine Fisheries Service, Office of Protected Resources

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

LGL Report TA4584-2

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ACRONYMS AND ABBREVIATIONS

3-D	Three Dimensional
Bf	Beaufort Wind Force
CITES	Convention on International Trade in Endangered Species
CPA	Closest (Observed) Point of Approach
CRE	Center for Regulatory Effectiveness
CV	Coefficient of Variation
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; equivalent to 1/(effective strip width)
ft	feet
GI	Generator Injector
GIS	Geographic Information System
GMT	Greenwich Mean Time
$g(0)$	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	micro Pascal
m	meters
MBES	Multibeam Bathymetric Echosounder
min	minutes
MMC	(U.S.) Marine Mammal Commission
MMO	Marine Mammal (and Sea Turtle) Observer
MMPA	(U.S.) Marine Mammal Protection Act
n	sample size
NEPO	Northeast Pacific Ocean
NMFS	(U.S.) National Marine Fisheries Service
No.	Number
NSF	(U.S.) National Science Foundation

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
s	seconds
SD	Shut Down of both GI guns not associated with mitigation
s.d.	standard deviation
SPL	Sound Pressure Level
SZ	Shut Down of both GI guns because of a marine mammal or sea turtle sighting near or within the safety radius
TTS	Temporary Threshold Shift
UNEP	United Nations Environmental Programme
U.K.	United Kingdom
U.S.	United States of America
"Useable"	Visual effort or sightings made under the following observation conditions: daylight periods within the study area, ***excluding*** periods 90 s to 2 h after GI guns were turned off (recently exposed), 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 *Thompson*'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 Institute for Geophysics

EXECUTIVE SUMMARY

Introduction

This document serves to meet reporting requirements specified in an Incidental Harassment Authorization (IHA) issued to the University of Texas Institute for Geophysics (UTIG) by the National Marine Fisheries Service (NMFS) on 27 June 2008. The IHA (Appendix A) authorized non-lethal takes of certain marine mammals incidental to a marine seismic survey by the R/V *Thomas G. Thompson* in the Northeast Pacific Ocean (NEPO) off the coast of Oregon. 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 unknown whether, under realistic field conditions, seismic exploration sounds are strong enough to cause temporary or permanent hearing impairment in any marine mammals or sea turtles 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

UTIG conducted an ultra-high resolution 3-dimensional (3-D) seismic survey around the methane vent systems of Hydrate Ridge off the Oregon coast in the NEPO. The study area was located between ~44º and 45ºN and 124.5º and 126ºW, ~100 km from shore within the U.S. Exclusive Economic Zone (EEZ). Water depth in the survey area ranged from ~650 to 1650 m. The cruise occurred from 30 June to 19 July 2008.

The purpose of the seismic survey was to investigate the methane vent systems that exist offshore of Oregon, and to understand how vent structure directs methane from the subsurface to be vented into the oceans or potentially stored in the subsurface as methane hydrate. Methane is a significant greenhouse gas, and methane release from vents or from hydrate has a large potential for affecting climate. The geophysical investigation was under the direction of Dr. Nathan Bangs of UTIG.

The *Thompson* deployed two low-energy Generator Injector (GI) guns as an energy source, with a discharge volume of 75 in^3 each or a total of 150 in^3. The GI guns were towed at a depth of 2 m. The acoustic receiving system consisted of a 12-m long P-Cable system with 10 to 12 towed streamers spaced ~12.5 m apart, each containing 11 hydrophones, all summed to a single channel. A 30-kHz multibeam bathymetric echosounder (MBES) and a dual-frequency (3.5 kHz and 12 kHz) chirp echosounder were also used during most of the survey.

Monitoring and Mitigation Description and Methods

Three trained marine mammal (and sea turtle) observers (MMOs) were aboard the *Thompson* during the period of operations for visual 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 shut down of the GI guns 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 the GI guns operated during daylight periods and whenever the vessel was underway but the GI guns were not firing. The MMOs used 7 x 50 binoculars and 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 shut down of the GI guns.

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 GI guns, whenever the GI guns were started after periods without GI gun operations. ***(B)*** Immediate shut downs of the GI guns whenever marine mammals or sea turtles were detected within or about to enter the safety radius. The safety radii for cetaceans and sea turtles during the survey were based on the distances within which the received levels of GI gun 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 distance within which the received levels of GI gun sounds were expected to diminish to 190 dB re 1 μPa_{rms}.

Monitoring Results

The *Thompson* traveled a total of ~3010 km in the NEPO, and 974 km of seismic operations occurred (Table ES.1). In total, 160 h of visual observations were undertaken (Table ES.1). Nearly all (98%) visual effort occurred during daylight. MMOs were on visual watch during all daytime seismic operations including ramp ups. MMOs were also on watch for 3.2 h at night prior to and during ramp ups (Table ES.1).

Analyses of marine mammal data focused on sightings and survey effort in the study area during "useable" survey conditions, which represented 45% or 51% of the total visual effort in hours or kilometers, respectively (Table ES.1). "Useable" effort excluded periods 90 s to 2 h after GI guns were turned off (recently exposed), poor visibility (<3.5 km) conditions, and periods with Beaufort Wind Force >5. Also excluded were periods when the *Thompson*'s speed was <3.7 km/h (2 kt) or periods with >60° of severe glare between 90º left and right of the bow.

Fifty-three sightings of marine mammals totaling ~5390 individuals were made during the survey; no sea turtles were seen. With the exception of one northern fur seal, all marine mammal sightings were of cetaceans; six cetacean species were identified. The majority of sightings (60% or 32 groups) involved Pacific white-sided dolphins, but short-beaked common and northern right whale dolphins, as well as Dall's porpoises, humpback whales, one minke whale, and one unidentified dolphin, were also seen. The detection rate, based on 32 useable sightings, was nearly three times greater with (83/1000 km, n = 29) than without GI gun operations (29/1000 km, n = 3). The limited number of sightings, especially during non-seismic periods, is insufficient to allow any meaningful conclusions from these results alone.

Number of Marine Mammals Present and Potentially Affected

During this project, the "safety radii" required by NMFS for cetaceans and sea turtles were the best estimates of the 180-dB radii for the two GI guns in use during the study based on water depth. The GI guns were shut down 21 times because of the presence of 21 marine mammal groups totaling ~3621 individuals within or near the designated safety zone. Because of the small size of the airgun array (2 GI guns), full shut downs rather than power downs were implemented. Shut downs were necessary for

Pacific white-sided, short-beaked common, and northern right whale dolphins, as well as Dall's porpoises and one northern fur seal. Eight of the 21 shut downs occurred for mixed-species groups. Only 11 of the 21 groups for which a shut down was implemented were in the safety zone when first observed; these 11 groups of 2370 individuals were very likely exposed to GI gun sounds with received levels ≥180 dB re 1 μPa_{rms} before mitigation measures could be implemented.

Any large cetaceans that might have been exposed to received sound levels ≥160 dB re 1 μPa_{rms}, and delphinids, Dall's porpoises, and pinnipeds exposed to received levels of ≥170 dB re 1 μPa_{rms} were assumed to have been potentially disturbed during the seismic study. Based on direct observations, one minke whale and two groups of four humpback whales were exposed to received sound levels ≥160 dB re 1 μPa_{rms}. In addition, 21 groups of ~3463 dolphins, three groups of 18 Dall's porpoises, and one northern fur seal were exposed to GI gun sounds ≥170 dB.

Minimum and maximum numbers of marine mammals 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. Based on observations during non-seismic periods, a minimum of 36 and up to 478 cetaceans might, prior to the approach of the *Thompson*, have been in the areas about to be exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms}. These estimates include up to 24 delphinids and 450 Dall's porpoises. When areas with received levels ≥170 dB re 1 μPa_{rms} are considered, ~13 to 131 porpoises and up to eight delphinids might have been present prior to the approach of the ship. The estimates based on actual density data during non-seismic periods are equal to or lower than the "harassment takes" estimated prior to the survey, based on number of individuals. No pinnipeds were sighted during non-seismic periods.

Observed densities of cetaceans were higher during seismic compared with non-seismic periods. Based on densities during seismic periods, a minimum of 346 and up to 4390 marine mammals were in the area exposed to GI gun sounds with received levels ≥160 dB re 1 μPa_{rms}. These estimates include 4242 exposures of delphinids, 128 exposures of Dall's porpoises, 14 exposures of a single humpback whale, 1 exposure of a minke whale, and five exposures of three northern fur seals. (In some cases, the marine mammals may have moved out of the 160-dB zone ahead of the approaching ship, before the received sound level reached ≥160 dB.) When areas with received levels ≥170 dB re 1 μPa_{rms} are considered, ~144 to 1245 delphinids and up to 39 porpoises might have been present in the area exposed. Only one northern fur seal might have been in the area about to be exposed to ≥170 dB. The estimates of individuals exposed based on density data from seismic periods are greater than the "takes" estimated prior to the survey for Pacific white-sided, short-beaked common, and northern right whale dolphins, as well as Dall's porpoise. This is because observed densities were generally higher than expected densities in the survey area.

During the NEPO survey, there was no clear indication that cetaceans may have been avoiding the area around the seismic vessel, except possibly at very close range. In fact, three species of dolphins and Dall's porpoises frequently approached the *Thompson*, requiring mitigation action (shut down of the GI guns). Given the small size of the airgun array and that mitigation measures were implemented immediately for marine mammals sighted close to the source vessel, effects were very likely localized and transient, without significant impact on either individual marine mammals or their populations.

TABLE ES.1. Summary of *Thompson* operations, visual monitoring effort, and marine mammal sightings during the Northeast Pacific Ocean seismic survey, 30 June to 19 July 2008.

	Non-Seismic			Seismic			
	Useable	Other	Recently Exposed[a]	Useable	Other	Total Useable[b]	Total
Operations in h							
Thompson Dark	0.0	81.5	4.9	0.0	66.8	0.0	153.2
Thompson Daylight	6.2	146.7	30.5	66.3	56.2	72.5	305.8
***Thompson* Total**	**6.2**	**228.1**	**35.3**	**66.3**	**123.0**	**72.5**	**459.0**
Observer Dark	0.0	0.6	1.2	0.0	1.4	0.0	3.2
Observer Daylight	6.2	4.9	23.2	66.3	56.2	72.5	156.8
Observer Total	**6.2**	**5.6**	**24.4**	**66.3**	**57.5**	**72.5**	**160.0**
Operations in km							
Thompson Dark	0.0	563.4	18.8	0.0	334.7	0.0	916.9
Thompson Daylight	104.4	1245.4	104.4	349.6	289.5	454.1	2093.4
***Thompson* Total**	**104.4**	**1808.8**	**123.3**	**349.6**	**624.2**	**454.1**	**3010.3**
Observer Dark	0.0	2.7	4.6	0.0	6.3	0.0	13.6
Observer Daylight	104.4	18.3	108.7	349.6	289.5	454.1	870.6
Observer Total	**104.4**	**21.0**	**113.3**	**349.6**	**295.8**	**454.1**	**884.1**
No. Marine Mammal Sightings[c]	**3**	**2**	**8**	**29**	**11**	**32**	**53**
No. Individual Marine Mammals Sighted	**28**	**2**	**188**	**4827**	**337**	**4855**	**5390**
No. Shutdowns for Cetaceans							**21**

[a] Effort from 90 s to 2 h after GI guns were turned off is considered recently exposed and not useable.
[b] See *Acronyms and Abbreviations* for the definition of “useable” effort.
[c] 53 cetacean sightings, including 1 northern fur seal seen in association with dolphins.

1. INTRODUCTION

The University of Texas Institute for Geophysics (UTIG) conducted a seismic survey in the Northeast Pacific Ocean (NEPO) from 30 June to 19 July 2008. The survey was conducted aboard the *R/V Thomas G. Thompson* which is operated by the University of Washington and owned by the U.S. Navy. UTIG conducted an ultra-high-resolution 3-dimensional (3-D) seismic survey around the methane vent systems of Hydrate Ridge, ~100 km off the coast of Oregon. The purpose of the seismic survey was to investigate how these vent structures direct subsurface methane into the oceans, or potentially stored in the subsurface as methane hydrate. Methane is a significant greenhouse gas, and methane release from vents or from hydrate has a large potential to affect climate. The study used two Generator Injector (GI) guns with a discharge volume of 75 in^3 each. The geophysical investigation was under the direction of Dr. Nathan Bangs 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 NEPO. Several of these species are listed as endangered under the ESA, including the North Pacific right, humpback, sei, fin, blue, and sperm whales. The southern resident killer whale stock, listed as endangered, the threatened Steller sea lion, and the threatened northern sea otter are unlikely to occur in offshore waters, and were not sighted during the study. The only ESA-listed species seen during the survey was the humpback whale.

On 4 March 2008, UTIG 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 GI gun operations in the NEPO (LGL Ltd. 2008). The IHA was requested pursuant to Section 101(a)(5)(D) of the MMPA. NMFS adopted the National Science Foundation's (NSF) 2007 Environmental Assessment (EA) for another survey in the NEPO (LGL Ltd. 2007), but also prepared a supplemental EA for the 2008 seismic survey in the NEPO (NMFS 2008a). The IHA was issued to UTIG by NMFS on 27 June 2008 (Appendix A).

The IHA authorized "potential take by harassment" of marine mammals during the seismic program described in this report. The *Thompson* survey vessel departed from Seattle, Washington, on 30 June 2008 and returned on 19 July 2008. The GI guns operated for a total of ~189 h. Seismic operations commenced on 3 July and concluded on 18 July 2008.

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

Incidental Harassment Authorization

IHAs issued 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 practicable. During this project, sounds were generated by the GI guns used during the seismic study and also by a multibeam bathymetric echosounder (MBES), a chirp echosounder, and general vessel operations. No serious injuries or deaths of marine mammals (or sea turtles) were anticipated from or attributed to the seismic survey, given the nature of the operations and the mitigation measures implemented, 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. 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 assume 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, NMFS specified a safety (shut-down) criterion of 180 dB re 1 μPa_{rms} for sea turtles.

Disturbance to marine mammals could occur at distances beyond the safety (=shut down) radii if the mammals were exposed to moderately strong pulsed sounds generated by the airgun array (Richardson et al. 1995). NMFS assumes that marine mammals exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} are likely to be disturbed appreciably. That assumption is based mainly on data concerning behavioral responses of baleen whales, as summarized by Richardson et al. (1995) and Gordon et al. (2004). Dolphins, Dall's porpoise, and most pinnipeds are generally less responsive (e.g., Stone 2003; Gordon et al. 2004), and 170 dB re 1 μPa_{rms} may be a more appropriate criterion of behavioral disturbance for those groups (see LGL Ltd. 2007, 2008). 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 NEPO seismic study was published by NMFS in the *Federal Register* on 23 May 2008, and public comments were invited (NMFS 2008b). The Marine Mammal Commission (MMC) and the Center for Regulatory Effectiveness (CRE) submitted comments.

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

On 27 June 2008, UTIG received the IHA that had been requested for the seismic study. On 23 July 23 2008, NMFS published a second notice in the *Federal Register* to announce the issuance of this IHA (NMFS 2008c). 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 UTIG 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 UTIG's IHA Application (LGL Ltd. 2008) and in the IHA issued by NMFS to UTIG (Appendix A). Explanatory material about the monitoring and mitigation requirements was published by NMFS in the *Federal Register* (NMFS 2008b,c).

The main purpose of the mitigation program was to avoid or minimize potential effects of UTIG's seismic study on marine mammals and sea turtles. This required that — during daytime GI gun operations — UTIG detect marine mammals and sea turtles within or about to enter the safety radius, and in such cases initiate an immediate shut down of the GI guns. An additional mitigation objective was to detect marine mammals or sea turtles within or near the safety radii prior to starting the GI guns or during ramp up to full power. In these cases, the start of GI gun operation was to be delayed or ramp up discontinued until the safety radius was free of marine mammals or sea turtles (see Appendix A and Chapter 3).

The primary objectives of the monitoring program were as follows:

1. Provide real-time sighting data needed to implement the mitigation requirements.
2. Estimate the numbers of marine mammals potentially exposed to strong seismic pulses.
3. 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 seismic study that occurred in the NEPO from 30 June to 19 July 2008, including the associated monitoring and mitigation programs, 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.

In addition, there are seven Appendices. The Appendices include

A. a copy of the IHA issued to UTIG for this study;

B. background on development and implementation of safety radii;

C. characteristics of the *Thompson*, the GI guns, 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 list of marine mammals seen during this cruise; and

G. additional supporting details regarding numbers of marine mammals exposed to seismic sounds.

2. SEISMIC PROGRAM DESCRIBED

This seismic program consisted of an ultra-high-resolution 3-D seismic survey around the methane vent systems of Hydrate Ridge, off the Oregon coast in the NEPO (Fig. 2.1). The *Thompson* source vessel deployed two low-energy GI guns as the energy source (with a discharge volume of 75 in^3 each or a total of 150 in^3), and a 12-m long P-Cable system supplied by Northampton Oceanographic Center in the U.K. The P-Cable system consisted of 10 to 12 streamers spaced ~12.5 m apart, each containing 11 hydrophones, all summed to a single channel. The energy to the GI guns was compressed air supplied by compressors aboard the source vessel. As the GI guns were towed along the survey lines, the P-Cable system received the returning acoustic signals.

Along with the GI gun operations, additional acoustical systems were operated during the cruise. The Simrad EM300 MBES was used to examine venting into the water column. In addition, the 12 kHz frequency of the dual-frequency Knudsen 320BR chirp echosounder was used to record water depth.

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 *Thompson* and the equipment is provided in Appendix C.

Operating Areas, Dates, and Navigation

The study encompassed the area between ~44º and 45ºN and between 124.5º and 126ºW in the NEPO within the Exclusive Economic Zone (EEZ) of the U.S. (Fig. 2.1). Water depths in the survey area ranged from ~600–1650 m. The *Thompson* left the port of Seattle on 30 June 2008. Following several days of streamer deployment, seismic operations commenced on 3 July 2008. The last GI gun operations occurred on 18 July, and the vessel returned to Seattle on 19 July 2008. Airgun operations occurred during the day and at night. A summary of the total distances traveled by the *Thompson* during the survey, distinguishing periods with and without seismic operations, are presented in Table ES.1 (in the Executive Summary).

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

Airgun Array Characteristics

The *Thompson* towed two GI guns and the 12-m long P-Cable system along predetermined survey lines. Seismic pulses were emitted at intervals of ~3.5 s. The *Thompson* traveled at an average speed of 5.1 km/h (2.8 kt) during seismic acquisition; this corresponded to a shot interval of ~5 m. The generator chamber of each GI gun, the one responsible for introducing the sound pulse into the ocean, was 75 in^3. The injector chamber (also 75 in^3) injects air into the previously-generated bubble to maintain its shape, and does not introduce more sound into the water. Thus, the total discharge volume was 150 in^3. Compressed air supplied by compressors aboard the source vessel powered the GI guns.

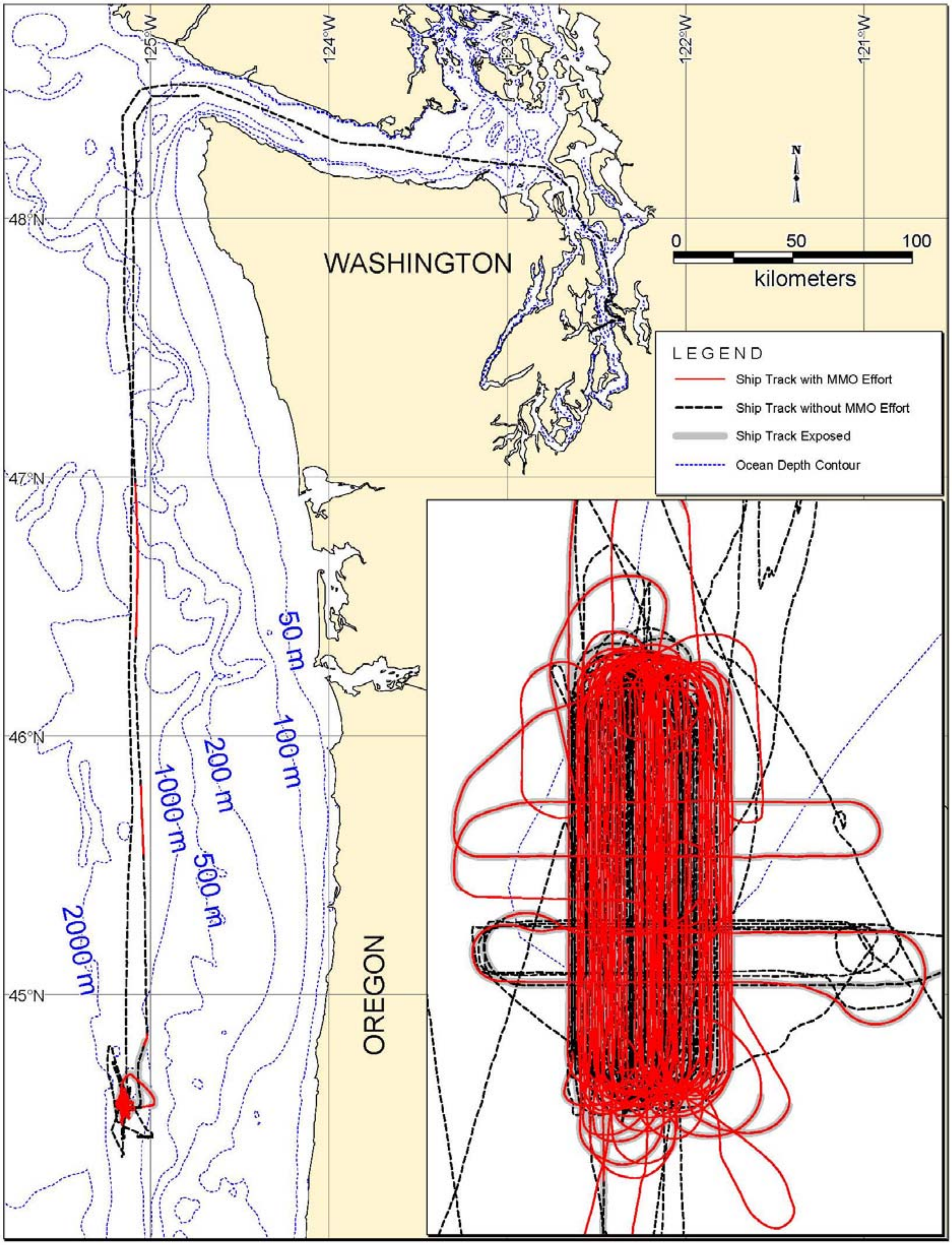

FIGURE 2.1. Map of the study area showing ship tracks with and without observer effort and acquired seismic lines in the Northeast Pacific Ocean, 30 June to 19 July 2008.

The two GI guns were towed 15–20 m behind the ship at a depth of ~2 m (Fig. 2.2). The towed P-Cable system received the reflected gun signals and transferred the data to the on-board processing system. Given the relatively short streamers behind the vessel, the maneuverability of the vessel was not limited much during operations. A total of 974 km of seismic operations were conducted off the Oregon coast; both GI guns operated for 944 km, and the remaining operations occurred with one GI gun during ramp-up procedures (see Appendix F).

The nominal source level for downward propagation of low-frequency energy from the two GI guns is shown below. 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 (in this case two GI guns) 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, because of the slightly directional nature of the sound from the two GI guns, the effective source level for sound propagating in some near-horizontal directions would be somewhat lower. 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 below, but source levels of airguns are not normally determined on an rms basis by airgun manufacturers or geophysicists.

Array Specifications

Energy Source	Two GI guns, 75 in^3
Source output (downward)[2]	0-pk is 7.2 bar-m (237 dB re 1 μPa·m); pk-pk is 14.0 bar·m (243 dB)
Towing depth of energy source	~2 m
Air discharge volume	~150 in^3
Dominant frequency components	2–188 Hz

Multibeam Bathymetric Echosounder and Chirp Echosounder

Along with the GI gun operations, two additional acoustic systems operated during the cruise. A 12-kHz Simrad EM120 MBES and a dual-frequency (3.5 kHz and 12 kHz) Knudsen 320BR chirp echosounder were 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 GI guns. The echosounders are described in Appendix C.

Other Types of GI Gun Operations

GI gun(s) operated during certain other periods besides seismic acquisition (line shooting), including ramp-up periods and turns between lines. Ramp ups were required by the IHA (see Chapter 3 and Appendix A). During a ramp up, one GI gun was turned on and 5 min later the second GI gun was started up. This ramp-up procedure ensured that the source level of the array increased in steps not exceeding 6 dB per 5-min period as required in the IHA (Appendix A). Ramp ups occurred when operations with the GI guns commenced after an extended period (>4 min) without GI gun operations.

[2] Given for two 105-in^3 GI guns towed at 3 m; source output not available for two 75-in^3 GI guns. For one 45-in^3 GI gun, 0-pk is 1.8 bar-m (225.3 dB re 1 μPa·m) and pk-pk is 3.4 bar·m (230.7 dB).

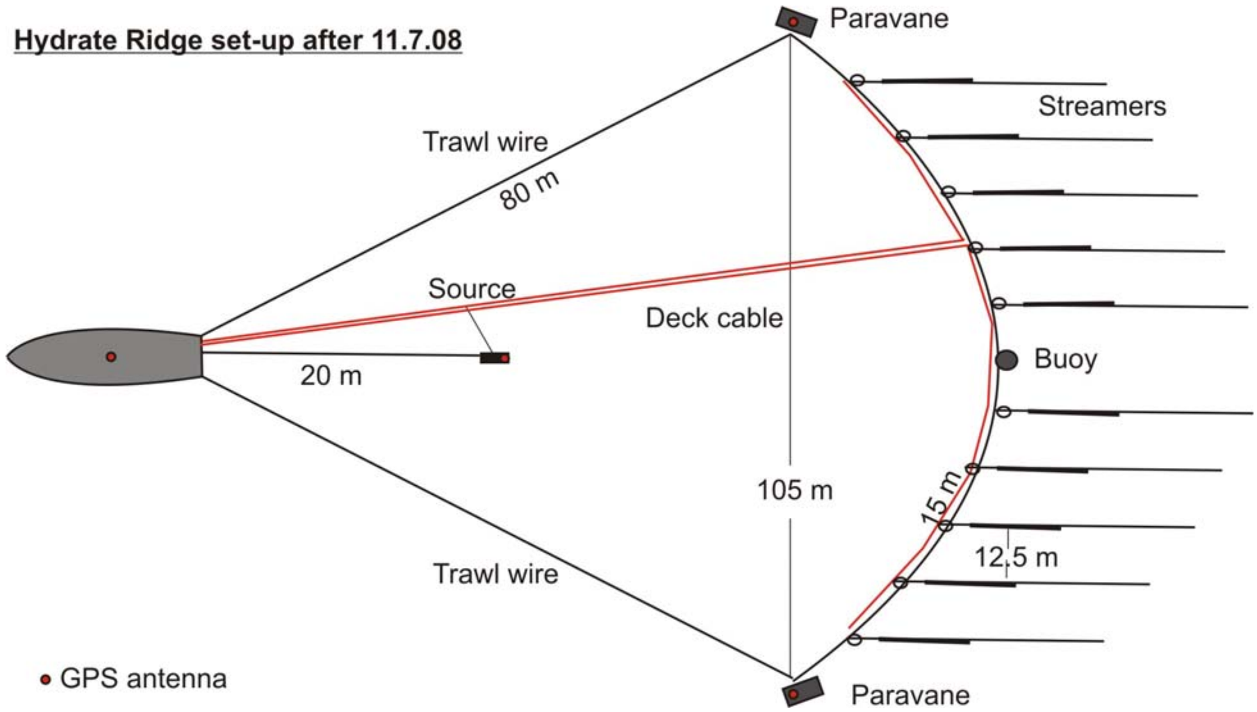

FIGURE 2.2. Towing configuration of the two GI guns and the P-Cable system (10 streamers shown) during the NEPO seismic study, 30 June to 19 July 2008.

3. MONITORING AND MITIGATION METHODS

This chapter describes the marine mammal and sea turtle monitoring and mitigation measures implemented for UTIG'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 *Thompson*, 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 UTIG 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 *Thompson* source vessel throughout the seismic study.
- Visually monitor the occurrence and behavior of marine mammals and sea turtles near the GI guns during daytime whether the GI guns were operating or not.
- Record (insofar as possible), the effects of the GI gun operations and the resulting sounds on marine mammals and turtles.
- Use the monitoring data as a basis for implementing the required mitigation measures.
- Estimate the number of marine mammals potentially exposed to seismic sounds.

Safety and Potential Disturbance Radii

The "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 (see NMFS 2000). 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 (see Chapter 1). In this report, all frequencies are weighted equally (i.e., the levels are flat-weighted).

Radii within which received levels from the two GI guns were expected to diminish to various values (i.e., 190, 180, 170, and 160 dB re 1 μPa_{rms}) were estimated by Lamont-Doherty Earth Observatory (L-DEO; Table 3.1) and incorporated into the IHA (Appendix A). The 180-dB distance was used as the safety radius for cetaceans, and the 190-dB distance was used as the safety radius for pinnipeds; no sea turtles were seen during the seismic program. 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 ~3 m was used to estimate the safety radii for this cruise. Because the L-DEO model was based on a pair of larger GI guns with a total discharge volume of 210 in^3, the values in Table 3.1 overestimate the distances for the two GI guns with a discharge volume of 150 in^3 actually used during the survey.

TABLE 3.1. Distances to which sound levels ≥190, 180, 170, and 160 dB re 1 μPa_{rms} might be received from two 105 in^3 GI guns, operating in deep (>1000 m) and intermediate/slope (100–1000 m) waters. Distances are based on model results provided by L-DEO (see Appendix B and LGL Ltd. 2008).

			Predicted rms Radii (m)			
Source (Volume)	**Tow Depth (m)**	**Water Depth**	**190 dB**	**180 dB**	**170 dB**	**160 dB**
2 GI airguns		>1000 m	20	69	214	670
(210 in^3)	~2–3	100–1000 m	30	104	321	1005

Mitigation Measures as Implemented

The primary mitigation measures implemented during the present seismic study included ramp up and shut down of the GI guns. Because only two GI guns were used during the study, power downs were not included as a mitigation measure. These measures are standard procedures employed during 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 GI guns 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 to GI gun sounds, especially to the side of the track.
2. Safety radii implemented for the seismic study were based on acoustic modeling as well as empirical data from an acoustic calibration study conducted by L-DEO in the northern Gulf of Mexico in 2003 (Tolstoy et al. 2004a,b; see Appendix B).
3. Shut-down procedures were implemented when a marine mammal was sighted within or near the applicable safety radius while the GI guns were operating (no sea turtles were seen).
4. A change in vessel course and/or speed alteration was identified as a potential mitigation measure if a marine mammal was detected outside the safety radius and, based on its position and motion relative to the ship track, was judged likely to enter the safety radius. However, substantial alteration of vessel course or speed was not practical during the seismic study, given the design of the survey. Power downs or shut downs are the preferred and most practical mitigation measures when mammals or turtles are sighted within or about to enter the safety radii, although only shut downs were implemented during this particular survey.
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 other academic seismic cruises.
6. Ramp up could not proceed if marine mammals or sea turtles were known to be within the safety radius, or if there had been visual detection(s) inside the safety zone within the following periods: 15 min for mysticetes, sperm whales, and beaked whales, and 10 min for small odontocetes. (The period for sea turtles is based on the amount of time it would take the vessel to leave the turtle behind and outside of the safety radius).

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 *Thompson* were as follows: ***(1)*** Conduct monitoring and implement mitigation measures to avoid or minimize exposure of cetaceans and sea turtles to airgun sounds with received levels >180 dB re 1 μPa_{rms} and pinnipeds to received levels >190 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 are presented in Chapter 4.

During the present seismic study, at least one but at most times two MMOs maintained a visual watch for marine mammals and sea turtles during all daylight hours from dawn to dusk. Visual observations occurred from the *Thompson*'s bridge. Observers focused search effort forward of the vessel but also searched aft of the vessel while it was underway. Watches were conducted with the naked eye and Fujinon 7 × 50 reticle binoculars. Night-time visual watches occurred only during ~4% of observation effort during that survey. Appendix D provides further details regarding visual monitoring methods.

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 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 GI guns were operating, including ramp ups, and periods up to 90 s after the GI guns were shut off. Non-seismic included all data obtained before GI guns were turned on (pre-seismic) or >2 h after the GI guns were turned off. Data collected during post-seismic periods from 90 s to 2 h after cessation of seismic were considered “recently exposed” (90 s–2 h) to seismic. The “recently exposed” category was not included in either the “seismic” or “non-seismic” categories and was excluded from all analyses. The 2-h post-seismic cut-off is the same cut-off applied during L-DEO cruises that used a small GI gun configuration (e.g., 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 could be assumed that they had no effect on current behavior and distribution of animals. The rate of recovery toward “normal” during the post-seismic period is uncertain. Therefore, the post-seismic period was defined so as to be sufficiently long (2 h in the case of the small 2-GI airgun array) to ensure that any carry-over effects of exposure to the sounds from this configuration 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.

Effort and sightings during the transit to and from Seattle were combined with data from the actual survey grid, because the entire cruise occurred within the California Upwelling Coastal province

(Longhurst 2008). Thus, marine mammal habitat was expected to be similar off the coast of Washington and Oregon.

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 (#/1000 km^2) of marine mammals and turtles 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 both within the seismic survey area and during transit to and from that area, excluding post-seismic periods 90 s to 2 h after the GI guns were turned off, when ship speed was <3.7 km/h (2 kt), or when sightability was seriously impaired. 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 severe glare between 90º left and 90º right of the bow. Also, sightings outside of the truncation distance (used for density calculations) were considered non-useable. Although "non-useable" sightings (and associated survey effort) were not considered when calculating densities of marine mammals, such sightings were taken into account when determining the need for real-time mitigation measures.

Correction factors for missed cetaceans, i.e., *f*(0) and *g*(0), were taken from other related studies (e.g., 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 during non-seismic periods were used to estimate the numbers of animals that presumably would have been present in the absence of seismic activities. Densities during seismic periods were used to estimate the numbers of animals present near the seismic operation and exposed to various sound levels. The difference between the two estimates could be taken as an estimate of the number of animals that moved in response to the operating seismic vessel, or that changed their behavior sufficiently to affect their detectability to visual observers. Further details on the line-transect methodology used during the survey are provided in Appendix D.

Estimating Numbers of Marine Mammals Potentially Affected

For purposes of the IHA, NMFS assumes that any marine mammal that might have been exposed to GI gun 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 two GI guns 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. MARINE MAMMAL MONITORING RESULTS

Introduction

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

Status of Marine Mammals off Oregon

Thirty-two marine mammal species are known or expected to occur in the marine waters off Oregon and Washington, excluding extralimital sightings or strandings (Fiscus and Niggol 1965; Green et al. 1992, 1993; Mangels and Gerrodette 1994; Barlow 1997, 2003; Von Saunder and Barlow 1999; Barlow and Taylor 2001; Buchanan et al. 2001; Calambokidis and Barlow 2004; Calambokidis et al. 2004). These 32 species include 19 odontocetes (toothed cetaceans, such as dolphins), 7 mysticetes (baleen whales), 5 pinnipeds (seals and sea lions), and the sea otter. Six of the species that may occur in the project area are listed under the ESA as endangered, including the North Pacific right, humpback, sei, fin, blue, and sperm whales. In addition, the southern resident killer whale stock (listed as endangered), the threatened Steller sea lion, and the threatened northern sea otter are known to occur in the NEPO, but are unlikely to occur in offshore waters. Appendix E summarizes the abundance, habitat, and conservation status of the marine mammal species known to occur in the area.

Monitoring Effort and Sighting Results

This section summarizes the monitoring effort and sightings from the *Thompson* during the NEPO survey, 30 June to 19 July 2008. Summaries of the monitoring results are presented below. Detailed data summaries presented in Appendix F, including visual survey effort subdivided by seismic activity, Bf, and water depth. A general summary of effort and sightings is shown in Table ES.1.

Visual Survey Effort

The *Thompson* traveled a total of ~3010 km during 459 h in the NEPO, and visual observations were obtained for a total of ~884 km or 160 h (Fig. 4.1; Table ES.1). Observations occurred during all daytime GI gun operations and most daytime periods when the vessel was underway but not firing the GI guns. Only 3 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, but typically occurred from sunrise to sunset. Two observers were on duty during most visual watches. About 73% of all visual effort (in km) occurred during seismic periods (Fig. 4.2). Survey conditions “useable” for estimating marine mammal densities in “non-seismic” and “seismic” conditions included 51% of total visual effort in km (Table ES.1). “Useable” effort excluded nighttime observations, periods 90 s to 2 h after GI guns were turned off, poor visibility conditions (visibility <3.5 km or extensive glare), Bf >5, and ship speed <3.7 km/h (2 kt). Also, sightings outside of the truncation distance (used to determine densities) were considered non-useable. Bf during observations ranged from zero to seven; the majority of “useable” observations occurred during Bf 4 (Fig. 4.3; Appendix F). Sightings and survey effort during “non-useable” conditions were excluded when calculating mammal densities, but were used to determine when shut downs were necessary.

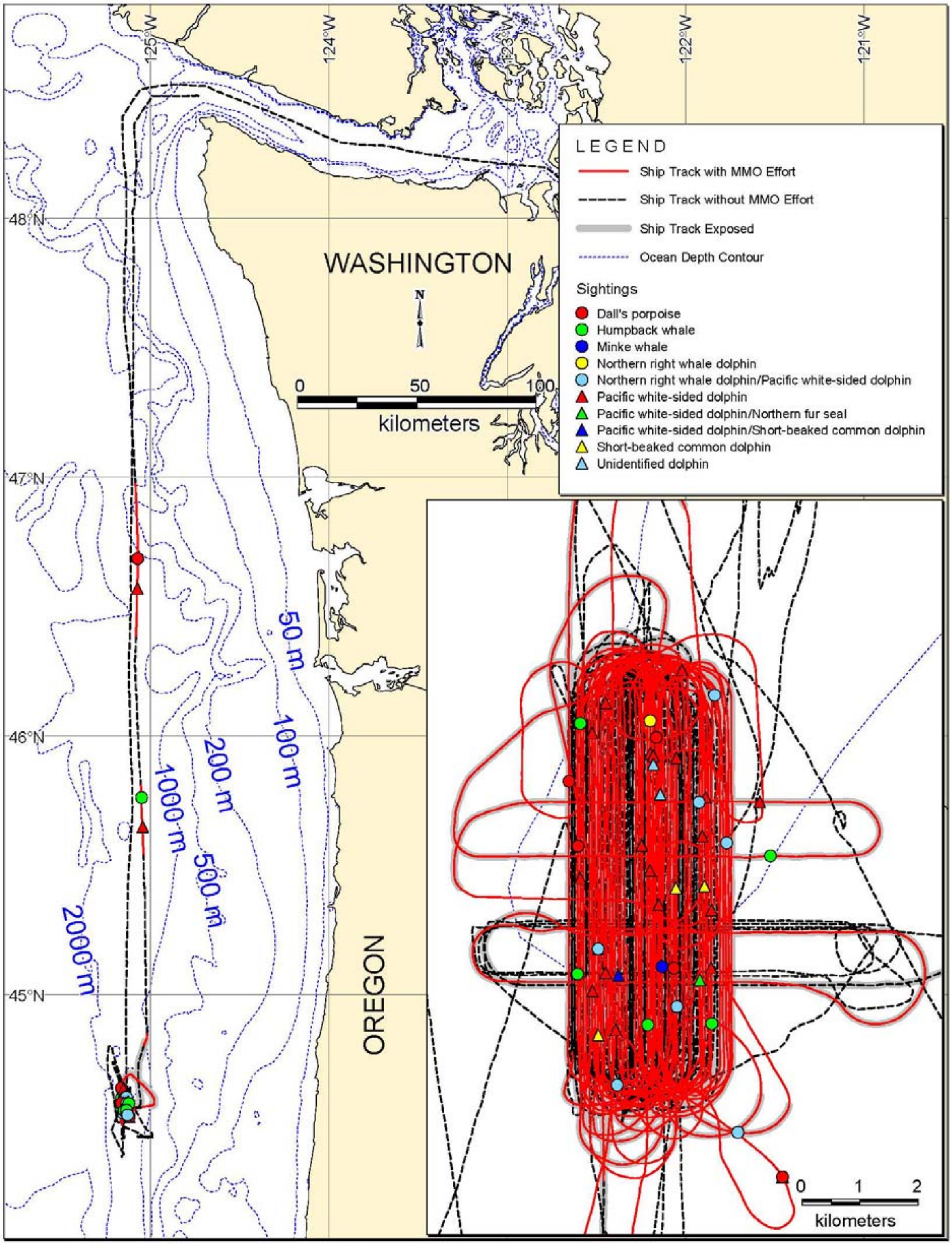

FIGURE 4.1. The NEPO study area showing the ship tracks, seismic lines, and sightings of marine mammals, 30 June to 19 July 2008.

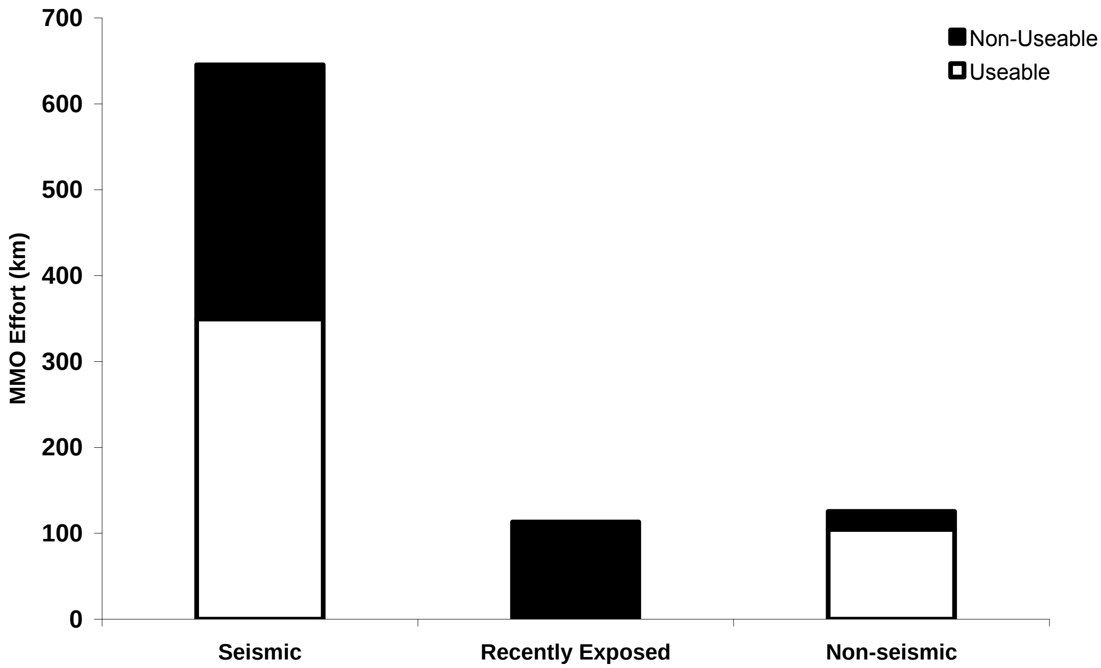

FIGURE 4.2. Total observer effort, categorized by seismic activity, during operations of the *Thompson* in the NEPO, 30 June to 19 July 2008. Recently exposed = exposed within 90 s to 2 h after seismic.

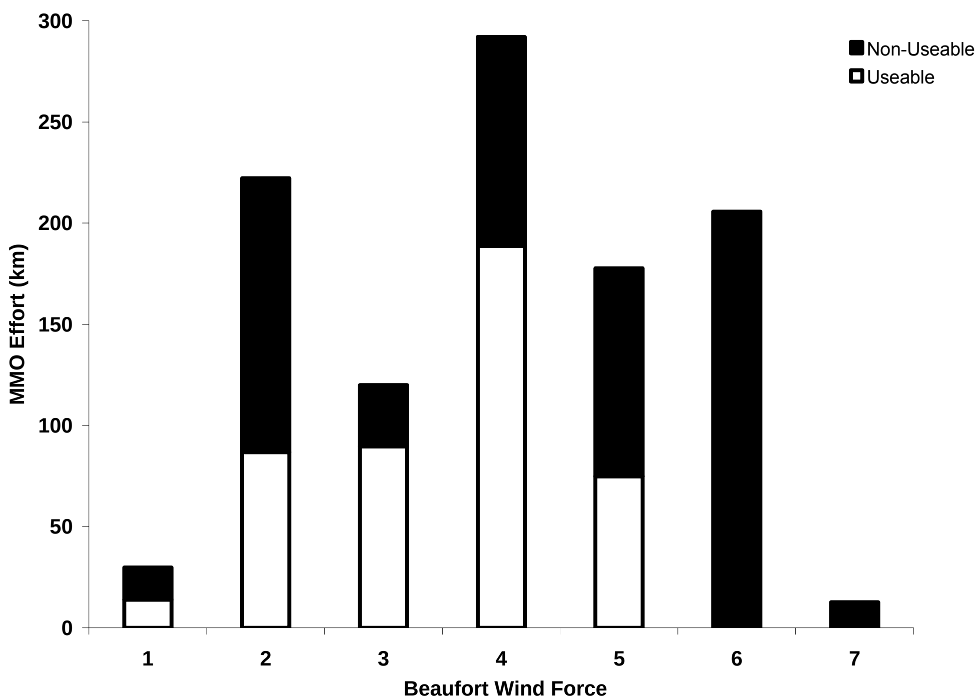

FIGURE 4.3. Total observer effort, categorized by Beaufort wind force, during operations of the *Thompson* in the NEPO, 30 June to 19 July 2008.

Sightings of Marine Mammals

Numbers of Marine Mammals Observed

A total of 53 groups of ~5390 marine mammals were sighted during the NEPO survey. Seven species were identified: one pinniped species (northern fur seal), two mysticete species (humpback and minke whales), and four odontocete species (Pacific white-sided, short-beaked common, and northern right whale dolphins and Dall's porpoise) (Table 4.1). The Pacific white-sided dolphin was by far the most frequently sighted species (n = 32 sightings including 23 single-species groups plus 9 mixed-species sightings), followed by Dall's porpoise (n = 8 groups), and humpback whales (n = 6 groups). Ten of the 53 sightings were mixed-species groups, most (n = 8) of which were Pacific white-sided with northern right whale dolphins; another mixed-species group consisted of an aggregation of Pacific white-sided, short-beaked common, and northern right whale dolphins, and another one consisted of one northern fur seal with ~100 Pacific white-sided dolphins (Table 4.1, Appendix F).

The majority of the sightings (60% or 32 groups totaling ~4855 individuals) occurred during "useable" observation effort (Table 4.1). Only "useable" sightings, along with the corresponding useable effort data, are considered in the ensuing analyses of behavior, detection rates, and densities of marine mammals. Although the northern fur seal/Pacific white-sided dolphin group was considered a single sighting, behavioral data and densities are presented separately for those two species.

Sightings by Seismic State

During the survey, there was ~3.5 times more useable effort during seismic (350 km) than during non-seismic periods (104 km) (Table ES.1). Of the 32 useable sightings, about nine times more were recorded during seismic operations (n = 29) compared with non-seismic periods (n = 3). Twenty-one shut downs were required due to marine mammals being sighted within or near the 180-dB re 1 μPa_{rms} safety radius around the operating GI guns. Further details on these encounters are provided later in this chapter (see Table 4.3 under *Mitigation Measures Implemented*).

Detection Rates

The detection rate (# groups sighted per 1000 km of "useable" effort) was ~3 times greater with GI guns on (83 groups/1000 km, n = 29) compared with GI guns off (29 groups/1000 km, n = 3). This 3:1 ratio is similar to that of useable effort during seismic (350 km) vs. non-seismic periods (104 km). Detection rates were highest during Bf 3 and Bf 5; however, nearly twice as much useable effort occurred during Bf 4 than during Bf 3 or Bf 5 (Fig. 4.4; Appendix F). During marine mammal surveys, detection rates are typically related to sea state and wind speed, i.e., Bf, and rougher sea conditions make it more difficult for observers to detect animals particularly as distance increases (e.g., Buckland et al. 2001).

Other Vessels

One large container ship passed within ~2.8 km of the *Thompson* while a group of seven Pacific white-sided dolphins was surface-active within 100 m of the *Thompson,* 12 min after the GI guns had been shut down for the sighting. No change in behavior was observed among the dolphins while the ship passed by. The dolphins remained near the *Thompson* for another 65 min (while the GI guns were shut down) continuing their surface-active behavior.

TABLE 4.1. Numbers of marine mammals observed from the *Thompson* in the NEPO, 30 June to 19 July 2008.

	Seismic		Recently Exposed		Non-seismic		Total	
Species	**Groups**	**Individuals**	**Groups**	**Individuals**	**Groups**	**Individuals**	**Groups**	**Individuals**
All Sightings								
Humpback whale	4	8	1	1	1	2	6	11
Minke whale	1	1	0	0	0	0	1	1
Northern right whale dolphin	0	0	1	20	0	0	1	20
Pacific white-sided dolphin	17	594	3	36	3	28	23	658
Short-beaked common dolphin	2	26	1	120	0	0	3	146
Mixed dolphin groups[b]	9	4400	1	1	0	0	10	4401
Dall's porpoise	6	35	1	10	1	8	8	53
Pacific white-sided dolphin/ Northern fur seal	1	100	0	0	0	0	1	100
Total	***40***	***5164***	***8***	***188***	***5***	***38***	***53***	***5390***
Useable Sightings [a]								
Humpback whale	3	6	-	-	1	2	4	8
Minke whale	1	1	-	-	0	0	1	1
Northern right whale dolphin	0	0	-	-	0	0	0	0
Pacific white-sided dolphin	10	472	-	-	1	18	11	490
Short-beaked common dolphin	2	26	-	-	0	0	2	26
Mixed dolphin groups[b]	8	4200	-	-	0	0	8	4200
Dall's porpoise	4	22	-	-	1	8	5	30
Pacific white-sided dolphin/ Northern fur seal	1	100	-	-	0	0	1	100
Total	***29***	***4827***			***3***	***28***	***32***	***4855***

[a] Useable sightings are those made during useable daytime periods of visual observations,as defined in Acronyms and Abbreviations, and exclude sightings during recently-exposed (90 s to 2 h after seismic) periods.
[b] Mixed dolphin groups include Pacific white-sided dolphins plus northern right whale dolphins and/or short-beaked common dolphins.

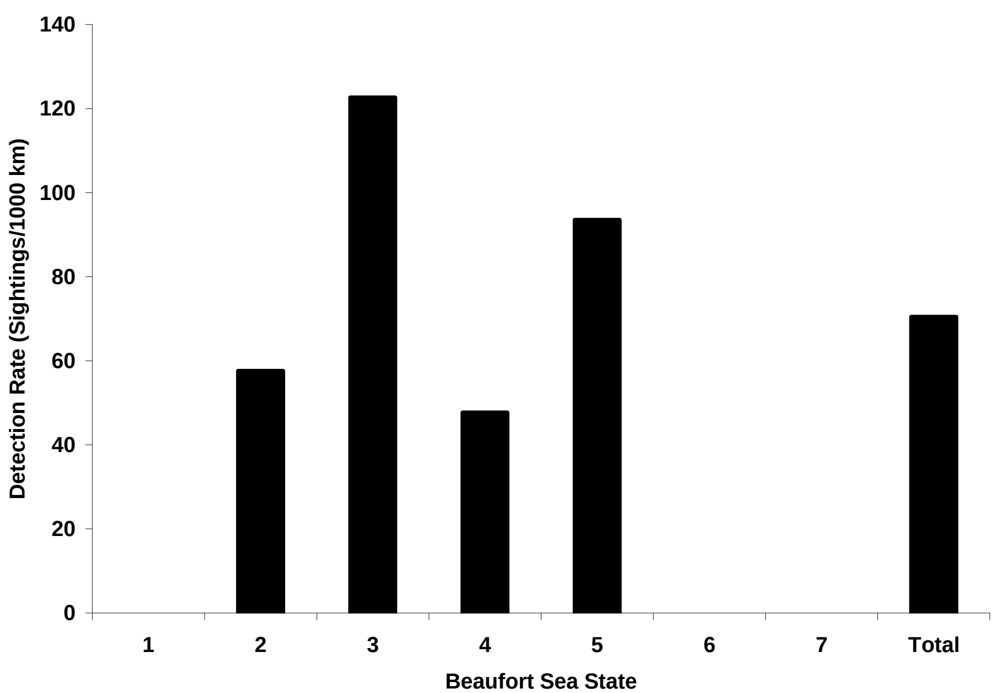

FIGURE 4.4. Marine mammal detection rates (based on useable sightings and effort) from the *Thompson* in the NEPO during different Beaufort Wind Force conditions, 30 June to 19 July 2008.

Distribution and Behavior

Data collected during visual observations provide information about behavioral responses of marine mammals to the seismic survey. The relevant data collected from the *Thompson* include the closest observed point of approach (CPA) to the GI guns, movement relative to the vessel, and behavior of animals at the time of the initial sighting. However, the relatively small number of sightings made during useable non-seismic periods (*n* = 3) compared with seismic periods (*n* = 29) limits meaningful comparisons. In addition, marine mammal behavior is difficult to observe, especially from a seismic vessel, because individuals and/or groups are often at the surface only briefly, there may be avoidance behavior, and the seismic vessel stays on course and does not follow sightings. This causes difficulties in resighting those animals, and in determining whether two sightings some minutes apart are repeat sightings of the same individual(s).

The position of MMOs on the vessel, and where they focused their observation efforts, yielded a distribution of animal sightings relative to the *Thompson* that was skewed towards the front of the vessel. Nearly all sightings were of animals located in the forward 180° relative to the orientation of the vessel.

Closest Point of Approach

The mean CPA calculations are based on very small sample sizes, particularly for non-seismic periods (*n* = 3; Table 4.2). In addition, the mean CPA during seismic periods has the potential to be underestimated if some animals avoided the GI guns at distances beyond those where they could be detected by MMOs. For delphinids, the average CPA during seismic was 757 m (*n* = 21 sightings) compared with a CPA of 1218 m for one delphinid group seen during non-seismic (Table 4.2). For the five Dall's porpoise sightings, the mean CPA was 1161 m compared with 354 m for the one porpoise group seen during non-seismic (Table 4.2). The mean CPA during seismic for the four mysticete whale sightings was 1950 compared with the CPA (3359 m) of the single whale that was sighted during non-seismic (Table 4.2). The one northern fur seal sighted during the survey had a CPA of 80 m to the operating GI guns (Table 4.2)

TABLE 4.2. Closest observed points of approach (CPA) of marine mammals to the GI guns during non-seismic and seismic periods in the NEPO, 30 June to 19 July 2008. s.d. = standard deviation.

		Non-seismic				Seismic			
Group	**No. of Groups[a]**	**Mean CPA (m)**	**s.d.**	***n***	**Range (m)**	**Mean CPA (m)**	**s.d.**	***n***	**Range (m)**
Delphinids	22	1218	-	*1*	-	757	1130	*21*	(1 - 4000)
Porpoises	5	354	-	*1*	-	1161	1530	*4*	(73 - 3359)
Mysticetes	5	3359	-	*1*	-	1950	1580	*4*	(335 - 3306)
Pinnipeds	1	-	-	*0*	-	80	-	*1*	-

[a] Initial useable sightings made during useable visual effort. Total no. of groups equals 33, as data for the pinniped are shown separately from the mixed group it was seen in.

First Observed Behavior

During seismic periods, the most common observed first behavior for delphinids (*n* = 21 groups) was recorded as surface-activity, primarily surface-active travel (Fig. 4.5a). Similarly, Dall's porpoises (*n* = 4) were most often seen to be surface-active and/or traveling during seismic periods (Fig. 4.5a), as were mysticete whales (*n* = 4) (Fig. 4.5b). Other behaviors were rarely observed for any of the cetacean groups (Fig. 4.5; Appendix F). The northern fur seal was seen in association with a surface-active traveling group of dolphins during seismic operation. There were only three sightings during non-seismic periods (Fig. 4.5), so comparisons between seismic and non-seismic periods would not be meaningful.

Movement

For delphinids recorded during seismic periods, the most common movement categories relative to the vessel were recorded as swimming toward the vessel followed by swimming parallel to or across the vessel path (Fig. 4.6a; Appendix F). Nearly all instances of delphinids swimming toward the vessel while GI guns were operating resulted in a shut down of the GI guns (see Table 4.3 under *Mitigation Measures Implemented*). The one dolphin group seen during non-seismic was milling near the vessel (Fig. 4.6a). Dall's porpoise groups seen during seismic either approached the vessel (*n* = 2) or swam parallel to the vessel path (*n* = 1); the movement relative to the vessel of one other group seen during seismic could not be determined. The only group of Dall's porpoises seen during non-seismic was swimming across the vessel path (Fig. 4.6a). Most of the whale groups sighted during seismic (3 of 4 groups) were swimming across the vessel path; the one whale group seen during the non-seismic period was milling (Fig. 4.6b; Appendix F). The northern fur seal was swimming toward the vessel during seismic operations.

Distribution

As indicated by Figure 4.1, most effort (15 of the total 19 survey days) consisted of repeated observation effort along the same survey lines within the survey grid. As such, it is likely that some of the sightings were repeat sightings (see *Estimated Number of Marine Mammals Potentially Affected*). Of 53 sightings during the cruise, 49 were made within the actual survey grid off the coast of Oregon. Four sightings occurred during the transit from Seattle to the survey grid, including one sighting each of Dall's porpoises and Pacific white-sided dolphins off Washington, and one sighting each of humpback whales and Pacific white-sided dolphins off Oregon (Fig. 4.1). Most sightings (*n* = 43 or 81%) were made in water 100–1000 m deep where ~80% of all observation effort occurred; all these sightings were in waters 775–975 m deep (Fig. 4.1; Appendix F). The remaining 10 sightings (19%) occurred in water 1000–1620 m deep, where ~20% of the survey effort occurred (Fig. 4.1). The one minke whale was seen in water ~794 m deep, and the northern fur seal was seen ~75 km offshore in water 857 m deep. All short-beaked common dolphins were seen in water <1000 m deep (~790–925 m). Pacific right-sided dolphins, northern right whale dolphins, Dall's porpoises, and humpback whales were seen in both intermediate and deep water-depth categories (Fig. 4.1).

Mitigation Measures Implemented

Only ramp ups and shut downs of the two GI guns were implemented as mitigation measures during the NEPO cruise. Ramp ups were conducted whenever the GI guns were started up after >4 min of inactivity. At night, the small safety radius (Table 3.1) was presumed to be visible to MMOs based on data from L-DEO surveys where light and/or night vision goggles enhanced visibility ~100−250 m from the vessel (e.g., Smultea and Holst 2003; Holst 2004; Smultea et al. 2004; MacLean and Koski 2005).

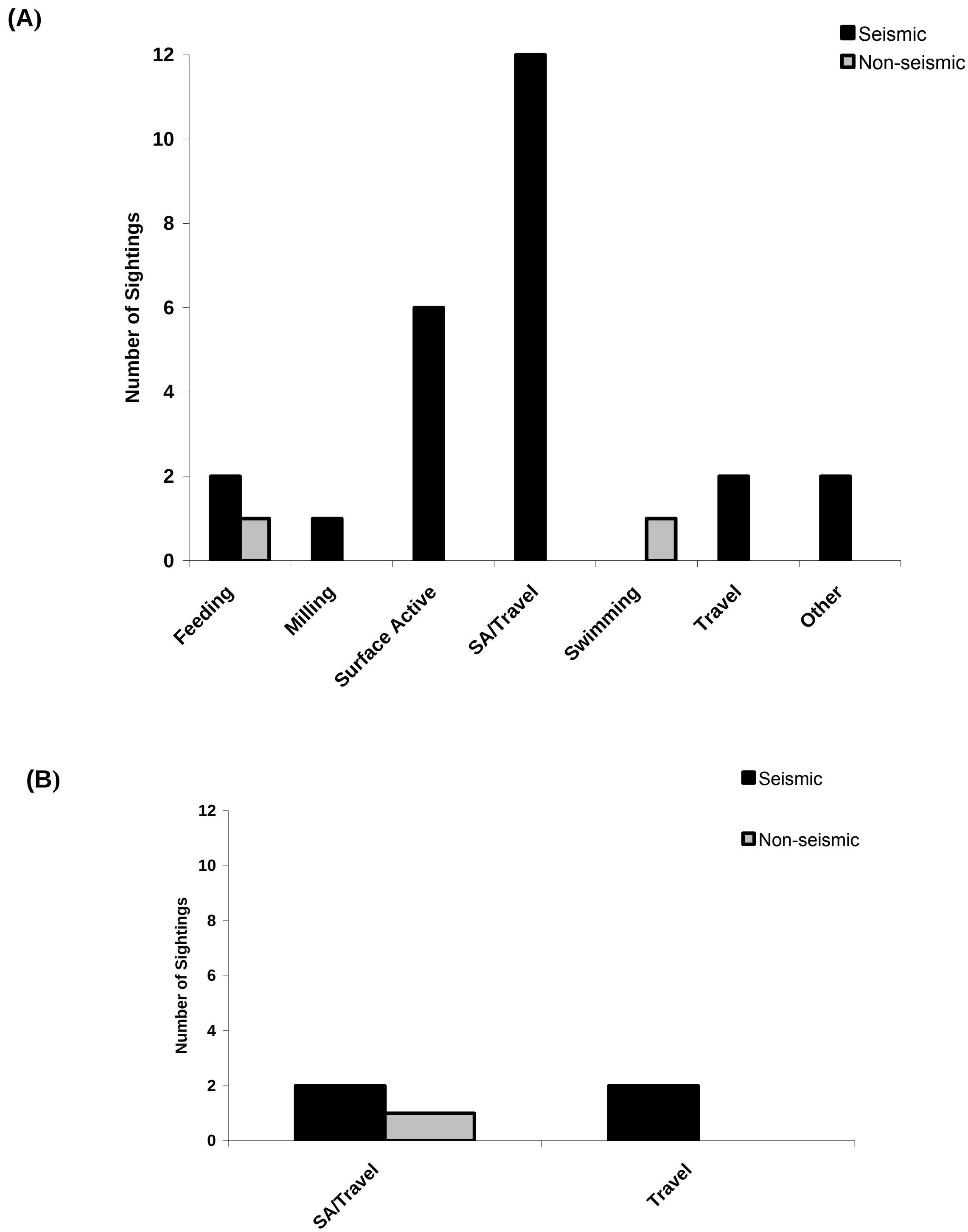

FIGURE 4.5. First observed behavior of "useable" (A) dolphins and Dall's porpoises and (B) mysticetes sighted from the *Thompson* in the NEPO, 30 June to 19 July 2008. SA = surface active.

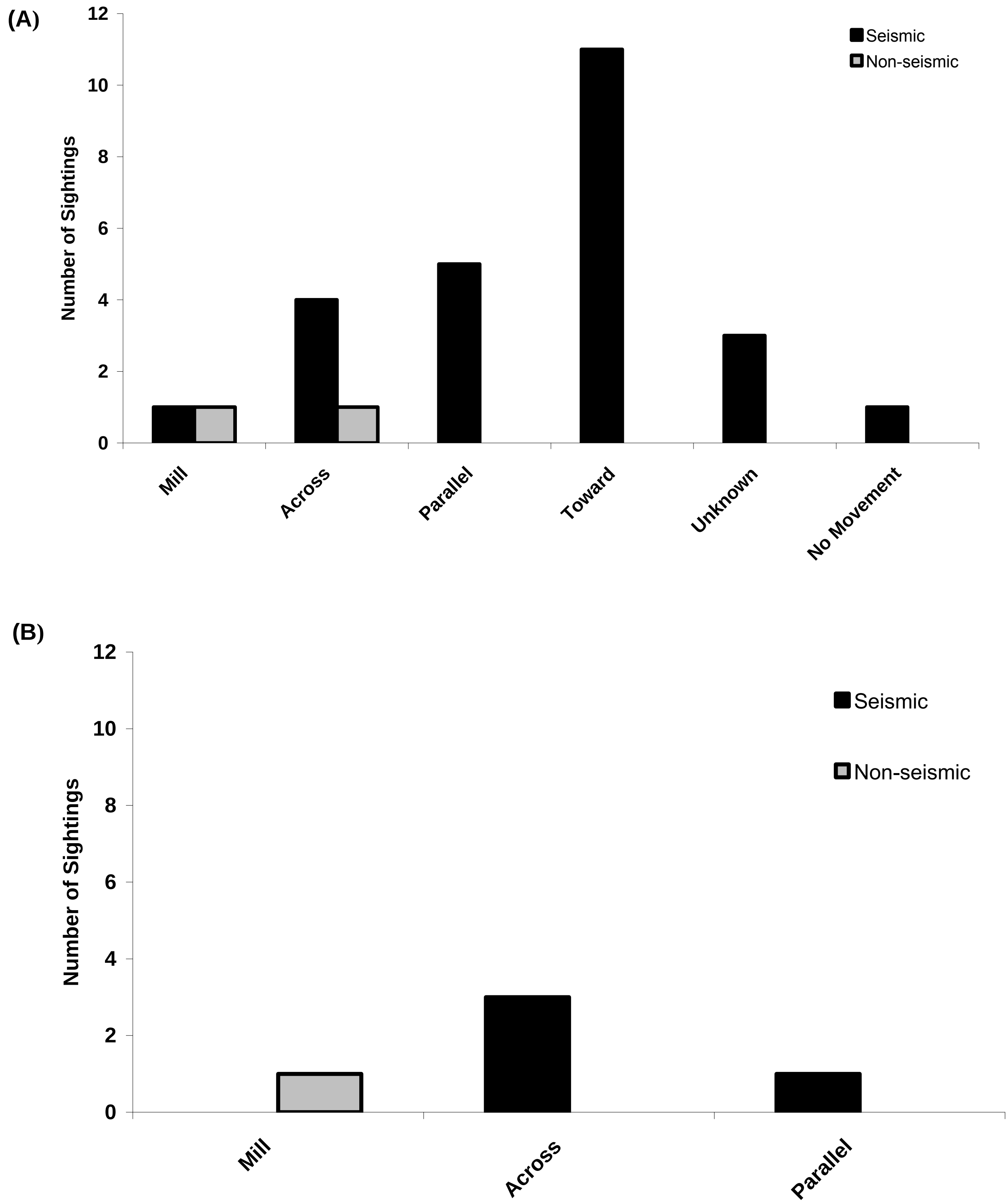

FIGURE 4.6. Movement categories for "useable" **(A)** dolphins and Dall's porpoises and **(B)** mysticete whale sightings from the *Thompson* in the NEPO, 30 June to 19 July 2008.

TABLE 4.3. List of shut downs of the GI guns implemented for marine mammals sighted in or near the safety radii during the NEPO survey, 30 June to 19 July 2008.

Species	Group Size	Date	Water Depth (m)	Movement[a]	First Behavior Observed[b]	Second Behavior Observed[b]	No. of GI Guns On Prior to SZ	Approx. 180-dB Radius (m)	Initial Sighting Distance From MMO	CPA[c] (m)	Estimated Received Sound Exposure (dB re 1 μPa_{rms})
Pacific white-sided dolphin	80	04/07/2008	912	SP	WR	UN	2	104	10	10	180 dB
Pacific white-sided dolphin	20	05/07/2008	874	SP	TR	TR	2	104	30	80	180 dB
Dall's porpoise	5	05/07/2008	846	ST	TR	UN	2	104	2000	73	180 dB
Northern right whale dolphin/Pacific white-sided dolphin	500	06/07/2008	960	ST	FG	SA	2	104	1519	1553	<160 dB
Northern right whale dolphin/Pacific white-sided dolphin	200	06/07/2008	851	ST	SA	UN	2	104	80	141	170 dB
Pacific white-sided dolphin	7	06/07/2008	976	SP	SA	UN	2	104	100	161	170 dB
Pacific white-sided dolphin	7	07/07/2008	1025	SP	ST	UN	2	69	80	105	170 dB
Pacific white-sided dolphin	4	12/07/2008	820	PE	ST	MI	2	104	110	58	180 dB
Pacific white-sided dolphin	5	12/07/2008	795	PE	MI	ST	2	104	60	1	190 dB
Northern right whale dolphin/Pacific white-sided dolphin	200	12/07/2008	966	SP	ST	TR	2	104	80	117	170 dB
Pacific white-sided dolphin	2	12/07/2008	878	SP	MI	ST	2	104	80	136	170 dB
Dall's porpoise	10	13/07/2008	913	SP	PO	UN	2	104	50	107	170 dB
Pacific white-sided dolphin/Northern fur seal	100	15/07/2008	857	ST	ST	SA	2	104	80	80	180 dB
Pacific white-sided dolphin	10	16/07/2008	835	ST	SA	ST	2	104	60	117	170 dB
Northern right whale dolphin/Pacific white-sided dolphin	400	16/07/2008	871	ST	ST	SA	2	104	343	70	180 dB
Pacific white-sided dolphin [d]	50	17/07/2008	820	UN	OT	OT	2	104	10	10	190 dB
Pacific white-sided dolphin [d]	6	17/07/2008	988	ST	SA	UN	1	104	100	10	190 dB
Northern right whale dolphin/Pacific white-sided dolphin	200	17/07/2008	880	ST	ST	SA	2	104	110	80	180 dB
Pacific white-sided dolphin [e]	15	17/07/2008	867	PE	ST	UN	2	104	533	503	160 dB
Northern right whale dolphin/Pacific white-sided dolphin	1500	17/07/2008	890	ST	ST	UN	2	104	10	62	180 dB
Northern right whale dolphin/Pacific white-sided dolphin	300	18/07/2008	1065	ST	SA	UN	2	69	1201	1232	<160 dB

[a] Initial movement of animal(s) relative to the vessel: SP = swimming parallel to the vessel track, ST = swimming toward the vessel, PE = swimming perpendicular or across vessel track, NO = no movement relative to the vessel, UN = unknown.

[b] Behavior: WR = wakeriding; TR = traveling; FG = feeding; SA = surface active; ST = surface active/traveling; MI = milling; PO = porpoising; OT = other; UN = unknown.

[c] The closest point of (observed) approach (CPA) of the animal(s) to the GI guns before mitigation was implemented.

[d] The 50 dolphins were initially seen in an aggregation of 700 mixed dolphins consisting of Pacific white-sided, short-beaked common and northern right whale dolphins. A smaller sub-group of Pacific white-sided dolphins from this aggregation was seen later, requiring a second shut down for the same sighting.

[e] Later seen in a mixed group of 400 Pacific white-sided and northern right whale dolphins.

Twenty-one shut downs occurred for a total of 3621 marine mammals seen within the safety radius (Table 4.3). Of those 21 shut downs, eight occurred for mixed-species groups. Only 11 of the 21 groups for which a shut down was implemented were in the safety zone when first observed and had presumably been exposed to strong GI gun pulses before the initial sighting. Thus, these 11 groups consisting of 2370 individuals were very likely exposed to GI gun sounds with received levels ≥180 dB re 1 μPa_{rms} and (in three cases) ≥190 dB re 1 μPa_{rms} for some of the GI gun shots prior to the shut down (Table 4.3). Only one or a few shots were fired between the initial detection and the time when the GI guns were shut down. This assumes that the animals, while inside the safety radius, were well below the surface when one or more of the GI gun pulses were received.

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 marine mammal that might have been exposed to GI gun 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 UTIG. 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, Dall's porpoises, or most pinnipeds. The hearing of small odontocetes is relatively insensitive to low frequencies, and behavioral reactions of small odontocetes and pinnipeds to airgun sounds indicate that they are usually less responsive than are some baleen whales (Richardson et al. 1995; Gordon et al. 2004; Southall et al. 2007). Probable exposure to rms received levels ≥170 dB was used as an alternative criterion in estimating potential disturbance of delphinids, Dall's porpoise, and the northern fur seal.

Table 3.1 shows the predicted received sound levels at various distances from the GI guns deployed from the *Thompson*. The ≥160-dB radius is an assumed behavioral disturbance criterion. The ≥180 dB- and ≥190-dB distances are the safety radii for cetaceans and pinnipeds, respectively, used in determining when mitigation measures are required. During this project, NMFS required that mitigation measures be applied to avoid, or minimize, the exposure of cetaceans (and sea turtles) to impulse sounds with received levels ≥180 dB re 1 μPa_{rms}. During this study, several shut downs were required (as described above) due to marine mammals being sighted within or near the applicable safety radii around the operating GI guns. 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 180-dB distances.

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 a disturbance or other potential impacts.

The procedures include ***(A)*** minimum estimates based on marine mammals observed by MMOs during the survey, 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 were likely 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 for this project (LGL Ltd. 2008) 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 *Thompson* during the seismic study provides a minimum estimate of the number potentially affected by seismic sounds. This likely underestimates the actual number potentially affected. Some animals may have 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 cannot be seen 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. Furthermore, marine mammals cannot be seen effectively during periods of darkness. However, a very limited amount (~3 h) of survey effort occurred at night.

Cetaceans Potentially Exposed to Sounds ≥180 dB re 1 μPa$_{rms}$.—During the NEPO survey, 21 marine mammal groups totaling 3621 individuals were sighted within or near the safety radius around the GI guns; a shut down was implemented on each of those occasions (Table 4.3). The sound levels received by 11 of the 21 marine mammal groups (2370 individuals) likely exceeded 180 dB prior to mitigation (Table 4.3). These 11 groups consisted mostly of dolphins, but also included one group of 5 Dall's porpoises and one northern fur seal (Table 4.3)

The estimated 180-dB radii are the *maximum* distances from the GI guns 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 GI guns) 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 bow- or wake-riding dolphins observed at or near the surface for extended periods, the received airgun sounds are reduced relative to levels at deeper depths. However, dolphins observed bow- or wake-riding may be at depth for portions of the time while within the safety radius.
- 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.
- Visual observations occurred from the bridge forward of the GI guns. The nominal safety zone was not centered on the bridge, but rather on the center of the GI guns. This difference was accounted for in the observer's decisions regarding whether it was necessary to shut down the GI guns for sightings immediately forward or astern.

GI gun 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 this project, ~30% of the GI gun 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 at least 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, ~45% of daytime observation effort during seismic occurred during periods of poor visibility.

Cetaceans Potentially Exposed to Sounds ≥160 dB re 1 μPa$_{rms}$.—Fifty-three sightings totaling ~5390 marine mammals were made during the NEPO cruise (Table 4.1; Appendix F). Of these, 31 groups of 3920 individuals (mostly dolphins) were seen within the ≥160-dB radius of the operating GI gun(s), including 24 groups of dolphins, four groups of 21 Dall's porpoises, one northern fur seal (in association with a dolphin group), one minke whale, and two groups of four humpback whales. However, most dolphins, Dall's porpoises, and pinnipeds exposed to received levels of ~160–170 dB re 1 μPa$_{rms}$ may not have been disturbed significantly, as discussed below. Additional marine mammals would be exposed during GI gun operations at night and in periods of poor visibility. However, the additional number of baleen whales that might have been exposed during the night would have been small. Missed animals are accounted for in estimates presented later in this section based on densities of animals during "useable" seismic and non-seismic periods.

Dolphins, Dall's Porpoises and Pinnipeds Potentially Exposed to Sounds ≥170 dB 1 μPa$_{rms}$.— For delphinids, Dall's porpoises, and most pinnipeds, 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. Of the 28 groups of dolphins, porpoises, and pinnipeds exposed to received levels >160 dB re 1 μPa$_{rms}$, 24 groups were exposed to levels ≥170 dB re 1 μPa$_{rm}$. The 24 groups included 21 groups of 3463 dolphins, three groups of 18 Dall's porpoises, and one northern fur seal. There would be additional exposures at night and in periods of poor visibility.

Estimates Extrapolated from Marine Mammal Density

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

The corrected densities were used to estimate the number of marine mammal exposures to ≥160 dB, ≥170 dB, and ≥180 dB, and the number of different individuals exposed. These numbers provide estimates of the number of animals potentially affected by seismic operations, as described in Chapter 3 and Appendix D.

Table 4.4 summarizes the estimated numbers of marine mammals exposed to airgun sounds with received levels ≥160 dB and ≥170 dB re 1 μPa$_{rms}$ relative to the number of "takes" requested in the IHA

TABLE 4.4. Numbers potentially disturbed in the NEPO: Estimated numbers of exposures and minimum number of individual marine mammals exposed to GI gun sounds with flat-weighted received levels ≥160 dB re 1 μPa$_{rms}$ (and ≥170 dB for delphinids, Dall's porpoises, and pinnipeds) based on observed densities during non-seismic and seismic periods, 30 June–19 July 2008 (see Appendix G). Also shown is the "harassment take" authorized by NMFS under the IHA. Species in italics are listed under the ESA as endangered.

	Estimated numbers that may have been exposed to ≥160 dB re 1 μPa (rms) (and ≥170 dB) based on observations during **non-seismic** periods [1]				Estimated numbers that may have been exposed to ≥160 dB re 1 μPa (rms) (and ≥170 dB) based on observations during **seismic** periods [1]				**Requested / Authorized Take** [2]
	Exposures		**Individuals**		**Exposures**		**Individuals**		
Odontocetes									
Delphinidae									
Pacific white-sided dolphin	24	(8)	6	(3)	2394	(703)	182	(82)	**6**
Northern right whale dolphin	0	()	0	()	1131	(333)	90	(41)	**5**
Bottlenose dolphin	0	()	0	()	0	()	0	()	**0**
Striped dolphin	0	()	0	()	0	()	0	()	**0**
Short-beaked common dolphin	0	()	0	()	366	(107)	24	(11)	**7**
Risso's dolphin	0	()	0	()	0	()	0	()	**3**
Unidentified dolphin	0	()	0	()	351	(103)	23	(10)	
False killer whale	0	()	0	()	0	()	0	()	**0**
Killer whale	0	()	0	()	0	()	0	()	**1**
Short-finned pilot whale	0	()	0	()	0	()	0	()	**0**
Total Delphinidae	**24**	**(8)**	**6**	**(3)**	**4242**	**(1245)**	**319**	**(144)**	
Physeteridae									
Sperm whale	*0*		*0*		*0*		*0*		***8/2***
Dwarf/Pygmy sperm whale	0		0		0		0		**1**
Ziphiidae									
Cuvier's beaked whale	0		0		0		0		**0**
Baird's beaked whale	0		0		0		0		**2**
Blainville's beaked whale	0		0		0		0		**0**
Blainville's beaked whale	0		0		0		0		**0**
Hubb's beaked whale	0		0		0		0		**0**
Stejneger's beaked whale	0		0		0		0		**0**
Phocoenidae									
Dall's porpoise	450	(131)	29	(13)	128	(39)	23	(11)	**47**
Harbor porpoise	0		0		0		0		**0**
Mysticetes									
North Pacific right whale	*0*		*0*		*0*		*0*		***0***
Humpback whale	*4*		*1*		*14*		*1*		***2***
Minke whale	0		0		1		0		**0/1**
Sei whale	*0*		*0*		*0*		*0*		***1/0***
Fin whale	*0*		*0*		*0*		*0*		***1***
Blue whale	*0*		*0*		*0*		*0*		***1***
Total Mysticetes	**4**		**1**		**15**		**1**		
Total Cetaceans	**478**		**36**		**4385**		**343**		
Pinnipeds									
Northern fur seal	0	()	0	()	5	(1)	3	()	**19**
California sea lion	0	()	0	()	0	()	0	()	**0**
Steller sea lion	*0*	*()*	*0*	*()*	*0*	*()*	*0*	*()*	***0/1***
Harbor seal	0	()	0	()	0	()	0	()	**0**
Northern elephant seal	0	()	0	()	0	()	0	()	**0**

[1] Survey effort, numbers of sightings and densities on which these estimates are based are provided in Appendix G.

[2] The requested take was the same as the authorized take, except where indicated otherwise.

Application for the 2008 NEPO survey. A similar summary of estimated marine mammal exposures to GI gun sounds with received levels ≥180 dB is provided in Table 4.5. The data used to calculate these numbers, for non-seismic as well as seismic periods, are presented in Appendix G for the relevant received level criteria.

***Estimated Numbers of Cetaceans Exposed to ≥160 or ≥170 dB*.—**For all types of marine mammals, Table 4.4 shows numbers estimated to be exposed to ≥160 dB re 1 μPa_{rms}; the table also shows estimated numbers of delphinids, Dall's porpoise, and pinnipeds exposed to ≥170 dB. It is assumed that large non-delphinid cetaceans such as 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 delphinids, Dall's porpoise, and pinnipeds are unlikely to be disturbed appreciably unless exposed to received levels ≥170 dB, but we also estimate the (larger) numbers of delphinids, Dall's porpoise, and pinnipeds exposed to ≥160 dB. These are not considered to be "all-or-nothing" criteria; some individual mammals may react strongly at lower received levels, but others are unlikely to react strongly unless levels are substantially above 160 or 170 dB.

Estimates Based on Densities during Non-seismic Periods: "Corrected" estimates of the densities of marine mammals present during non-seismic periods are shown in Appendix G. These corrected densities were used to estimate the number of cetaceans that were exposed to ≥160 and ≥170 dB, and thus potentially disturbed by seismic operations (Table 4.4).

(A) 160 dB re 1 μPa_{rms}: We estimate that there would have been ~478 exposures of ~36 different individual cetaceans to ≥160 dB during the seismic survey if no cetaceans moved out of the ≥160-dB zone in response to the approaching airguns (Table 4.4). These estimates include four exposures of one humpback whale. 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 4.4.

(B) 170 dB re 1 μPa_{rms}: On average, delphinids, Dall's porpoises, and most pinnipeds may be disturbed only if exposed to received levels of airgun sounds ≥170 dB re 1 μPa_{rms}. If so, then the estimated number of exposures would be ~29% of the corresponding estimates for ≥160 dB, based on the proportionally smaller area exposed to ≥170 dB. Based on densities estimated from the NEPO survey during non-seismic periods, the estimated number of exposures to ≥170 dB was ~139 (131 Dall's porpoise and eight Pacific white-sided dolphins; Table 4.4). The number of individuals exposed to ≥170 dB (or that moved away before the received level reached 170 dB) is estimated as ~13 Dall's porpoise and three Pacific-white-sided dolphins or ~44% of the number of individual cetaceans exposed to ≥160 dB (Table 4.4).

Estimates Based on Densities during Seismic Periods: "Corrected" estimates of the densities of marine mammals present during seismic periods are given in Appendix G. These corrected densities were used to estimate the number of cetaceans that were exposed to ≥160 and ≥170 dB, and thus potentially disturbed by seismic operations (Table 4.4).

TABLE 4.5. Estimated numbers of exposures and estimated minimum numbers of individual marine mammals that were exposed to flat-weighted seismic sounds ≥180 dB re 1 μPa$_{rms}$. Based on densities calculated from sightings during seismic and non-seismic periods (see Appendix G).

	Seismic		Non-seismic	
Species / species group	**Exposures**	**Individuals**	**Exposures**	**Individuals**
Odontocetes				
Delphinidae				
Pacific white-sided dolphin	222	45	2	1
Northern right whale dolphin	105	22	0	0
Short-beaked common dolphin	34	6	0	0
Unidentified dolphin	32	6	0	0
Total Delphinidae	**393**	**79**	**0**	**1**
Phocoenidae				
Dall's porpoise	54	1	41	8
Mysticetes				
Humpback whale	*1*	*0*	0	0
Minke whale	0	0	0	0
Total Mysticetes	**1**	**0**	**0**	**0**
Total Cetaceans	**448**	**80**	**44**	**9**
Pinnipeds				
Northern fur seal	0	0	0	0

(A) 160 dB re 1 μPa$_{rms}$: Results from seismic periods indicate that an estimated 4390 exposures to levels ≥160 dB, totaling 346 individuals (mostly dolphins), may have occurred (Table 4.4). These estimates include 14 exposures of a single humpback whale, one exposure of a minke whale, and five exposures of three northern fur seals.

(B) 170 dB re 1 μPa$_{rms}$: On average, delphinids, Dall's porpoises, and most pinnipeds may be disturbed only if exposed to received levels of airgun sounds ≥170 dB re 1 μPa$_{rms}$. Results from seismic periods indicate that an estimated 1285 exposures to levels ≥160 dB, totaling ~155 marine mammals, may have occurred during the NEPO survey (Table 4.4). These estimates include 1245 exposures of 144 dolphins, 39 exposures of 11 Dall's porpoises, and 1 northern fur seal exposure.

Cetaceans Potentially Exposed to Sounds ≥180 dB.—Based on densities of marine mammals estimated from observations during seismic periods, ~407 cetacean exposures and 80 individuals would have been expected to occur within the 180-dB radius around the operating GI guns during the NEPO survey (Table 4.5). Based on densities during non-seismic periods, ~44 exposures of nine individual cetaceans would have been expected to occur within the 180-dB radius. These estimates are lower than those indicated by direct observations, because several large groups (up to 1500 individuals) of delphinids were spotted during seismic operations.

Summary of Exposure Estimates.—Estimates of the numbers of exposures to strong sounds are considered *maximum* estimates of the number of mammals exposed. In this method, repeated exposures of some of the same animals are counted separately, with no allowance for overlapping survey lines. This method, when based on densities during non-seismic periods, also assumes that no mammals move away before received sound levels reach the sound level in question. Based on densities during non-seismic periods, it was estimated that 478 exposures to received levels ≥160 dB re 1 μPa_{rms} involving 36 individuals may have occurred. Based on densities during seismic periods, 4390 exposures of 436 marine mammals were estimated.

The estimated exposures based on direct observations exceed the authorized takes for Pacific-white sided, short-beaked common, and northern right whale dolphins (as large aggregations were seen), as well as for the humpback whale. Similarly, the estimates of individuals exposed based on density data from seismic periods are greater than the "takes" estimated prior to the survey for Pacific white-sided, northern right whale, and short-beaked common dolphins as well as Dall's porpoise. Observed densities were generally higher than those expected in the survey area based on prior available data. The estimates based on actual observed density data during non-seismic periods are equal to or lower than the "harassment takes" that were estimated prior to the survey, based on number of individuals. Note that the estimates *do* include allowance for animals missed by 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 account for animals encountered during seismic operations at night.

Summary and Conclusions

The 2008 NEPO seismic program included 160 h of visual observation effort. In total, 53 groups of 5390 marine mammals were seen, including a single northern fur seal. Six cetacean species were identified: Pacific white-sided, short-beaked common, and northern right whale dolphins, Dall's porpoise, and humpback and minke whales. Most (32 of 53) sightings were of Pacific-white sided dolphins, nine of which were associated with other marine mammal species.

The analyses considered only "useable" survey effort totaling 72.5 h or 454 km and "useable" sightings (n = 32). Densities of marine mammals near the ship during seismic and non-seismic periods were difficult to compare, as only three sightings were made during non-seismic periods. The detection rate was ~3 times greater during seismic (83 groups/1000 km) compared with non-seismic periods (29/1000 km), corresponding to ~3.5 times greater useable effort with GI guns on vs. off (350 vs. 104 km, respectively).

Twenty-one shut downs occurred for marine mammal groups during the NEPO survey. However, only 11 groups totaling 2370 individuals were estimated to have been exposed to received sound levels ≥180 dB re 1 μPa_{rms} (flat-weighted) given that they were seen well within the safety radius. These exposures involved Pacific white-sided, short-beaked common, and northern right whale dolphins, as well as Dall's porpoise, and one northern fur seal.

All estimates of individuals exposed based on density data from non-seismic periods are at or below the "harassment takes" estimated prior to the survey. However, estimates based on density data from seismic periods are above this level for Pacific white-sided, short-beaked common, and northern right whale dolphins, as well as humpback whales.

5. ACKNOWLEDGEMENTS

The University of Texas Institute for Geophysics (UTIG) and the National Science Foundation (NSF) provided the funding for this survey and the associated marine mammal and sea turtle monitoring program. Lamont-Doherty Earth Observatory (L-DEO) also provided logistical support for the survey. We thank Meagan Cummings and Dr. John Diebold of L-DEO, Dr. William Lang and Holly Smith of NSF, and Dr. Nathan Bangs of UTIG for assistance during planning and preparation for the cruise. MH and William Cross were primarily responsible for preparing the IHA Application.

The crew on the seismic source vessel *Thompson* was supportive of the marine mammal monitoring and mitigation effort. The vessel-based fieldwork was made possible by the dedicated participation of three marine mammal observers: Michael Force (team leader), Sara Ashworth, and Kris Hartin.

Mark Fitzgerald of LGL helped develop and implement procedures to estimate numbers of cetaceans that might have been exposed to seismic sounds, assisted with processing and analyzing data, and produced the maps and figures. Dr. W. John Richardson, LGL's project director for the marine mammal monitoring, assisted at various stages during planning and fieldwork, and contributed to the draft report.

This work was conducted under an Incidental Harassment Authorization issued by the U.S. National Marine Fisheries Service (NMFS), Office of Protected Resources. We thank Ken Hollingshead, Jolie Harrison, Howard Goldstein, and others of NMFS for processing the application, addressing the various agency and public comments, and working with L-DEO to define the monitoring and mitigation requirements for this project. We also thank Meagan Cummings of L-DEO for reviewing a draft of this report.

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APPENDIX A:[3]

INCIDENTAL HARASSMENT AUTHORIZATION ISSUED TO UTIG FOR THE SEISMIC STUDY IN THE NORTHEAST PACIFIC OCEAN

DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NATIONAL MARINE FISHERIES SERVICE

Incidental Harassment Authorization

University of Texas, Institute for Geophysics, 10100 Burnet Road, Austin, TX 78758, 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 low-energy seismic survey conducted by the *R/V Thomas G. Thompson* in the northeastern Pacific Ocean, June-July, 2008:

1. This Authorization is valid from June 30, 2008, through July 31, 2008.

2. This Authorization is valid only for the *R1V Thomas* G. *Thompson's* seismic survey as described in the application, in the northeastern Pacific Ocean, during June-July, 2008.

3. (a) The incidental taking of marine mammals, by Level B harassment only, is limited to the following species:

(i) Odontocetes - humpback whale (*Megaptera novaeangliae*), minke whale *(Balaenoptera acutorostrata),* fin whale (*B. physalus*)*,* blue whale (*B. musculus*)*,* sperm whale (*Physeter macrocephalus*)*,* pygmy sperm whale (*Kogia breviceps*)*,* Baird's beaked whale (*Berardius bairdii*)*,* unidentified beaked whale (*Mesoplodon* spp.), short-beaked common dolphin (*Delphinus delphis*), Pacific white-sided dolphin (*Lagenorhynchus obliquidens*), northern right whale dolphin (*Lissodelphis borealis*)*,* Risso's dolphin (*Grampus griseus*), killer whale (*Orcinus orca*), and Dall's porpoise (*Phocoenoides dalli*).

(ii) Pinnipeds - northern fur seal (*Callorhinus ursinus*), and Steller sea lion (*Eumetopias jubatus*).

(iii) If any marine mammal species are encountered during seismic activities that are not listed here for authorized taking, then the holder of the permit must shut down the airguns.

(b) The taking by Level A harassment, serious injury or death of any of these species 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.

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

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

Federal, state or local agency monitoring the impacts of the activity on marine mammals.

6. Mitigation and Monitoring

The Holder of this Authorization is required to:

(a) Utilize NMFS-approved, vessel-based marine mammal visual observers (MMVOs) to monitor marine mammals near the seismic source vessel during any start ups of the airgun (day or night) and at least one MMVO to monitor the safety radius during all daytime seismic operations, as described in (b) below. Vessel crew will also assist in detecting marine mammals. 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) Visually observe the entire extent of the safety radius (190 dB for pinnipeds, 180 dB for cetaceans, see table for distances) using NMFS-approved MMVOs, for at least 30 minutes prior to starting the airguns (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 marine mammals or sea turtles are near, approaching, or in the safety radius, the airguns may not be started up.

(c) When operating sound source(s), minimize approaches to slopes and submarine canyons, if possible, because of sensitivity of beaked whales.

(d) Alter speed or course during seismic operations if a marine mammal, based on its position and relative motion, appears likely to enter the 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, the airguns will be shut down immediately.

(e) Shut-down the airguns if a marine mammal appears likely to enter the safety radius or is already within the safety radius when first seen (see attached). The airgun activity shall 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 10 min (small odontocetes and pinnipeds) or 15 min (mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, and beaked whales).

(f) If no marine mammals have been observed while undertaking monitoring and mitigation measures, airgun arrays may be ramped-up at no greater than 1 GI-gun per 5-minute interval or approximately 6 dB per 5-minute period. Ramp-ups shall occur at the commencement of seismic operations, and, anytime after the airgun array has been shut down for more than 4 minutes.

(g) If a North Pacific right whale is visually sighted, the airgun array will be shutdown regardless of the distance of the whale to the sound source.

7. Reporting

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 *R/V Thomas* G. *Thompson's* cruise. This report must contain and summarize the following information:

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

(2) Species, number, location, and behavior of any marine mammals, as well as associated seismic activity, observed throughout all monitoring activities.

(3) 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 in application) 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.

(4) A description of the implementation and effectiveness of the mitigation and monitoring measures required by this document for minimizing the adverse effects of the action on marine mammals.

8. In the unanticipated event that any cases of marine mammal injury or mortality are judged to result from these activities, UTIG will immediately shut down the airguns and report the incident to NMFS and the local stranding network. Airgun operation will then be postponed until NMFS is able to review the circumstances and work with UTIG to determine whether modifications in the activities are appropriate and necessary.

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

JUN 27 2008

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

Date

Attachments

Attachments

Safety Radii for Implementing Shut-down Procedures

Water Depth	Estimated Distances (m) at Received Levels: Shut-down zone for pinnipeds 190 dB	Shut-down zone for cetaceans 180 dB	Behavioral harassment take zone 160 dB
100-1000 m	30	104	1005
> 1000 m	20	69	670

Authorized Take Numbers for Each Species in the Northeast Pacific Ocean

Species	Authorized Take in the Northeastern Pacific Ocean
Humpback whale (*Megaptera novaeangliae*)	1
Minke whale (*Balaenoptera acutorostrata*)	1
Fin whale (*B. physalus*)	1
Sperm whale (*Physeter macrocephalus*)	2
Pygmy sperm whale (*Kogia breviceps*)	1
Baird's beaked whale (*Barardius bairdii*)	2
Unidentified beaked whale (*Mesoplodon spp.*)	1
Killer whale (*Orcinus orca*)	1
Short-beaked common dolphin(*Delphinus delphis*)	7
Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)	6
Northern right whale dolphin (*Lissodelphis borealis*)	5
Risso's dolphin (*Grampus griseus*)	3
Dall's porpoise (*Phocoenoides dalli*)	47
Blue whale (*B. musculus*)	1
Northern fur seal (*Callorhinus ursinus*)	19
Steller sea lion (*Eumetopias jubatus*)	1

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 the seismic study discussed in this report.

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. 1995:372*ff*). This was 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 this project as well as for most other L-DEO surveys (e.g., Smultea et al. 2004, 2005; Holst et al. 2005; Holst and Beland 2008; Hauser et al. 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 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 [4], 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. 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

[4] 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).

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 a 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 μPa_{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.

The sound pressure field of two 105-in^3 GI airguns has been modeled by L-DEO in relation to distance and direction from the GI guns. The predicted received levels depend on distance and direction from the GI guns. The model does not allow for bottom interactions and is most directly applicable to close distances and/or deep water. Based on the modeling, estimates of the maximum distances from the GI guns where sound levels of 190, 180, 170, and 160 dB re 1 μPa_{rms} are predicted to be received in deep (>1000-m) water are shown in Table B.1. Because the L-DEO model is for a pair of larger GI guns with a total discharge volume of 210 in^3, the values in Table B.1 overestimate the distances for two GI guns with a discharge of 150 in^3 as used during the NEPO study.

Empirical data concerning the 180-, 170-, and 160-dB distances for various airgun configurations, including a pair of 105 in^3 GI-guns, have been acquired based on measurements during an acoustic verification study conducted by L-DEO in the northern Gulf of Mexico (Tolstoy et al. 2004a,b). Although the results are limited, data showed that radii around the airguns where the received level would be 180 dB re 1 μPa_{rms}, the safety criterion applicable to cetaceans (NMFS 2000), vary with water depth. Similar depth-related variation is likely in the 190-dB distances applicable to pinnipeds. Correction factors were developed for water depths 100–1000 m and <100 m. The 2008 NEPO survey occurred in depths of ~650–1650 m, so the correction factors for the latter are not relevant here. For intermediate/slope waters (100–1000 m deep), it is assumed that the various radii would be 1.5× the corresponding radii in deep (>1000 m) water.

TABLE B.1. Distances to which sound levels ≥190, 180, 170, and 160 dB re 1 μPa_{rms} might be received from two 105 in^3 GI guns operating in deep (>1000 m) and intermediate/slope (100–1000 m) waters.

Source and Volume	Tow Depth (m)	Water Depth	Predicted RMS Radii (m)			
			190 dB	180 dB	170 dB	160 dB
2 GI airguns		>1000 m	20	69	214	670
210 in^3	3	100–1000 m	30	104	321	1005

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

The GI guns were to be shut down immediately when cetaceans were detected within or about to enter the 180-dB re 1 μPa_{rms} radius, or when pinnipeds were detected within or about to enter the 190-dB re 1 μPa_{rms} radius. The 180- and 190-dB shut-down criteria are consistent with NMFS guidelines listed for cetaceans and pinnipeds, respectively (NMFS 2000).

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. During the current seismic program, the tow depth was ~2 m.

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

UTIG used the R/V *Thomas G. Thompson* (Fig. C.1) for the seismic study to tow the two GI guns and the P-Cable system. The *Thompson* is self-contained, with the crew living aboard the vessel. The *Thompson* has a length of 83.5 m, a beam of 16 m, and a full load draft of 5.8 m. The ship is equipped with twin 360°-azimuth stern thrusters each powered by a 3000-hp DC motor and a water-jet bow thruster powered by a 1600-hp DC motor. The motors are driven by up to three 1500-kW and three 715-kW generators; normal operations use two 1500-kW and one 750-kW generator, but this changes with ship speed, sea state, and other variables. An operation speed of 5.1 km/h (2.8 knots) is used during seismic acquisition. When not towing seismic survey gear, the *Thompson* cruises at 22 km/h (12 knots) and has a maximum speed of 26.9 km/h (14.5 knots). It has a normal operating range of ~24,400 km.

Other details of the *Thompson* include the following:

Owner:	U.S. Navy
Operator:	University of Washington
Flag:	United States of America
Launch Date:	8 July 1991
Gross Tonnage:	3250 LT
Echosounders:	Simrad EM300 multibeam, Knudsen 320BR echo-sounder, Hydrosweep multibeam, EIS-10 navigational echosounder
Acoustic Doppler Current Profiler:	RDI 75-kHz Ocean Surveyor
Compressors for GI guns:	2 x LMF DC, capable of 175 scfm at 2000 psi
Accommodation Capacity:	60 including 36 scientists

The *Thompson* also served as a platform from which vessel-based MMOs watched for marine mammals and sea turtles.

Airgun Description

The *Thompson* source vessel towed two GI guns and the 12-m long P-Cable system along predetermined lines. Seismic pulses were emitted at intervals of ~3.5 s. At a speed of 5.1 km/h (2.8 knots), the 3.5-s spacing corresponds to a shot interval of ~5 m.

The generator chamber of each GI gun, the one responsible for introducing the sound pulse into the ocean, was 75 in^3. The injector chamber (also 75 in^3) injects air into the previously generated bubble to maintain its shape, and does not introduce more sound into the water. Thus, the total discharge volume was 150 in^3. The two GI guns were towed ~15−20 m behind the *Thompson* at a depth of ~2 m.

As the two GI guns were towed along the survey lines, the towed P-Cable system received the reflected signals and transferred the data to the on-board processing system. Given the relatively short streamer length behind the vessel, the maneuverability of the vessel was not limited much during operations.

Array Specifications

Energy Source	Two GI guns, 75 in^3
Source output (downward)[5]	0-pk is 7.2 bar-m (237 dB re 1 µPa·m); pk-pk is 14.0 bar·m (243 dB)
Towing depth of energy source	~2 m
Air discharge volume	~150 in^3
Dominant frequency components	2–188 Hz

Multibeam Bathymetric Echosounder and Chirp Echosounder

Along with the GI gun operations, additional acoustical systems operated at times during the cruise. The Simrad EM300 MBES was used to look at venting into the water column. The 12-kHz frequency of the dual-frequency Knudsen 320BR echosounder was used to determine water depth. These two systems were operated simultaneously with the GI guns. Other acoustical systems available on the *Thompson* were not be used during the cruise.

Multibeam Echosounder

A Simrad EM300 30-kHz MBES was the primary bottom-mapping echosounder used during the cruise. The Simrad EM300 transducer is hull-mounted within a transducer pod that is located midship. The system's normal operating frequency is ~30 kHz. The transmit fan-beam is split into either three or nine narrower beam sectors with independent active steering to correct for vessel yaw. Angular coverage is 36° (in Extra Deep Mode, for use in water depths 3000 to 6000 m) or 150° (in shallower water). The total angular coverage of 36° or 150° consists of the 3 or 9 beams transmitted at slightly different frequencies. The sectors are frequency coded between 30 and 34 kHz and they are transmitted sequentially at each ping. Except in very deep water where the total beam is 36° × 1°, the composite fan beam is 150° × 1°, 150° × 2° or 150° × 4° depending on water depth. The nine beams comprising the composite fan beam will overlap slightly if the vessel yaw is less than the fore-aft width of the beam (1, 2, or 4°, respectively). Achievable swath width on a flat bottom will normally be ~5× the water depth. The maximum source level is 237 dB re 1 µPa·m_{rms} (Hammerstad 2005).

In deep water (500–3000 m) a pulse length of 5 ms is normally used. At intermediate water depths (100–1000 m), a pulse length of 2 ms is used, and in shallow water (<300 m), a pulse length of 0.7 ms is used. The ping rate is mainly limited by the round trip travel time in the water up to a ping rate of 10 pings/s in shallow water.

Chirp Echosounder

The Knudsen 320BR is a deep-water, dual-frequency echosounder with operating frequencies of 3.5 and 12 kHz. The high frequency (12 kHz) can be used to record water depth or to track pingers attached to various instruments deployed over the side, and that is the mode used in this project. The low frequency (3.5 kHz) is used for sub-bottom profiling. Pulse lengths up to 24 ms and bandwidths to 5 kHz are available. Maximum output power at 3.5 kHz is 10 kW and at 12 kHz it is 2 kW.

[5] Given for two 105-in^3 GI guns towed at 3 m; source output not available for two 75-in^3 GI guns. For one 45-in^3 GI gun, 0-pk is 1.8 bar-m (225.3 dB re 1 µPa·m) and pk-pk is 3.4 bar·m (230.7 dB).

FIGURE C.1. The source vessel, the R/V *Thomas G. Thompson.*

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

This appendix provides details on the standard visual 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 occurred during all daytime GI gun activity and at most times during the daytime when the source vessel was underway but the GI guns 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 made from the *Thompson*'s bridge, which is the highest suitable vantage point on the *Thompson*. When stationed on the observation tower, the eye level is ~14.5 m above sea level (asl), and the observer has a good view around the entire vessel.

Three observers trained in marine mammal identification and observation methods were present on the *Thompson*. Onboard visual watches were usually conducted in 1–2 h shifts (max. 4 h), alternating with 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 to detect animals and to identify species or group size during sightings. The Fujinon 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 *Thompson* 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 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 rather than from the nominal center of the seismic source (the distance from the sighting to the GI guns 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 GI gun was estimated and recorded for the purposes of implementing 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 GI guns in use, total volume of the GI guns in use, and type of vessel/seismic activity. The position of the vessel was automatically logged every minute by the *Thompson's* navigation system. 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 bridge and the ship's science lab was used by the MMOs to alert the geophysicists when a shut down was needed.

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.

Mitigation

Ramp-up 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 GI guns, 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 (Appendix A). A shut down occurred when all the GI guns were turned off.

Ramp-up Procedures

A "ramp-up" procedure was followed at the commencement of seismic operations and anytime after the GI guns were shut down for a specified duration (>4 min). 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

TABLE D.1. Summary of data codes used during the seismic survey.

WS	Watch Start
WE	Watch End

LINE

Enter Line ID or leave blank

SEISMIC ACTIVITY

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

 # GUNS

Enter Number of Operating Airguns, or

X	Unknown

ARRAY VOLUME

Enter operating volume, or

X	Unknown

(BEAUFORT) SEA STATE

See Beaufort Scale sheet.

LIGHT OR DARK

L	Light (day)
D	Darkness

GLARE AMOUNT

NO	None
LI	Little
MO	Moderate
SE	Severe

POSITION

Clock Position, or

V	Variable (vessel turning)

WATER DEPTH

In meters

MARINE MAMMAL SPECIES

Baleen Whales

BLW	Blue Whale
BRW	Bryde's Whale
FW	Fin Whale
SW	Sei Whale
HW	Humpback Whale
MW	Minke Whale
NPRW	North Pacific Right 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

BLBW	Blainville's Beaked Whale
BBW	Baird's Beaked Whale
CBW	Cuvier's Beaked Whale
GBW	Gervais' Beaked Whale
HBW	Hubb's 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
PWSD	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

HP	Harbor Porpoise
BD	Dall's Porpoise

Pinnipeds

HS	Harbor Seal
NFS	Northern Fur Seal
CSL	California Sea Lion
NES	Northern Elephant 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

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. During a ramp up, the safety zone was taken to be that appropriate for both GI guns and the water depth at the time. First, a single GI gun was turned on, and 5 min later, the second GI gun was started up. Thus, the source level of the GI guns was increased by no more than 6 dB per 5-min period (Appendix A).

Shut-down Procedures

GI gun operations were immediately shut down when one or more marine mammals or sea turtles were detected within, or judged about to enter, the appropriate safety radius. A shut down 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. GI gun operations were not to resume until the animal was seen outside the safety radius, had not been seen for a specified amount of time (10 min for dolphins and pinnipeds, 15 min for 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 geophysicists that seismic surveys could re-commence, and ramp up was initiated.

The MMOs were stationed on the bridge ahead of the GI guns; the GI guns were located ~15–20 m aft of the *Thompson*'s stern (Fig. 2.2). The decision to initiate a shut down was based on the distance from the observers rather than from the GI guns, unless the animals were sighted close to the guns. This was another precautionary measure, given that most sightings were ahead of the vessel.

Analyses

This section describes the analyses of the marine mammal sightings and survey effort as documented during the cruise. It also describes the methods used to calculate densities of marine mammals and estimate the number of cetaceans and pinnipeds potentially exposed to seismic sounds associated with the seismic study. The analysis categories 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 >2 h after GI guns were turned off. The analyses (for effort and marine mammals), excluded the "recently exposed" period 1.5 min to 2 h after the GI guns 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; 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 near the *Thompson* 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.
- By 2 h after the cessation of seismic operations 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 *Thompson* >2 h post-seismic would be appreciably different from "normal" even if they had been exposed to seismic sounds earlier. Therefore, we consider animals seen >2 h after cessation of operations by a small airgun array to be unaffected by the seismic operations.

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

The formulas for calculating densities using this procedure were briefly described in Chapter 3 and are further described below. As 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 area assumed to be ensonified to ≥160 dB by the "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 GI gun 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. The buffer includes areas that were exposed to GI gun sounds ≥160 dB multiple times (as a result of crossing tracklines or tracklines that were close enough for their 160-dB zones to overlap). The buffer area only counts the repeated-coverage areas once, as opposed to the "exposures" method outlined above. The calculated number of different individual marine mammals exposed to ≥160 dB re 1 μPa_{rms} is considered a minimum estimate because it does not account for the movement of marine mammals during the course of the study.

The buffer process outlined above was repeated for delphinids, Dall's porpoise, and the northern fur seal, 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}. The process was also repeated for marine mammals based on the estimated 180-dB radius. That was done to estimate the numbers of animals that would have been subjected to sounds with received levels ≥180 dB re 1 μPa_{rms} if they had not altered their course to avoid those sound levels (or the ship).

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APPENDIX E:
BACKGROUND ON MARINE MAMMALS IN THE NEPO

TABLE E.1. The habitat, occurrence, and conservation status of marine mammals occurring in the study area of the NEPO.

Species	Habitat	Abundance[1]	ESA[2]	IUCN[3]	CITES[4]
Mysticetes					
North Pacific right whale (*Eubalaena japonica*)	Inshore, occasionally offshore	N.A. [5]	EN	EN	I
Humpback whale (*Megaptera novaeangliae*)	Mainly nearshore waters and banks	1391	EN	VU	I
Minke whale (*Balaenoptera acutorostrata*)	Pelagic and coastal	1015	NL	LR-nt	I
Sei whale (*Balaenoptera borealis*)	Primarily offshore, pelagic	56	EN	EN	I
Fin whale (*Balaenoptera physalus*)	Continental slope, mostly pelagic	3279	EN	EN	I
Blue whale (*Balaenoptera musculus*)	Pelagic and coastal	1744	EN	EN	I
Odontocetes					
Sperm whale (*Physeter macrocephalus*)	Usually pelagic and deep seas	1233	EN	VU	I
Pygmy sperm whale (*Kogia breviceps*)	Deep waters off the shelf	247	NL	LR-lc	II
Dwarf sperm whale (*Kogia sima*)	Deep waters off the shelf	N.A.	NL	LR-lc	II
Cuvier's beaked whale (*Ziphius cavirostris*)	Pelagic	1884	NL	DD	II
Baird's beaked whale (*Berardius bairdii*)	Pelagic	228	NL	LR-cd	I
Blainville's beaked whale (*Mesoplodon densirostris*)	Slope, offshore	1247 [6]	NL	DD	II
Hubb's beaked whale** (*Mesoplodon carlhubbsi*)	Slope, offshore	1247 [6]	NL	DD	II
Stejneger's beaked whale (*Mesoplodon stejnegeri*)	Slope, offshore	1247 [6]	NL	DD	II
Offshore bottlenose dolphin (*Tursiops truncatus*)	Offshore, slope	5,065	NL	DD	II
Striped dolphin (*Stenella coeruleoalba*)	Off continental shelf	13,934	NL	LR-cd	II
Short-beaked common dolphin (*Delphinus delphis*)	Shelf and pelagic, seamounts	449,846	NL	LR-lc	II
Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)	Offshore, slope	59,274	NL	LR-lc	II
Northern right whale dolphin (*Lissodelphis borealis*)	Slope, offshore waters	20,362	NL	LR-lc	II
Risso's dolphin (*Grampus griseus*)	Shelf, slope, seamounts	16,066	NL	DD	II
False killer whale (*Pseudorca crassidens*)	Pelagic, occasionally inshore	N.A.	NL	LR-lc	II
Killer whale (*Orcinus orca*)	Widely distributed	466 (Offshore)	NL	LR-cd EN*	II
Short-finned pilot whale (*Globicephala macrorhynchus*)	Mostly pelagic, high-relief topography	304	NL	LR-cd	II
Harbor porpoise (*Phocoena phocoena*)	Coastal and inland waters	37,745 (OR/WA)	NL	VU	II
Dall's porpoise (*Phocoenoides dalli*)	Shelf, slope, offshore	99,517	NL	LR-cd	II
Pinnipeds					
Northern fur seal (*Callorhinus ursinus*)	Pelagic, offshore	721,935 [5]	NL	VU	NL
California sea lion (*Zalophus californianus californianus*)	Coastal, shelf	237,000–244,000	NL	LR/lc	NL
Steller sea lion (*Eumetopias jubatus*)	Coastal, shelf	47,885 [5] Eastern US	T	EN	NL

Species	Habitat	Abundance[1]	ESA[2]	IUCN[3]	CITES[4]
Harbor seal (*Phoca vitulina richardsi*)	Coastal	24,732 (OR/WA)	NL	LR-lc	NL
Northern elephant seal (*Mirounga angustirostris*)	Coastal, pelagic when migrating	101,000 (CA)	NL	LR-lc	NL

N.A. Not available or not assessed.

*Southern Resident stock is listed as endangered but is unlikely to occur in offshore waters off Oregon.

[1] Abundance given for U.S., Eastern North Pacific, or California/Oregon/Washington Stock, whichever is included in the 2006 U.S. Pacific Marine Mammal Stock Assessments (Carretta et al. 2007), unless otherwise stated

[2] Endangered Species Act: EN = Endangered, T = Threatened, NL = Not listed

[3] Codes for IUCN classifications: EN = Endangered; VU = Vulnerable; LR = Lower Risk (-cd = Conservation Dependent; -nt = Near Threatened); DD = Data Deficient. Classifications are from the 2007 IUCN *Red List of Threatened Species* (IUCN 2007), although the status of marine mammals has not been reassessed since 1996.

[4] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2007); NL = Not listed.

[5] Angliss and Outlaw (2007).

[6] All mesoplodont whales

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APPENDIX F: VISUAL EFFORT AND SIGHTINGS

TABLE F.1. All and useable[a] visual observation effort from the *Thompson* during the NEPO survey, 30 June – 19 July 2008 in **(A)** kilometers and **(B)** hours, subdivided by water depth and GI gun status.

GI Gun Status	All Effort by Water Depth[a]			Useable[b] Effort by Water Depth[a]		
	100-1000 m	**>1000 m**	**Total**	**100-1000 m**	**>1000 m**	**Total**
(A) Effort in km						
Total GI Guns On (Seismic)	**547.1**	**98.2**	**645.4**	**308.6**	**41.0**	**349.6**
0 GI Guns on (up to 90 s after seismic)	3.4	1.0	4.5	2.1	0.6	2.7
1 GI Gun	19.6	4.9	24.5	10.4	1.5	11.8
2 GI Guns	524.1	92.3	616.4	296.2	38.9	335.1
Total GI Guns Off	**133.9**	**104.9**	**238.8**	**35.1**	**69.4**	**104.4**
Non-seismic	46.4	79.1	125.4	35.1	69.4	104.4
Recently-exposed (>90 s - 2 h after seismic)	87.5	25.8	113.3	0	0	0
Total Effort (GI Guns On&Off)	**681.0**	**203.1**	**884.1**	**343.7**	**110.3**	**454.1**
(B) Effort in hr						
Total GI Guns On (Seismic)	**104.3**	**19.5**	**123.8**	**58.5**	**7.8**	**66.3**
0 GI Guns on (up to 90 s after seismic)	0.7	0.2	0.9	0.4	0.1	0.5
1 GI Gun	3.9	1.1	5.0	2.0	0.3	2.3
2 GI Guns	99.8	18.2	118.0	56.2	7.4	63.6
Total GI Guns Off	**23.4**	**12.7**	**36.1**	**2.3**	**3.9**	**6.2**
Non-seismic	5.0	6.7	11.7	2.3	3.9	6.2
Recently-exposed (>90 s - 2 h after seismic)	18.4	6.0	24.4	0	0	0
Total Effort (GI Guns On&Off)	**127.7**	**32.2**	**160.0**	**60.9**	**11.6**	**72.5**

[a] No observation effort occurred in water <100 m deep.
[b] See "useable" definition in *Acronyms and Abbreviations.*

TABLE F.2. All and useable[a] visual observation effort from the *Thompson* during the NEPO survey, 30 June – 19 July 2008 in **(A)** kilometers and **(B)** hours, subdivided by Beaufort Wind Force (Bf) and GI gun status.

	All Effort by Beaufort Wind Force								Useable[a] Effort by Beaufort Wind Force					
GI Gun Status	**1**	**2**	**3**	**4**	**5**	**6***	**7***	**Total**	**1**	**2**	**3**	**4**	**5**	**Total**
(A) Effort in km														
Total GI Guns On (Seismic)	**1.8**	**32.3**	**74.2**	**241.9**	**118.8**	**163.8**	**12.6**	**645.38**	**0.0**	**24.3**	**70.1**	**185.0**	**70.2**	**349.6**
0 GI Guns on (up to 90 s after seismic)	0	0.2	0.8	1.2	1.3	0.9	0	4.5	0	0.2	0.8	0.9	0.8	2.7
1 GI Gun	1.8	3.7	1.6	8.5	5.1	3.8	0	24.5	0	3.3	1.6	4.1	2.8	11.8
2 GI Guns	0.0	28.4	71.8	232.2	112.4	159.0	12.6	616.4	0	20.8	67.7	180.0	66.6	335.1
Total GI Guns Off	**15.5**	**67.7**	**45.8**	**32.7**	**56.5**	**20.6**	**0**	**238.76**	**13.9**	**62.6**	**19.6**	**3.7**	**4.6**	**104.4**
Non-seismic	15.5	62.6	19.6	6.0	11.2	10.5	0	125.4	13.9	62.6	19.6	3.7	4.6	104.4
Recently-exposed (>90 s - 2 h after seismic)	0.0	5.1	26.2	26.7	45.4	10.0	0	113.3	0	0	0	0	0	0
Total Effort (GI Guns On&Off)	**17.3**	**100.0**	**120.0**	**274.6**	**175.4**	**184.3**	**12.6**	**884.1**	**13.9**	**86.9**	**89.7**	**188.8**	**74.9**	**454.1**
(B) Effort in hr														
Total GI Guns On (Seismic)	**0.5**	**6.6**	**13.7**	**48.2**	**22.8**	**29.8**	**2.3**	**123.8**	**0.0**	**4.6**	**13.0**	**35.9**	**12.9**	**66.3**
0 GI Guns on (up to 90 s after seismic)	0.0	0.1	0.1	0.3	0.3	0.2	0	0.9	0	0	0.1	0.2	0.2	0.5
1 GI Gun	0.5	0.7	0.3	1.7	1.1	0.7	0	5.0	0	0.6	0.3	0.8	0.5	2.3
2 GI Guns	0.0	5.8	13.3	46.2	21.5	28.9	2.3	118.0	0	3.9	12.5	34.9	12.3	63.6
Total GI Guns Off	**1.4**	**4.4**	**5.9**	**7.7**	**11.9**	**4.8**	**0**	**36.1**	**0.6**	**3.1**	**0.8**	**0.9**	**0.8**	**6.2**
Non-seismic	1.4	3.1	0.8	1.3	2.2	3.0	0	11.7	0.6	3.1	0.8	0.9	0.8	6.2
Recently-exposed (>90 s - 2 h after seismic)	0.0	1.3	5.1	6.4	9.8	1.8	0	24.4	0	0	0	0	0	0
Total Effort (GI Guns On&Off)	**1.9**	**11.0**	**19.7**	**55.8**	**34.7**	**34.6**	**2.3**	**160.0**	**0.6**	**7.6**	**13.8**	**36.7**	**13.7**	**72.5**

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

* Effort in these categories is not "useable"

TABLE F.3. Sightings of marine mammals made from the *Thompson* during the NEPO survey, 30 June – 19 July 2008.

Species	Useable? [a]	Group Size	Date & Time	Latitude	Longitude	Initial Sighting Distance (m)	CPA [b] (m)	Movement [c]	Initial Behavior [d]	Wind Force [e]	Water Depth [f] (m)	Vessel Activity [g]	Number of Guns On	Mitigation [h]
Dall's porpoise	Y	8	02/07/2008 17:15:00	46.6843	-125.072	533	354	PE	SW	2	844	OT	0	None
Pacific white-sided dolphin	N	8	02/07/2008 17:48:00	46.5688	-125.075	X	X	PE	SW	1	946	OT	0	None
Humpback whale	Y	2	02/07/2008 21:33:26	45.76	-125.051	3306	3359	SP	ST	3	1495	OT	0	None
Pacific white-sided dolphin	Y	18	02/07/2008 22:04:11	45.6479	-125.045	4813	1218	MI	FG	2	1617	OT	0	None
Dall's porpoise	Y	12	04/07/2008 01:47:53	44.6376	-125.164	993	1046	ST	ST	3	1082	LS	2	None
Dall's porpoise	Y	2	04/07/2008 02:45:00	44.5892	-125.167	3306	3359	UN	ST	4	1007	LS	2	None
Pacific white-sided dolphin	N	80	04/07/2008 18:00:50	44.5936	-125.149	2000	10	ST	ST	5	912	LS	2	SZ
Northern right whale dolphin	N	20	04/07/2008 18:08:00	44.5986	-125.149	100	156	PE	ST	5	945	OT	0	None
Humpback whale	N	1	04/07/2008 19:07:20	44.5982	-125.164	600	653	SA	FL	5	1076	OT	0	None
Pacific white-sided dolphin	N	15	04/07/2008 21:23:58	44.5743	-125.164	600	644	MI	FG	5	920	OT	0	None
Short-beaked common dolphin	Y	20	04/07/2008 21:57:26	44.573	-125.137	2074	2135	UN	SA	5	830	LS	2	None
Pacific white-sided dolphin	Y	20	04/07/2008 22:17:36	44.5868	-125.137	1000	1001	MI	FG	5	842	LS	2	None
Pacific white-sided dolphin	N	5	05/07/2008 12:54:52	44.5702	-125.147	30	91	PE	TR	4	775	LS	2	None
Unidentified dolphin	N	1	05/07/2008 13:21:20	44.5873	-125.147	50	111	SP	TR	4	858	OT	0	None
Pacific white-sided dolphin	N	20	05/07/2008 16:50:05	44.5569	-125.162	30	80	SP	TR	5	874	LS	2	SZ
Dall's porpoise	Y	5	05/07/2008 23:14:14	44.5633	-125.16	2000	73	ST	TR	2	846	LS	2	SZ
Pacific white-sided dolphin	Y	3	05/07/2008 23:14:14	44.5633	-125.16	1000	156	ST	TR	2	846	OT	0	None
Northern right whale dolphin/Pacific white-sided dolphin	Y	500	05/07/2008 23:14:14	44.5633	-125.16	4500	1553	ST	SA	2	846	OT	0	None
Short-beaked common dolphin	N	120	05/07/2008 23:29:12	44.55	-125.16	5000	4938	PE	SA	2	923	OT	0	None
Pacific white-sided dolphin	N	20	06/07/2008 14:55:50	44.5281	-125.12	45	16	ST	WR	5	1085	OT	0	None
Dall's porpoise	N	10	06/07/2008 14:55:50	44.5281	-125.12	500	554	ST	ST	5	1085	OT	0	None
Northern right whale dolphin/Pacific white-sided dolphin	Y	200	06/07/2008 16:48:50	44.5544	-125.143	80	141	ST	SA	5	851	LS	2	SZ
Pacific white-sided dolphin	Y	7	06/07/2008 19:28:45	44.6355	-125.153	100	161	SP	SA	5	976	LS	2	SZ
Pacific white-sided dolphin	N	4	06/07/2008 23:26:39	44.5929	-125.143	232	291	ST	TR	6	860	LS	2	None
Pacific white-sided dolphin	N	1	07/07/2008 00:06:00	44.6013	-125.159	40	21	PE	DI	6	1034	OT	0	None
Pacific white-sided dolphin	N	7	07/07/2008 01:04:34	44.5509	-125.157	120	105	SP	ST	6	906	LS	2	None
Pacific white-sided dolphin	N	2	12/07/2008 01:09:21	44.5596	-125.159	100	122	SP	ST	6	839	OT	0	None
Pacific white-sided dolphin	N	4	12/07/2008 03:26:49	44.5793	-125.151	120	58	SP	ST	6	836	LS	2	SZ
Humpback whale	N	2	12/07/2008 16:45:00	44.5595	-125.165	847	900	SA	BL	6	912	LS	2	None
Dall's porpoise	Y	3	12/07/2008 17:23:05	44.5792	-125.165	110	166	SP	ST	5	950	LS	2	None
Pacific white-sided dolphin	Y	5	12/07/2008 21:23:38	44.5754	-125.149	60	1	PE	MI	5	795	LS	2	SZ
Northern right whale dolphin/Pacific white-sided dolphin	N	200	12/07/2008 22:05:29	44.5423	-125.156	80	117	SP	ST	6	966	LS	2	SZ
Pacific white-sided dolphin	N	2	12/07/2008 23:52:44	44.5932	-125.148	150	136	SP	MI	6	894	LS	2	SZ
Dall's porpoise	N	10	13/07/2008 18:19:19	44.596	-125.148	50	107	SP	PO	5	913	LS	2	SZ
Pacific white-sided dolphin	Y	4	13/07/2008 20:37:52	44.5967	-125.162	100	64	PE	SA	5	1040	LS	2	None
Dall's porpoise	N	3	14/07/2008 18:15:37	44.5603	-125.144	300	354	PE	PO	6	838	LS	2	None
Pacific white-sided dolphin/Northern fur seal	Y	100	15/07/2008 12:44:55	44.5586	-125.138	80	80	ST	ST	3	857	LS	2	SZ
Pacific white-sided dolphin	Y	10	15/07/2008 18:18:00	44.5808	-125.138	800	832	NO	FG	4	819	LS	2	None
Pacific white-sided dolphin	Y	10	16/07/2008 03:39:10	44.5693	-125.136	60	117	ST	SA	4	835	LS	2	SZ
Minke whale	Y	1	16/07/2008 17:34:00	44.5606	-125.146	300	335	SP	ST	3	794	LS	2	None
Northern right whale dolphin/Pacific white-sided dolphin	Y	400	16/07/2008 19:07:24	44.5797	-125.133	343	70	ST	ST	4	871	LS	2	SZ
Short-beaked common dolphin	Y	6	16/07/2008 20:38:58	44.5728	-125.143	4000	4000	SP	ST	3	789	LS	2	None
Pacific white-sided dolphin/Short-beaked common dolphin/Northern right whale dolphin	Y	700	17/07/2008 02:55:00	44.5593	-125.156	1000	10	UN	FG	3	820	LS	2	SZ
Northern right whale dolphin/Pacific white-sided dolphin	Y	200	17/07/2008 13:25:19	44.586	-125.138	110	80	ST	ST	4	880	LS	2	SZ
Humpback whale	Y	2	17/07/2008 14:41:29	44.5516	-125.15	1500	853	PE	ST	3	867	LS	2	None
Pacific white-sided dolphin	Y	400	17/07/2008 16:55:04	44.5604	-125.136	533	503	PE	ST	3	867	LS	2	SZ
Unidentified dolphin	Y	400	17/07/2008 19:25:53	44.5919	-125.148	3306	3306	SP	ST	3	892	LS	2	None
Pacific white-sided dolphin	Y	12	17/07/2008 19:47:18	44.6064	-125.142	200	209	SP	ST	3	922	LS	2	None
Northern right whale dolphin/Pacific white-sided dolphin	Y	1500	17/07/2008 19:56:35	44.6025	-125.135	100	62	ST	ST	3	890	LS	2	SZ
Pacific white-sided dolphin	Y	1	17/07/2008 22:47:35	44.5861	-125.125	120	175	PE	ST	4	887	LS	2	None
Humpback whale	Y	2	17/07/2008 23:36:23	44.5777	-125.123	3306	3306	PE	TR	4	868	LS	2	None
Humpback whale	Y	2	18/07/2008 02:38:12	44.5518	-125.136	3306	3306	PE	TR	4	922	LS	2	None
Northern right whale dolphin/Pacific white-sided dolphin	Y	300	18/07/2008 03:08:21	44.535	-125.13	1201	1232	ST	SA	4	1036	LS	2	SZ

X = not recorded.

[a] Useable or non-useable sighting. Y = Sighting made during daylight periods. N = periods 90 s to 2 h after GI guns 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 *Thompson*'s speed was <3.7 km/h (2 kt) or with >60º of severe glare between 90º left and 90º right of the bow.

[b] CPA is the distance at the closest observed point of approach to the nearest GI gun. 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.

[d] The initial behavior observed. BL = blowing; FG = feeding; FL = fluking; PO = porpoising; SA = surface active; ST = surface active/traveling; DI = diving; TR = traveling; SW = swimming; WR = wakeriding; MI = milling; OT = other.

[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. OT = other or no seismic activity; LS = line shooting with GI guns.

[h] SZ = safety zone shut down.

APPENDIX G:
MARINE MAMMAL DENSITIES AND EXPOSURE ESTIMATES

TABLE G.1. Sightings and densities of marine mammals during non-seismic periods in intermediate water depths 100–1000 m during the NEPO survey, 30 June – 19 July 2008. Useable survey effort was 35 km.

Species	Number of sightings	Mean group size	Average density [a] corrected for *f* (0) and *g* (0) (# /1000 km^2)	
			Density	CV [b]
Odontocetes				
Phocoenidae				
Dall's porpoise	1	8	242.11	0.94
Total Cetaceans	**1**		**242.11**	**0.94**

[a]Values for *f* (0) and *g* (0) are from Koski et al. (1998) and Barlow (1999).

[b] CV (Coefficient of Variation) is a measure of a number's variability. The larger the CV, the higher the variability. It is estimated by the equation 0.94 - 0.162$\log_e$n from Koski et al. (1998), but likely underestimates the true variability.

TABLE G.2. Sightings and densities of marine mammals during non-seismic periods in water depths >1000 m during the NEPO survey, 30 June – 19 July 2008. Useable survey effort was 69 km. Species in italics are listed under the ESA.

Species	Number of sightings	Mean group size	Average density [a] corrected for *f* (0) and *g* (0) (# /1000 km^2)	
			Density	CV [b]
Odontocetes				
Delphinidae				
Pacific white-sided dolphin	1	18	113.27	0.94
Mysticetes				
Humpback whale	*1*	2	*18.96*	0.94
Total Cetaceans	**2**		**132.22**	**0.83**

[a]Values for *f* (0) and *g* (0) are from Koski et al. (1998) and Barlow (1999).

[b]CV (Coefficient of Variation) is a measure of a number's variability.

TABLE G.3. Sightings and densities of marine mammals during seismic periods in water depths 100–1000 m during the NEPO survey, 30 June – 19 July 2008. Useable survey effort was 309 km. Species in italics are listed under the ESA.

Species	Number of sightings	Mean group size	Average density [a] corrected for *f* (0) and *g* (0) (# /1000 km^2) Density	CV [b]
Odontocetes				
Delphinidae				
Pacific white-sided dolphin	16	146	1208.37	0.49
Northern right whale dolphin	6	197	558.96	0.65
Short-beaked common dolphin	3	125	197.20	0.76
Unidentified dolphin	1	400	189.00	0.94
Total Delphinidae	**26**		**2153.52**	**0.41**
Phocoenidae				
Dall's porpoise	2	4	27.42	0.83
Mysticetes				
Humpback whale	*3*	*2*	7.55	*0.76*
Minke whale	1	1	0.71	0.94
Total Mysticetes	**4**		**8.26**	**0.72**
Total Cetaceans	**32**		**2189.20**	**0.38**
Pinnipeds				
Northern fur seal	1	1	2.52	0.94

[a] Values for f(0) and g(0) are from Koski et al. (1998) and Barlow (1999).

[a] CV (Coefficient of Variation) is a measure of a number's variability.

TABLE G.4. Sightings and densities of marine mammals during seismic periods in water depths >1000 m during the NEPO survey, 30 June – 19 July 2008. Survey effort was 41 km.

Species	Number of sightings	Mean group size	Average density [a] corrected for *f* (0) and *g* (0) (# /1000 km^2) Density	CV [b]
Odontocetes				
Delphinidae				
Pacific white-sided dolphin	2	91	706.29	0.83
Northern right whale dolphin	1	123	438.00	0.94
Total Delphinidae	**3**		**1144.29**	**0.76**
Phocoenidae				
Dall's porpoise	2	7	361.69	0.83
Total Cetaceans	**5**		**1505.98**	**0.68**

[a] Values for f(0) and g(0) are from Koski et al. (1998) and Barlow (1999).

[a] CV (Coefficient of Variation) is a measure of a number's variability.

TABLE G.5. Estimated numbers of exposures and estimated minimum numbers of individual marine mammals that would have been exposed to seismic sounds ≥160 dB (and ≥170 dB) during the NEPO survey if **no animals had moved away from the active seismic vessel**, 30 June – 19 July 2008. Based on calculated densities[a] in **non-seismic periods** (Table G1, G2). The sound source was 2 GI guns with a total volume of 150 in^3. Received levels of airgun sounds are expressed in dB re 1 μPa_{rms} (averaged over pulse duration). Species in italics are listed under the ESA.

Species/species group	**Numbers of exposures**[b]			**Minimum number of individuals**[b]		
Water depth (m)	**100-1000**	**>1000**	**All depths**	**100-1000**	**>1000**	**All depths**
Area (km^2) ensonified to ≥160 dB (≥170 dB)	1857 (543)	213 (67)	2070 (610)	119 (53)	54 (25)	174 (79)
Odontocetes						
Delphinidae						
Pacific white-sided dolphin	0 () 0	24 (8)	24 (8)	0 ()	6 (3)	6 (3)
Phocoenidae						
Dall's porpoise	450 (131)	0 ()	450 (131)	29 (13)	0 ()	29 (13)
Mysticetes						
Humpback whale	*0*	*4*	*4*	*0*	*1*	*1*
Total Cetaceans	**450**	**28**	**478**	**29**	**7**	**36**

[a] Values for *f* (0) and *g* (0) are from Koski et al. (1998) and Barlow (1999).

[b] Slight apparent discrepancies in totals result from rounding to integers.

TABLE G.6. Estimated numbers of exposures and estimated minimum numbers of individual marine mammals that would have been exposed to seismic sounds ≥160 dB (and ≥170 dB) in the NEPO 30 June – 19 July 2008. Based on calculated densities[a] in **seismic periods** (Table G3, G4). The sound source was 2 GI guns with a total volume of 150 in^3. Received levels of airgun sounds are expressed in dB re 1 μPa_{rms} (averaged over pulse duration). Species in italics are listed under the ESA.

Species/species group	**Numbers of exposures** [b]						**Minimum number of individuals** [b]					
Water depth (m)	**100-1000**		**>1000**		**All depths**		**100-1000**		**>1000**		**All depths**	
Area (km^2) ensonified to ≥160 dB (≥170 dB)	1857	(543)	213	(67)	2070	(610)	119	(53)	54	(25)	174	(79)
Odontocetes												
Delphinidae												
Pacific white-sided dolphin	2243	(656) 0	151	(47)	2394	(703)	144	(65)	38	(18)	182	(82)
Northern right whale dolphin	1038	(303) 0	93	(29)	1131	(333)	67	(30)	24	(11)	90	(41)
Short-beaked common dolphin	366	(107) 0	0	()	366	(107)	24	(11)	0	()	24	(11)
Unidentified dolphin	351	(103) 0	0	()	351	(103)	23	(10)	0	()	23	(10)
Total Delphinidae	**3998**	**(1169)**	**244**	**(76)**	**4242**	**(1245)**	**257**	**(115)**	**62**	**(29)**	**319**	**(144)**
Phocoenidae												
Dall's porpoise	51	(15)	77	(24)	128	(39)	3	(1)	20	(9)	23	(11)
Mysticetes												
Humpback whale	*14*		*0*		*14*		*1*		*0*		*1*	
Minke whale	1		0		1		0		0		0	
Total Mysticetes	**15**		**0**		**15**		**1**		**0**		**1**	
Total Cetaceans	**4064**		**321**		**4385**		**261**		**82**		**343**	
Pinnipeds												
Northern fur seal	5	(1) 0	0	()	5	(1)	0	()	0	()	3	()

[a] Values for *f* (0) and *g* (0) are from Koski et al. (1998) and Barlow (1999).

[b] Slight apparent discrepancies in totals result from rounding to integers.

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