MARINE MAMMAL MONITORING AND MITIGATION DURING OPEN WATER SEISMIC EXPLORATION BY GX TECHNOLOGY IN THE CHUKCHI SEA, OCTOBER-NOVEMBER 2006: 90-DAY REPORT

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LIST OF ACRONYMS AND ABBREVIATIONS

~	approximately
AASM	Airgun Array Source Model
AEWC	Alaska Eskimo Whaling Commission
Bf	Beaufort Wind Force
BO	Biological Opinion
CAA	Conflict Avoidance Agreement
CFR	(U.S.) Code of Federal Regulations
CITES	Convention on International Trade in Endangered Species
cm	centimeter
CPA	Closest (Observed) Point of Approach
CTD	conductivity, temperature, depth
dB	decibel
EA	Environmental Assessment
EFD	Energy Flux Density
ESA	(U.S.) Endangered Species Act
$f(0)$	sighting probability density at zero perpendicular distance from survey track; equivalently, 1/(effective strip width)
ft	feet
FRC	Fast Rescue Craft
GI	Generator Injector
GIS	Geographic Information System
GMT	Greenwich Mean Time
GPS	Global Positioning System
$g(0)$	probability of seeing a group located directly on a survey line
h	hours
hp	horse power
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
kt	knots
L-DEO	Lamont-Doherty Earth Observatory (of Columbia University)
LoA	Letter of Authorization
μPa	micro Pascal
m	meters
MBB	Multibeam Bathymetric (sonar)
MCS	Multi-Channel Seismic
min	minutes

MMO	Marine Mammal Observer
MMPA	(U.S.) Marine Mammal Protection Act
MONM	Marine Operations Noise Model
n	sample size
n.mi.	nautical miles
NMFS	(U.S.) National Marine Fisheries Service
No.	number
NTCL	Northern Transportation Co., Ltd.
PAM	Passive Acoustic Monitoring
PD	Power down of the airgun array to one airgun (in this study, from an output of 3147 in^3 to 30 or 155 in^3)
PE	Parabolic Equation
pk-pk	peak-to-peak
psi	pounds per square inch
RAM	Range-dependent Acoustic Model
re	in reference to
rms	root-mean-square: an average, in the present context over the duration of a sound pulse
s	seconds
SD	Shut Down of airguns not associated with mitigation
s.d.	standard deviation
SEL	Sound Exposure Level: a measure of energy content, in dB re 1 $\mu Pa^2 \cdot s$
SOI	Shell Offshore, Inc.
SPL	Sound Pressure Level; the SPL for a seismic pulse is equivalent to its rms level
SZ	Shut Down of all airguns because of a marine mammal sighting near or within the safety radius
TTS	Temporary Threshold Shift
UNEP	United Nations Environmental Programme
"Useable"	Visual effort or sightings made under the following observation conditions: daylight periods within the Chukchi and Beaufort Seas, ***excluding*** periods 3 min to 1 h (pinnipeds) or 2 h (for cetaceans) after airguns were turned off (post-seismic), periods when ship speed was <3.7 km/h (2 kt), and periods with seriously impaired sightability. The following conditions were defined as involving seriously impaired sightability: all nighttime periods, and daytime periods with one or more of the following: visibility <3.5 km, Bf >5 (Bf >2 for porpoises), or >60º of severe glare between 90º left and 90º right of the bow. Sightings of marine mammals hauled out o]n the ice in both the Beaufort and Chukchi seas were considered "useable" for analyses. Sightings of cetaceans from the *Octopus* were considered "unuseable" for analyses because they were not classified as seismic or non-seismic sightings.

EXECUTIVE SUMMARY

Background and Introduction (Chapter 1).— GX Technology (GXT) collected marine seismic data in the Chukchi Sea during the fall of 2006 in support of potential future oil and gas leasing and development. Two-dimensional seismic acquisition for GXT was conducted in the Chukchi Sea using the source vessel M/V *Discoverer*.

Marine seismic surveys emit sounds into the water that could affect marine mammal behavior and distribution, or perhaps cause temporary or permanent reduction in hearing sensitivity. These effects could constitute "taking" under the provisions of the U.S. Marine Mammal Protection Act (MMPA) and the U.S. Endangered Species Act (ESA). The National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) share jurisdiction over the marine mammal species that were likely to be encountered during the project. Cetaceans and most pinnipeds are managed by NMFS; Pacific walruses and polar bears are managed by USFWS.

GXT's seismic surveys in the Chukchi Sea were conducted under the jurisdiction of Incidental Harassment Authorizations (IHAs) issued by NMFS and USFWS. These IHAs were granted to GXT on the assumptions that

- the numbers of whales and pinnipeds 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,
- there would be no unmitigated adverse effects on the availability of marine mammals for subsistence hunting in Alaska, and
- the agreed upon monitoring and mitigation measures would be implemented.

Under current NMFS guidelines, "safety radii" for marine mammals around airgun arrays are 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. Those safety radii are based on an assumption that seismic pulses above these levels *might* injure these mammals or impair their hearing abilities. The IHA issued by NMFS required that shipboard personnel monitor the designated ≥180 and ≥190 dB "safety radii" and initiate a power down or shut down of the airguns when marine mammals were seen within or about to enter those zones. The USFWS IHA also required that the 190 dB safety radius be applied for both walruses and polar bears. In addition, the NMFS IHA required monitoring of the distance within which received sound levels are ≥160 dB re 1 μPa_{rms}, the sound level at which NMFS believes that behavioral disturbances occur. This larger area was monitored by the chase boat, *Octopus*, that accompanied the seismic vessel. Power down of the seismic airgun array was required if ≥12 non-migratory bowhead or gray whales were detected ahead of, or perpendicular to, the seismic vessel track. USFWS also required that vessels, while traveling, maintain an 800 m (0.5 mi.) exclusion zone around walruses and polar bears observed either on land or ice. Additionally, the USFWS IHA did not allow seismic operations within 64 km (40 mi.) of communities to limit possible interaction with nearshore subsistence hunters.

The primary objectives of the overall monitoring program were as follows:

1. provide real-time sighting data needed to implement the mitigation requirements;
2. estimate numbers of marine mammals potentially exposed to strong seismic pulses; and

3. determine the reactions (if any) of marine mammals potentially exposed to seismic sound impulses.

This 90-day report describes the methods and results for the monitoring work specifically required to meet the above primary objectives.

Seismic Surveys Described (Chapter 2).—The *Discoverer* was the seismic source vessel during GXT's activities in the Chukchi Sea in 2006. During most survey activities, the *Discoverer* was accompanied by its chase vessel, the *Octopus*. The *Discoverer* arrived in the Chukchi Sea study area on 7 Oct. and began collecting seismic data in the Chukchi Sea on 13 Oct. The airguns and streamers were retrieved on 11 Nov. The *Discoverer* departed southward from the project area and arrived in Dutch Harbor on 21 Nov. The geographic region where the seismic survey occurred was located in the Chukchi Sea MMS OCS Program Area designated as Chukchi Sea Sale 193 (1989) and in the proposed 2002–2007 Chukchi Sea Program Area.

GXT used a bolt/sleeve airgun array for its 2-D seismic survey operations in the Chukchi Sea. The 3320 in^3 array was towed ~50 m behind the *Discoverer*. Air compressors aboard the *Discoverer* were the source of high pressure air (2000 psi) used to operate the airgun array. The receiving system included a single hydrophone streamer 9000 m in length, which recorded reflected sound energy. Seismic pulses were emitted at intervals of ~50 m (~20 s) while the *Discoverer* traveled at a speed of 4–5 knots (7.4–9.3 km/h).

Acoustic Modeling, Measurements and Model Validation (Chapters 3,4,5).—Prior to conducting seismic survey activities, GXT contracted JASCO Research Ltd. to provide an acoustic model to estimate the extent of ensonification from the proposed airgun array. GXT's airguns ranged in size from 40 to 150 in^3 and its discharge was 3320 in^3. JASCO modeled the use of the airgun in four hypothetical survey locations in the Chukchi Sea. Their models take account of the specific configuration of the airgun array. It also allows for the effects of the anticipated environmental conditions, including water properties, bathymetry, and bottom conditions on the propagation of the sound through the water and bottom.

The acoustic modeling predicted distances at which the received sound level, on an rms basis, would be 190, 180, 170 and 160 dB re 1 μPa rms. These original ("flat-weighted") calculations provided the safety radii applied during initial airgun operations, while sound source levels were measured. Additionally, sensitivity weighting (*M*-weighting) was applied to modeled underwater sound levels to weight the sound at various frequencies in accordance with the hearing characteristics of different marine mammal groups, i.e., baleen whales, toothed whales, and pinnipeds.

Prior to the start of operations in the Chukchi Sea, JASCO conducted field measurements of the underwater sound levels produced by the 3320 in^3 airgun array that was to be used for the seismic surveys. Underwater sound level measurements were obtained from two autonomous Ocean Bottom Hydrophone (OBH) recorder systems deployed from the support vessel *Octopus* on 21 Aug. 2006 in the Chukchi Sea near the proposed seismic survey area. After deployment of the OBHs, the *Discoverer* proceeded along a planned survey track starting at 65 km from the OBH systems. The survey vessel fired its airguns at intervals of ~20 s during the source verification measurement period and completed its survey track on 21 Aug. 2006 after approximately 24.5 h. The OBH's were retrieved and the acoustic data were downloaded and analyzed to determine sound exposure level versus range for the full 3320 in^3 array. Safety radii based on these measurements were calculated and presented to GXT shortly after the test and were then used by marine mammal observers on the seismic vessel during data acquisition, which did not start until 13 Oct.

A comparison of the final empirical vs. modeled SPL values showed that the empirical distances exceeded modeled distances (by 1.02–1.38×). This was attributed mainly to differing bottom types between the locations at which pre-season model estimates were performed and at the location of the source verification tests. For the 3320 in^3 array, the final empirical values in the endfire aspect were 620 m for 190 dB, 1460 m for 180 dB, 3360 m for 170 dB, and 7280 m for 160 dB. The broadside aspect had measured distances of 480 m for 190 dB, 1770 m for 180 dB, 5110 m for 170 dB, and 10,970 m for 160 dB. The measured broadside sound pressure levels at all distances (160–190 dB) were greater than the endfire range for the 3320 in^3 array. The distances of the broadside sound pressure levels were used to estimate the number of individual animal exposures to different sound levels, as a conservative measure. During the course of the project the marine mammal observers applied "safety" radius distances of 693 m for 190 dB, 2035 m for 180 dB and 12,535 m for 160 dB.

Monitoring and Mitigation Methods (Chapter 6).—The main purposes of the vessel-based monitoring program were to ensure that the provisions of the IHAs issued to GXT by NMFS and USFWS were satisfied, effects on marine mammals were minimized, and residual effects on animals were documented.

During GXT seismic surveys in the Chukchi Sea in 2006, at least one MMO onboard the source vessel maintained a visual watch for marine mammals during all daylight hours while seismic surveys were underway. During the surveys, two visual observers were on duty for 52% of the time watches were conducted on the *Discoverer*. Observers focused their search effort forward and to the side of the vessel, but also searched aft of the vessel. Watches were conducted with the naked eye, Fujinon 7 × 50 reticle binoculars, and Cannon 18 × 60 binoculars. MMOs instructed seismic operators to power down or shut down the airguns if marine mammals were sighted within, or about to enter, the appropriate safety radii.

In general, vessel-based data were categorized as "seismic", "post-seismic", or "non-seismic". "Seismic" included all data collected from the source vessel (*Discoverer*) while the airguns were operating. Data collected during "post-seismic" periods from 3 min to 1 h (for pinnipeds) or 2 h (for cetaceans) after cessation of seismic activity were considered either "recently exposed" (3–30 min) or "potentially exposed" (30 min to 1 or 2 h) to seismic sound levels, and were excluded from analyses. "Non-seismic" included all data obtained before the airguns were activated (pre-seismic) or after the "post-seismic" period.

Marine mammal sightings during the "seismic" and "non-seismic" periods were used to calculate sighting rates. Sighting rates were then used to calculate the corresponding densities of marine mammals near the survey and chase vessels during seismic and non-seismic periods. These densities were used to estimate the numbers of marine mammals that may have been exposed to various levels of ensonification to determine the estimated take by harassment.

Monitoring and Mitigation Results (Chapter 7).—Marine mammal observers aboard the *Discoverer* conducted 2664 km and 345 h of visual observation and MMOs aboard the chase vessels conducted 2055 km and 194 h of visual observation, together documenting 74 sightings of 110 pinnipeds and 18 sightings of 30 cetaceans (Table ES.1). There were numerous sightings of supply and chase vessels within 5 km of each of the observation vessels.

Based on the estimated densities of marine mammals in the Chukchi Sea during this project, about 12,298 individual seals, 112 Pacific walruses, and 696 cetaceans would be expected to occur within the areas ensonified to ≥160 dB re 1 μPa_{rms} at some time during the field season, if they did not move away from the vessel in response to the seismic sounds. Corresponding estimates in GXT's IHA applications for seals, walruses and cetaceans were 19,397, 2359 and 1396, respectively.

TABLE ES.1. Summary of *Discoverer* and chase vessel, *Octopus,* operations, observer monitoring effort, and marine mammal sightings during GXT marine geophysical surveys in the Chukchi Sea 2006.

	Non-Seismic			Seismic			
	Useable	**Other**	**Post-seismic**	**Useable**	**Other**	**Total Useable**	**Total**
A. Discoverer							
Total observer effort in h	7	86	12	43	197	50	**345**
Total observer effort in km	49	597	79	361	1578	410	**2664**
Marine mammal sightings (indv.)							
Cetaceans	0	0	0	1(1)	0	1(1)	**1(1)**
Pinnipeds in water	0	4(4)	0	3(5)	3(3)	3(5)	**10(12)**
Pacific Walrus	0	0	0	1(3)	0	1(3)	**1(3)**
Power downs/shut downs							**0/1**
B. *Octopus*							
Total observer effort in h	157	37	N/A	N/A	N/A	157	**194**
Total observer effort in km	1734	321	N/A	N/A	N/A	1734	**2055**
Marine mammal sightings (indv.)							
Cetaceans	N/A	15(25)	N/A	N/A	N/A	N/A	15(25)
Pinnipeds in water	57(91)	7(9)	N/A	N/A	N/A	57(91)	**64(100)**
Pacific Walrus	1(2)	0	N/A	N/A	N/A	1(2)	**1(2)**
Unidentified Pinniped	1(1)	0	N/A	N/A	N/A	1(1)	**1(1)**

Note: N/A means not applicable.

[a] See *Acronyms and Abbreviations for description of "useable" sightings.*

1. BACKGROUND AND INTRODUCTION[1]

GX Technology (GXT) collected marine seismic data in the Chukchi Sea during the fall of 2006 in support of potential future oil and gas leasing and development. Deep seismic acquisition for GXT was conducted in the Chukchi Sea using the M/V *Discoverer*, a seismic vessel that towed an airgun array as well as hydrophone streamer to record reflected seismic data.

Marine seismic surveys emit strong sounds into the water (Greene and Richardson 1988; Tolstoy et al. 2004a,b), and have the potential to affect marine mammals, given the reported auditory and behavioral sensitivity of many such species to underwater sounds (Richardson et al. 1995; Gordon et al. 2004). The effects could consist of behavioral 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 cetaceans and pinnipeds inhabit parts of the Chukchi Sea. Several species listed as "Endangered" under the ESA do or may occur in portions of the survey area, including the bowhead whale (*Balaena mysticetus*) and perhaps the fin whale (*Balaenoptera physalus*). The National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) share jurisdiction over the marine mammal species that were likely to be encountered during this project. USFWS manages two species occurring in the Chukchi Sea, the Pacific walrus (*Odobenus rosmarus*) and the polar bear (*Ursus maritimus*); NMFS manages all the other marine mammals occurring in the Chukchi Sea.

Other species of concern (birds) that might occur in the survey area are the spectacled (*Somateria fischeri*) and Steller's (*Polysticta stelleri*) eiders that are listed as "Threatened" under the ESA. Of the two species, spectacled eiders are likely to be more abundant in the project area and use some lagoon systems in the Chukchi Sea during their molt migration.

On 3 Apr. 2006, GXT requested that NMFS issue an Incidental Harassment Authorization (IHA) to authorize non-lethal "takes" of marine mammals incidental to GXT's planned seismic operations in the Chukchi Sea (GXT 2006a). The IHA was requested pursuant to Section 101(a)(5)(D) of the MMPA. An IHA to cover GXT's seismic exploration activities in the Chukchi Sea was issued by NMFS on 23 Aug. 2006 (effective dates 15 Aug. through 31 Dec. 2006; NMFS 2006a; Appendix A). The IHA authorized "potential take by harassment" of various cetaceans and pinnipeds during the marine geophysical cruises described in this report. On 15 Mar. 2006, GXT also requested from USFWS an IHA to authorize potential "taking" of Pacific walruses and polar bears in the Chukchi Sea (GXT 2006b). USFWS issued that IHA to GXT on 29 June 2006 (Appendix B).

This document serves to meet reporting requirements specified in the IHAs. The primary purposes of this report are to describe the seismic survey in the Chukchi Sea, to describe the associated marine mammal monitoring and mitigation programs and their results, and to estimate the numbers of marine mammals potentially exposed to levels of sound generated by the project at or above presumed effect levels.

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[1] Chapter 1 by R. Rodrigues, D. Ireland, B. Haley and M. Jankowski (LGL).

Incidental Harassment Authorization

IHAs issued to seismic operators include provisions to minimize the possibility that marine mammals close to the seismic sources might be exposed to levels of sound high enough to cause hearing damage or other injuries. During this project, sounds were generated by the *Discoverer's* airguns, as used during the seismic study. No serious injuries or deaths of marine mammals were anticipated from the seismic surveys, given the nature of the operations and the mitigation measures that were implemented, and no injuries or deaths were attributed to these activities. 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 C provides further background on the issuance of IHAs relative to seismic operations and "take".

Under current NMFS guidelines (e.g., NMFS 2005a, 2006a), "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}[2] for cetaceans and ≥190 dB re 1 μPa_{rms} for pinnipeds. Those safety radii are based on an assumption that seismic pulses received at lower received levels will not 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 the numbers of cetaceans and pinnipeds exposed to sound levels exceeding 180 and 190 dB (rms), respectively. The development and implementation of the safety radii for the current project are discussed in detail in Appendix C.

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 airguns or perhaps by sonar (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. 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 and pinnipeds are generally less responsive than baleen whales (e.g., Stone 2003; Gordon et al. 2004), and 170 dB (rms) may be a more appropriate criterion of potential behavioral disturbance for those groups (LGL Ltd. 2005a,b). In general, disturbance effects are expected to depend on the species of marine mammal, the activity of the animal at the time of disturbance, distance from the sound source, the received level of the sound and the associated water depth. Some individuals may exhibit behavioral responses at received levels somewhat below the nominal 160 or 170 dB (rms) criteria, but others may tolerate levels somewhat above 160 or 170 dB without reacting in any substantial manner. For example, migrating bowhead whales in the Alaskan Beaufort Sea show avoidance at received levels

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[2] "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, 2000a,b). 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. Received levels of pulsed sounds can also be described on an energy or "Sound Exposure Level" basis, for which the units are dB re $(1\ \mu Pa)^2 \cdot s$. The SEL value for a given airgun pulse, in those units, is typically 10–15 dB less than the rms level for the same pulse (Greene 1997; McCauley et al. 1998, 2000a,b), with considerable variability (Madsen et al. 2006; see also Chapter 4 of this report). SEL (energy) measures may be more relevant to marine mammals than are rms values, but the current regulatory requirements are based on rms values.

substantially lower than 160 dB re 1 μPa_{rms} (Miller et al. 1999; Richardson et al. 1999). In contrast, bowhead whales on the summer feeding grounds tolerate received levels of 160 dB or sometimes more (Richardson et al. 1986; G. Miller et al. 2005). Beluga whales also show avoidance at levels below 160 dB (G. Miller et al. 2005).

A notice regarding the proposed issuance of an IHA for the survey in the Chukchi Sea was published by NMFS in the *Federal Register* on 2 June 2006 and public comments were invited (NMFS 2006b). On 23 Aug. 2006, NMFS published a second notice in the *Federal Register* to announce the issuance of the IHA (NMFS 2006a). The second notice responded to 18 comments received by NMFS during the 30-day public comment period. A copy of the IHA is included in this report as Appendix A. The IHA issued by NMFS to GXT authorized harassment "takes" of one ESA-listed species, the bowhead whale, as well as non-listed species including gray (*Eschrichtius robustus*), killer (*Orcincus orca*), and beluga (*Delphinapterus leucas*) whales, harbor porpoise (*Phocoena phocoena*), and ringed (*Phoca hispida*), spotted (*Phoca largha*), and bearded (*Erignathus barbatus*) seals.

NMFS granted the IHA to GXT 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,
- there would be no unmitigated adverse effects on the availability of marine mammals for subsistence hunting in Alaska, and
- the agreed upon monitoring and mitigation measures would be implemented.

USFWS determined in 2006 that proponents of arctic seismic projects should operate under IHAs issued by USFWS. The process of obtaining an IHA from USFWS was very similar to that of obtaining one from the NMFS. In Mar. 2006, GXT requested an IHA from USFWS for the incidental taking of walruses and polar bears in conjunction with seismic activities in the Chukchi Sea (GXT 2006b). A notice regarding the proposed issuance by USFWS of an IHA for the survey in the Chukchi Sea was published in the *Federal Register* on 8 May 2006 and public comments were invited (USFWS 2006). USFWS did not publish a second notice in the *Federal Register* to announce the issuance of the IHA. This IHA was issued to GXT by USFWS on 29 June 2006 and was valid through 30 Nov. 2006 (Appendix B). A copy of the USFWS IHA is included in this report as Appendix B. The IHA required GXT to observe a 190 dB safety radius for walruses and polar bears. It also mandated that an 800 m (0.5 mi.) exclusion zone around walruses and polar bears, observed on land or ice, be maintained by vessels during travel status. The USFWS IHA did not allow seismic operations within a 64 km (40 mi.) radius of communities where nearshore subsistence hunting might be affected.

Mitigation and Monitoring Objectives

The objectives of the mitigation and monitoring program were described in detail in GXT's IHA application (GXT 2006a) and in the IHA issued by NMFS to GXT (Appendix A). Explanatory material about the monitoring and mitigation requirements was published by NMFS and USFWS in the *Federal Register* (NMFS 2006a,b; USFWS 2006).

The main purpose of the mitigation program was to avoid or minimize potential effects of GXT's seismic survey on marine mammals. This required that shipboard personnel detect marine mammals

within or about to enter the safety radii (190 dB for pinnipeds and polar bears, 180 dB for cetaceans), and in such cases initiate an immediate power down (or shut down if necessary) of the airguns. A power down involves reducing the source level of the operating airguns, in this case by reducing the air volume. A shut down involves temporarily terminating the operation of all airguns. An additional mitigation objective was to detect marine mammals within or near the safety radii prior to starting the airguns, or during ramp up toward full power. In these cases, the start of airguns was to be delayed or ramp up discontinued until the safety radius was free of marine mammals insofar as this can be determined visually for a period of 30 minutes (see Appendix A and Chapter 6).

In 2006 mitigation was also required, as specified by the NMFS IHA, at the 160 dB isopleth. This area was monitored by the chase boat that accompanied the seismic vessel. Power down of the seismic airgun array was required if an aggregation of 12 or more non-migratory bowhead or gray whales was detected ahead of, or perpendicular to, the seismic vessel track and within the 160 dB isopleth. Monitoring of the 120 dB isopleth around the seismic vessel(s) was also required after 25 September in the Chukchi Sea. Power down would be required if 4 migratory cow/calf pairs were detected within the surveyed 120 dB isopleth.

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; and
3. determine the reactions (if any) of marine mammals potentially exposed to seismic sound impulses.

Specific mitigation and monitoring objectives identified in the IHA are described in Appendices A and B. Mitigation and monitoring measures that were implemented during the activities in the Chukchi Sea are described in detail in Chapter 5.

This 90-day report describes the methods and results for the monitoring work specifically required to meet the above primary objectives. Various other marine mammal and acoustic monitoring and research programs not specifically tied to the above objectives were also implemented by GXT (or by GXT plus other industry operators) in the Chukchi Sea during 2006. Results of those additional efforts are, for the most part, not mentioned in this 90-day report. Those additional results will be reported at a later date.

Report Organization

The primary purpose of this report is to describe the 2006 seismic survey activities in the Chukchi Sea including the associated monitoring and mitigation programs, and to present results as required by the IHAs (see Appendix A and B). This report includes seven chapters:

1. background and introduction (this chapter);
2. description of GXT's seismic study;
3. sound source and propagation modeling prior to the field season;
4. sound source measurements during the field season;
5. determination of sound propagation based on the use of field measurements in the modeling program,
6. description of the marine mammal monitoring and mitigation requirements and methods, including safety radii; and

7. 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 nine Appendices that provide copies of relevant documents and details of procedures that are more-or-less consistent during seismic surveys where marine mammal monitoring and mitigation measures are in place. These procedural details are only summarized in the main body of this report. The Appendices include

A. a copy of the IHA issued by NMFS to GXT for this study;

B. a copy of the IHA issued by USFWS to GXT for this study;

C. background on development and implementation of safety radii;

D. characteristics of the *Discoverer*;

E. details on visual and acoustic monitoring, mitigation, and data analysis methods;

F. conservation status and densities of marine mammals in the project region;

G. monitoring effort and list of marine mammals seen or heard during this cruise;

H. marine mammal sightings with power downs and shut downs during the seismic activities;

I. marine mammal density estimates for the project area.

2. SEISMIC SURVEY DESCRIBED[3]

The *Discoverer* was used as the source vessel during GXT's 2D seismic exploration activities in the Chukchi Sea in 2006. The *Discoverer* was accompanied by the *Octopus*, a support vessel (chase vessel). Sound source measurements of GXT's airgun array were conducted in the Chukchi Sea in the summer prior to the fall seismic survey activities (see Chapters 3, 4, and 5 below for details on sound source modeling and measurements). Appendix D contains a description of the vessels used during the seismic activities. These vessels operated in accordance with the provisions of a Conflict Avoidance Agreement (CAA) between the seismic industry, the Alaska Eskimo Whaling Commission (AEWC), and the Whaling Captains Associations with respect to subsistence activities including but not limited to the hunts for bowhead and beluga whales. The objective of the CAA was to provide avoidance and other mitigation guidelines to be followed by industry participants working in or transiting the vicinity of active whaling crews. Under the terms of the CAA, communication centers were established at Barrow and Deadhorse, and Call Centers at Pt. Hope, Pt. Lay, Wainwright, and Kaktovik. The CAA outlined a communication program and specified times and areas to be surveyed in order to avoid any possible conflict with the subsistence hunts.

Operating Areas, Dates, and Navigation

The geographic region where the deep seismic survey occurred was located in the Chukchi Sea MMS OCS Program Area designated as Chukchi Sea Lease Sale 193 (1989) and in the proposed 2002-2007 Chukchi Sea Program Area (Fig. 2.1). In general, seismic acquisition occurred in the Chukchi Sea well offshore from the Alaska coast in OCS waters averaging greater than 40 meters (m) or 131 ft deep and outside the polynya zone.

The *Discoverer* entered the Chukchi Sea in Aug. to measure the sound propagation from its source array to verify the extent of various radii to be used for mitigation purposes during the exploration activities (see Chapter 4 below). Those radii had been predicted prior to the field season via acoustic modeling procedures (see Chapter 3), but site-specific empirical measurements were required to confirm or refine the predictions. The airgun sounds were recorded as a function of airgun configuration, distance, and aspect on 20-21 Aug., and safety and disturbance radii based on these measurements were determined within 72 h. The *Discoverer* departed the Chukchi Sea after completion of the sound source measurements.

The *Discoverer* returned to the Chukchi Sea on 7 Oct. to conduct seismic exploration activities and deployed the seismic equipment on 12 Oct. Seismic acquisition began on 13 Oct. 2006 and continued through most of the field season until 11 Nov. when the *Discoverer*'s airguns and streamer were retrieved. GXT completed a total of ~4707 km (2924 statute mi) of deep-seismic survey line in the Chukchi Sea in 2006, ~1939 km (1205 statue mi) of which was conducted during daylight conditions .

Throughout the survey the *Discoverer's* position, speed, and water depth were logged digitally every ~60 s. In addition, the position of the *Discoverer*, water depth, and information on the airgun array were logged for every airgun shot while the *Discoverer* was on a seismic line and collecting geophysical data. The geophysics crew kept an electronic log of events, as did the marine mammal observers (MMOs) while on duty. The MMOs also recorded the number and volume of airguns that were firing when the *Discoverer* was offline (e.g., prior to shooting at full volume) or was online but not recording data (e.g., during airgun or computer problems).

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[3]Chapter 2 by R. Rodrigues, B. Haley, and D. Ireland (LGL)

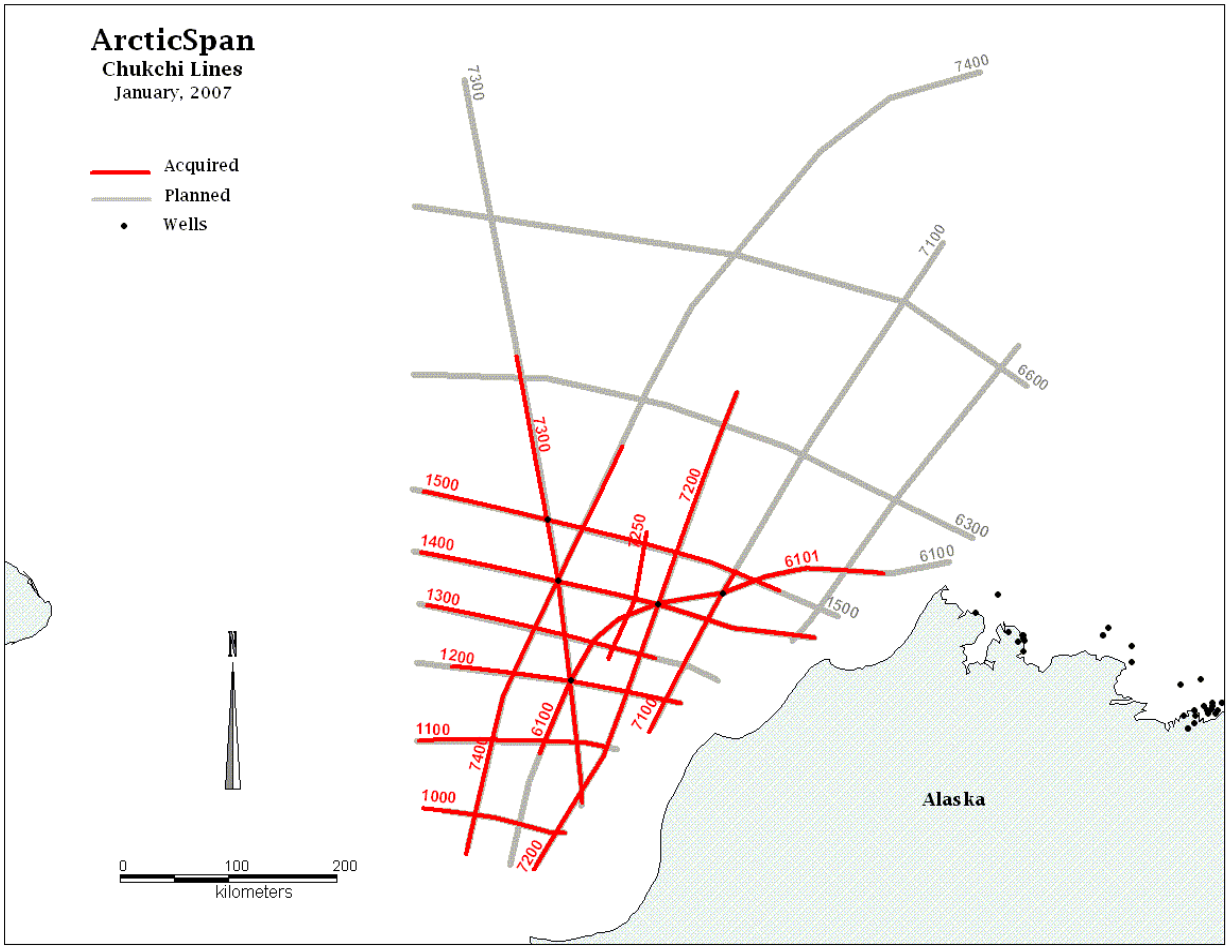

Figure 2-1. GXT's 2006 seismic survey tracklines in the MMS Chukchi Sea Lease Sale 193 .

Airgun Characteristics

GXT used a bolt/sleeve airgun array with a discharge volume of 3320 in^3 and a single hydrophone streamer for its 2-D seismic survey operations in the Chukchi Sea. GXT's airguns ranged in size from 40 to 150 in^3 and operated at an air pressure of 2000 psi. This energy source was towed ~50 m behind the *Discoverer* at a depth of 8.5 m The system also included a single hydrophone streamer 9 km in length which recorded reflected sound energy. In general, the *Discoverer* towed this system along a predetermined survey track although adjustments were made during the course of the field season in accordance with ice conditions.

Air compressors aboard the *Discoverer* were the source of high pressure air used to operate the airgun arrays. Seismic pulses were emitted at intervals of ~46 m (~20 s) while the *Discoverer* traveled at a speed of 4 to 5 kt (7.4-9.3 km/h). Characteristics of the airgun arrays are detailed in Appendix D.

Pinger

In addition to the airgun array, GXT also used a pinger system to position the 36-airgun array and streamer relative to the vessel. The pinger system (DigiRANGE I and II, Input/Output, Inc.) emited sounds

as very short pulses, occurring for 10 ms, with a source level ~180 dB re 1 μPa·m at 55 kHz, ~188 dB re μPa·m at 75 kHz, and ~184 dB re 1 μPa·m at 95 kHz. One pulse was emitted on command from the operator aboard the source vessel, which under normal operating conditions was once every ~10 s. Most of the energy in the sound pulses emitted by this pinger was at very high frequencies between 50 and 100 kHz. The signal was omnidirectional.

3. SUMMARY OF ACOUSTIC MODELING FOR CHARACTERIZATION OF AIRGUN ARRAY NOISE[4]

INTRODUCTION

This chapter presents a summary of the underwater noise estimation performed for GX Technology (GXT) prior to the 2006 seismic survey program in the Alaskan Chukchi Sea. The underwater noise estimation consisted of pre-season computer modeling of noise emissions from the proposed airgun array, which was later followed by field acoustic verification measurements of the airgun array. Model results were used to define preliminary marine mammal exclusion zones that were implemented during empirical measurements of the source array (Chapter 4). The field verification measurements were completed in late August 2006. Measurements of root-mean-square (*rms*) sound level as a function of distance from the airgun array in endfire and broadside directions were presented in the 72-hour field report by Austin et al. (2006). Those results were used to establish marine mammal exclusion zones that were implemented for the remainder of the seismic program.

Airgun array emission and acoustic propagation models were applied to compute the three-dimensional sound fields produced by GXT's four-string 3320 in^3 seismic array operating in the target areas. The modeling was done at four locations in the Chukchi Sea, one of which coincided with the location where the verification measurements in the field were done to cover different water depth ranges and geological properties of the areas at which the array would be operated.

Acoustic Modeling Methodology

JASCO Research's Marine Operations Noise Model (MONM) is an integrated sound prediction model comprising an airgun array source model and an acoustic propagation model. It computes 3-dimensional sound fields produced by seismic surveys, accounting for the influences of ocean sound speed variations, bathymetric profile and geoacoustic parameters of the seabed. Given the airgun array characteristics and sound propagation environment, the model generates estimates of received acoustic level as a function of direction and distance from the airgun array. This is achieved through the combination of airgun array source level modeling and directional propagation modeling in individual frequency bands, both of which are briefly reviewed here.

Airgun Array Source Model

The airgun array source model (AASM), which is part of MONM, predicts composite sound pressure signatures of airgun array systems (MacGillivray 2006). It simulates the throttled injection of high-pressure air from individual airgun chambers producing underwater air bubbles, and then models the complex oscillation of each bubble, taking into account the pressure effects of the pressure waves from all other airguns in the array. It includes effects from surface-reflected pressure waves, heat transfer from the bubbles to the surrounding water, and the buoyancy of the bubbles themselves. The result is a high-resolution notional pressure signature for each airgun. These pressure signatures are fed to a directivity module that applies appropriate time delays and amplitude scaling to compute the pressure signature

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[4]By Alex MacGillivray and David Hannay, JASCO Research Ltd., 2101-4464 Markham Street, Victoria, B.C. Canada, V8Z 7X8.

pattern in any direction relative to the array heading. AASM was applied here to model the 3320 in^3 airgun array used by GXT for the 2006 seismic survey. The array consisted of 36 individual guns, distributed in four substrings. Examples of the model output for this array in the broadside (sideways to tow direction) and endfire (directly behind and forward of the array) in the horizontal plane are given in Fig. 3.1. Separate arrivals of primary pulse pressure signatures from the four array substrings are apparent in the expanded signatures plot (Fig. 3.2) for the broadside direction. The modeled directivity patterns as a function of frequency are shown in Fig. 3.3.

Acoustic Propagation Model

A wide-angled parabolic equation (PE) acoustic propagation model is utilized within MONM. The specific PE code is based on the Naval Research Laboratory's Range-dependent Acoustic Model (RAM). This code has been benchmarked for accuracy and is widely employed in the underwater acoustics community (Collins 1993). The model has been augmented to account for shear wave losses in the seabed using the complex density approach (Zhang and Tindle 1995).

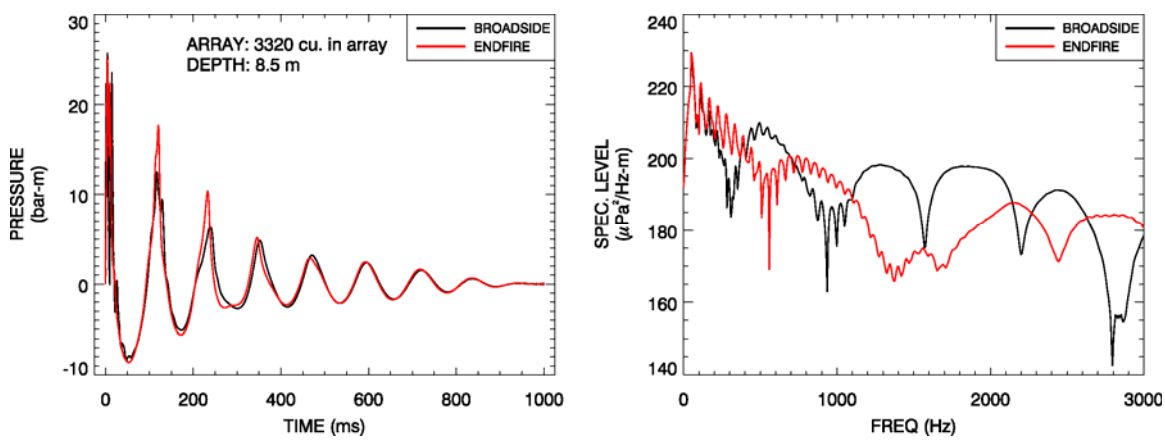

FIGURE 3.1. Broadside (black) and endfire (red) overpressure signatures and power spectrum for the 3320 in^3 array operated at a depth of 8.5m. Surface ghosts are not included in these signatures.

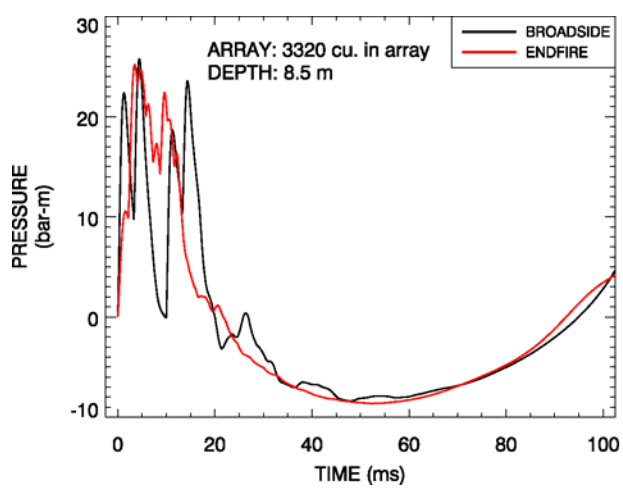

FIGURE 3.2. Expanded plot of the first 100 ms of broadside (black) and endfire (red) overpressure signatures.

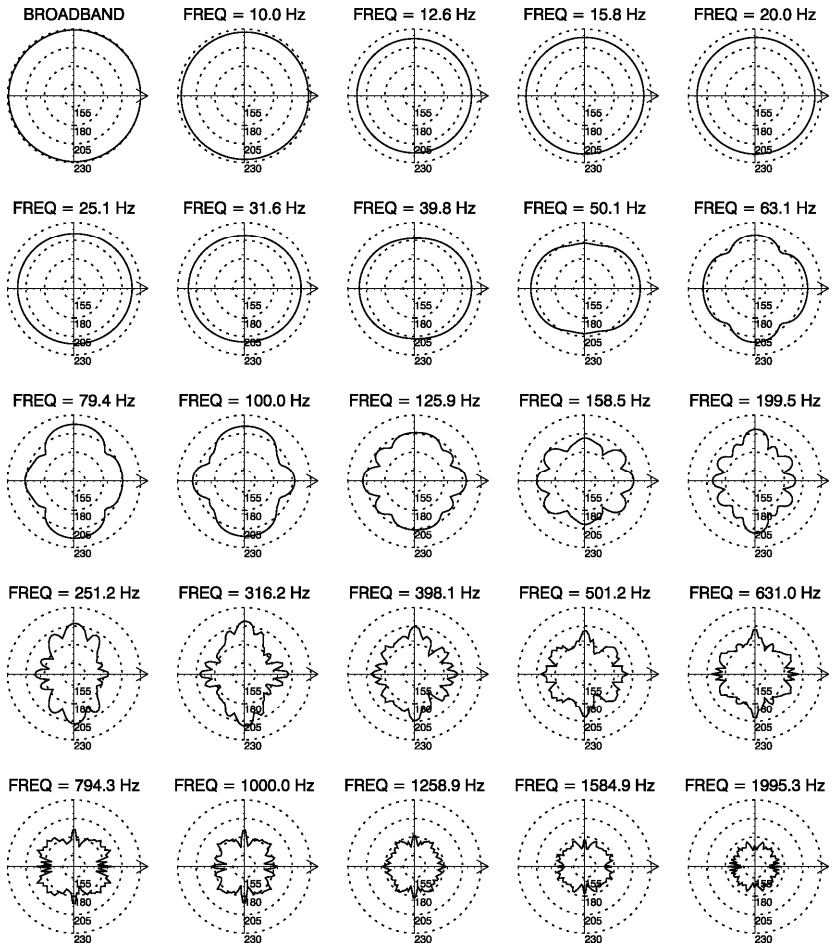

FIGURE 3.3. Airgun Array directivity patterns computed by AASM for frequencies from 10 Hz to 2 kHz. Broadband pattern is shown in top left corner.

MONM computes acoustic fields in three dimensions by modeling transmission loss along evenly spaced 2-D radial traverses covering a 360º swath from the source. This approach is referred to as N×2-D. MONM fully treats variations of several environmental parameters including bathymetry and sound speed profiles in the water column and the sea floor. It also treats layer reflection losses incurred by downgoing compressional waves that partly convert to shear waves. Compressional wave and shear wave attenuations are specified in all layers. The model samples the acoustic environment at a predetermined range step along radial traverses.

Frequency dependence is treated by computing acoustic transmission loss at the center frequencies of all 1/3-octave bands between 10 Hz and 2 kHz. This frequency range includes the important bandwidth of noise emissions for airgun array systems. 1/3-octave band received levels are computed by subtracting band transmission loss values from the band source levels. Broadband received levels are computed by summing the received band levels. MONM's sound propagation predictions have been validated both against industry standard benchmarks and against experimental data (Hannay and Racca 2005).

Environmental data for each modeling location, such as bathymetry, water column profiles, and geology were obtained from various sources for the appropriate times of year. For locations in the Chukchi Sea, water column data appropriate to the month of August at each specific site were used.

SURVEY NOISE MODELING RESULTS

MONM was used to predict the sound level footprint of the GXT seismic survey operations for the purpose of estimating takes of marine mammals, and for predicting the initial marine mammal exclusion zones (safety radii). Prior to the field season, the modeling was conducted for one location in the Chukchi Sea (Zykov et al. 2006). Three additional model runs in the Chukchi Sea, including one at the measurement site to be used for direct comparison of model and field data, were performed at a later time (Zykov et al. 2007). The location of the model sites and extent of the respective modeling boundaries are shown in Fig. 3.4. For each site the geo-acoustic properties of the bottom were estimated based on the best available knowledge of the local geology (Zykov et al. 2007).

The model generated estimates of received sound level as a function of direction and distance from the airgun array system. Broadband unweighted Sound Exposure Level (SEL) noise results were computed from the model output. Fig. 3.5 provides an example of a fully rendered noise contour map from the modeling at location C2.

Representative equivalent ranges for the irregular sound level isopleths were computed as the radius from the source that encompassed 95% of the area ensonified at or above the level of a given isopleth. This is a reasonable estimator for defining safety radii for noise mitigation of industrial marine operations, as it tends to yield more conservative radii than an equal-area conversion for the strongly anisotropic contour footprints typical of airgun noise propagation. In addition to computing radii based on flat-weighted broadband levels (each frequency band counting equally), a recently proposed

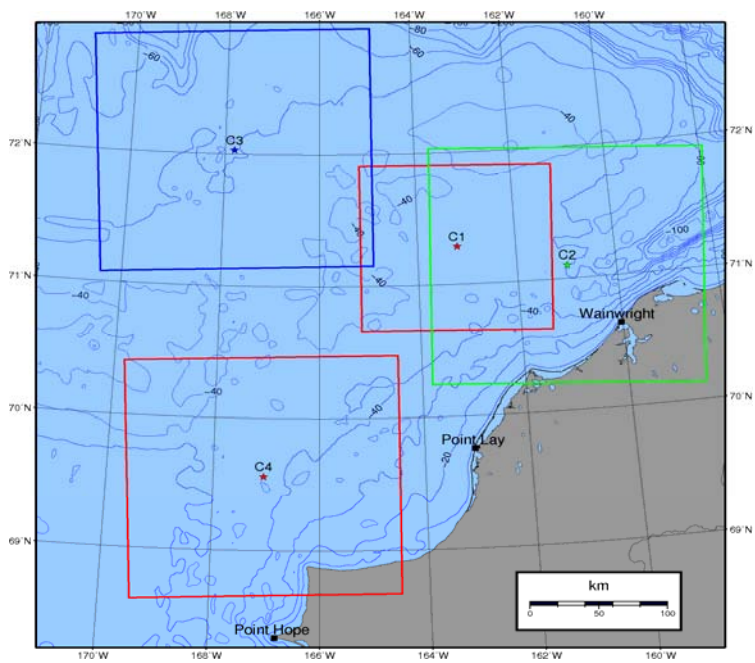

FIGURE 3.4. Modeled sites in the Chukchi Sea. Stars indicate source locations; boxes of the corresponding color denote model grid boundaries.

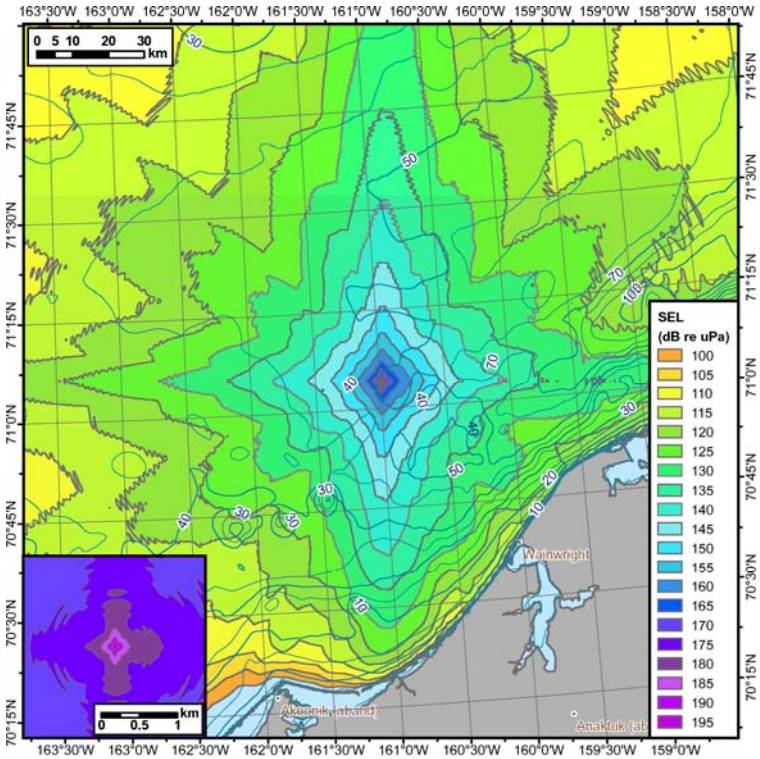

FIGURE 3.5. Contours of constant received SEL values (with expanded view at short ranges in inset) at C2 location for a receiver depth of 10m for the 3320 in^3 array, being towed west.

frequency weighting scheme for marine mammals referred to as M-weighting was also applied to take into account the frequency dependence of hearing for low-frequency cetaceans (bowheads), mid-frequency cetaceans (belugas) and pinnipeds (seals, sea lions and walruses). Effective radii to levels between 120 dB and 190 dB rms were computed based on the unweighted and M-weighted levels for different categories. Of these, the extreme case radii for the unweighted (maximum range) and mid-frequency M-weighted (minimum range) levels are presented for all locations in Table 3.1 and Table 3.2.

TABLE 3.1. Radii encompassing 95% of the contour area for the specified SELs, for the 3320 in^3 array, flat-weighted, for all four locations in the Chukchi Sea).

Flat-w SEL [dB re µPa]	C1	C2	C3	C4
110	58.9	>100	>100	72.7
120	43.8	88.4	>100	46.9
130	30.5	70.5	90.3	29.6
140	18.8	36.1	60.5	20.1
150	10.4	14.6	23.3	12.4
160	5.55	6.82	7.80	6.52
170	2.06	2.71	2.21	2.71
180	0.45	0.44	0.24	0.75
190	0.09	0.09	0.08	0.11

TABLE 3.2. Radii encompassing 95% of the contour area for the specified SELs, for the 3320 in^3 array, M-weighted for mid-frequency cetaceans, for all four locations in the Chukchi Sea).

M-w (mf) SEL [dB re µPa]	C1	C2	C3	C4
110	56.1	>100	>100	66.3
120	40.9	85.3	>100	43.4
130	28.3	65.8	90.7	26.8
140	16.9	32.5	53.2	15.7
150	8.07	12.00	19.0	8.07
160	2.85	3.61	4.55	3.10
170	0.70	0.65	0.50	0.85
180	0.10	0.13	0.07	0.10
190	0.020	0.020	0.020	0.020

The SEL metric has recently been recognized by a National Marine Fisheries Science (NMFS) committee as being the most suitable for gauging noise impact on marine mammals as it accounts for the entire acoustic energy delivered to the subject. The currently endorsed NMFS safety radii thresholds, however, are still expressed in terms of root-mean-square (rms) levels, requiring conversion of the modeled values to this metric. The rms metric is based on an integration interval corresponding to the pulse length of the received signal, generally defined as the shortest time window containing 90% of the pulse energy (90% rms). Computation of 90% rms levels from SEL requires knowledge of this pulse length, which in shallow water can be quite variable and dependent on several factors such as seabed composition, water sound speed profile and distance from the source. While received pulse length can be readily obtained from direct acoustic measurements in the field, its estimation at the modeling stage requires carrying out full-waveform model runs using a Fourier decomposition modeling approach. This process is formally precise but requires extensive computational effort. A nominal conversion offset of +10 dB from SEL to 90% rms, corresponding to a pulse arrival duration of 100ms, is commonly used but cannot account for specific propagation conditions. For this study, full waveform modeling was carried out for each scenario using the same environmental parameters used for the sound propagation modeling. The output from the full-waveform model runs allowed rigorous conversion between SEL and 90% rms values. For the deep water sites (B3 and B4), however, the method could not provide a meaningful pulse length estimation due to the multiple arrival features of the model synthesized seismograms, which blurred the interpretation of received pulse length. In this case the nominal conversion offset of 10 dB was used.

The resulting 90% rms based radii computed from unweighted modeling results for the Chukchi Sea sites are presented in Table 3.3, which also shows the equivalent SEL levels. Of particular importance are the ranges to the 180 and 190 dB rms levels, as these are the NMFS sanctioned safety radii for cetaceans and pinnipeds, respectively.

TABLE 3.3. Radii encompassing 95% of the contour area and equivalent SEL values for the specified 90% rms levels at modeling sites in the Chukchi Sea.

90% rms level [dB re µPa]	C1		C2		C3		C4	
	SEL	radii [km]	SEL	radii [km]	SEL	radii [km]	SEL	radii [km]
120	118	51.1	118	92.0	118	>100	118	51.0
130	128	37.6	128	77.5	128	91.1	128	32.3
140	138	24.3	138	41.6	138	70.0	138	21.8
150	148	12.2	148	17.7	148	28.7	148	13.9
160	158	6.65	158	8.10	158	9.58	158	7.62
170	168	3.69	168	2.98	168	2.93	168	3.02
180	175	1.81	175	1.46	175	0.90	175	1.35
190	183	0.45	183	0.25	183	0.20	183	0.35

CONCLUSIONS

The modeling of GXT's airgun array used in their 2006 Alaskan Chukchi Sea seismic survey program has provided a detailed forecasting of the noise characteristics generated. These estimates are likely to be considerably more accurate than could be achieved with simpler models that do not take into account site specific environmental conditions such as sound velocity profile, water depth, and bottom and sub-bottom characteristics. All of these factors are taken fully into account in JASCO's modeling, to the extent that these variables are known at the modeling stage. The model results showed that the noise propagation properties in the essentially flat-bottomed Chukchi Sea (water depth ranging from 41m to 56m across sites) are primarily determined by the variations in geo-acoustic parameters of the surficial and sub-bottom sediments.

Species-specific sensitivity weighting was applied to the model results to provide alternative safety radii that account for the relative sensitivity of different marine mammal groups to low-frequency sounds such as those that dominate seismic airgun sound. M-weighting curves were applied for "mid-frequency" cetaceans such as beluga whales, and for pinnipeds in water. These weighting functions reduced the predicted safety radii for airgun noise by a small amount for pinnipeds and by a larger amount for mid-frequency cetaceans; the results for the latter have been included in the present summary along with the unweighted values. Although M-weighted radii are not formally endorsed at the present time by regulatory bodies such as NMFS, the results indicate that the standard unweighted results can be considered precautionary with respect to pinnipeds and belugas.

Predicted safety radii were computed for the 180 dB and 190 dB rms levels as sanctioned by NMFS for cetaceans and pinnipeds respectively, as well as for levels down to 120 dB that are regarded as relevant in terms of disturbance. The conversion of the modeled sound exposure results (SEL metric) to rms was performed rigorously through full-wavelength propagation modeling of the airgun array signals to estimate their received pulse length. Impact radii based on 95% encompassing of irregular noise contours are tabulated in this summary for all eight modeling locations; for the 180 dB rms level they ranged from a minimum of 600 m to a maximum of 2.3 km, whereas at the 120 dB level they ranged from 28 km to over 100 km.

4. FIELD MEASUREMENTS OF AIRGUN ARRAY SOUND LEVELS[5]

INTRODUCTION

GXT conducted a field measurement program to quantify noise levels produced by the seismic airgun array that was used for its seismic program in the Chukchi Sea, in fall 2006. The primary survey vessel for this program was the M/V *Discoverer*, operated by Shanghai Offshore Petroleum Geophysical Corporation (SOPGC), towing a 3320 in^3 36-airgun array while surveying. Seismic surveys with airguns have the potential to harass marine mammals. Thus, prior to obtaining permits for the survey, acoustic modeling was necessary to estimate potential exposure of marine mammals to noise and a field measurement program was proposed. JASCO Research Ltd. was contracted to carry out the acoustic modeling and field measurement programs to characterize the sound transmission associated with GXT's 2006 Arctic Span seismic survey program. The model results are provided in a separate report (Zykov et al. 2006, 2007; see also Chapter 3 in this report). This chapter details the final field measurement results. Chapter 5 provides a comparative discussion of the measured and modeled data.

Harassment of marine mammals is considered a 'take' under the Marine Mammal Protection Act (MMPA). NOAA's National Marine Fisheries Service (NMFS) currently defines two types of harassment: Level A that is likely to cause injury and/or harm, and Level B that is likely to cause a behavioral response. NMFS's policy considers root-mean-squared (*rms*) sound levels above 180 dB for cetaceans and 190 dB for pinnipeds as causing Level A harassment. Level B harassment is expected at exposures above 160 dB *rms*, and some disturbance may occur to bowhead whales with sound levels as low as 120 dB *rms* (Richardson et al. 1995). NMFS and Fish and Wildlife Service (FWS) can issue incidental harassment authorizations (IHA) under the MMPA to allow seismic surveys to take place when limited takes are expected. These IHA's often specify marine mammal exclusion zones that are based on the Level A sound level thresholds. Consequently the radii of the 190 dB and 180 dB re μPa (*rms*) zones were determined from pre-survey modeling. These estimates were verified during the verification field measurements that are described in the following sections.

OBJECTIVES

The field verification measurements of airgun array sound levels were performed in Aug. in the Chukchi Sea after which the *Discoverer* departed the Chukchi Sea until the start of the seismic acquisition program in early Oct. 06. The measurements were made on 20-21 Aug. 2006, during a dedicated study in which the *Discoverer* operated its airguns while transiting along a survey track that was designed specifically to obtain sound level measurements at various ranges in the endfire and broadside directions from the array.

The main objectives for the acoustic field measurements were to:

1. measure the distances from the airgun array at which 190, 180, 170, 160, 150, 140, 130 and 120 dB *rms* sound pressure levels were reached;
2. measure sound level values (peak, *rms*, and SEL) for the airgun pulses as a function of direction and distance from the source;

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3. characterize the spectral properties of the airgun pulses as a function of distance and direction from the array;
4. compare the measured results with pre-survey modeling estimates.

STUDY DESCRIPTION

The acoustic measurements were made using two of JASCO Research's Ocean Bottom Hydrophone (OBH) autonomous recording systems, deployed from the 120-foot support vessel M/V *Octopus*. The OBH's were deployed 900 m apart, near location 69°56'N 167°03'W. The verification measurements were planned for a location closer to the location modeled in the pre-season model study, at 71°15.1'N 163°11.7'W, but the occurrence of other seismic programs near that location precluded this. After deploying the OBHs, the *Octopus* departed the deployment area so its own noise would not contaminate the OBH recordings. The *Discoverer* performed airgun array shooting along a pre-planned noise level verification survey track. Approximately 16 hours of shot data were obtained from both OBHs as the *Discoverer* transited along the 6 lines of the track. The *Octopus* then returned to the survey area to recover the OBH systems.

The 36-airgun, 3320 in^3 array (layout shown in Fig, 4,1) was towed along the planned transit lines. Seismic pulses were emitted at intervals of ~20 s, which corresponded to shot spacings of ~46 m at the normal survey speed of ~4-5 knots (8.3 km/h). The array was towed approximately 50 m from the stern of the Discoverer at a depth of 8.5 m.

OBH deployment locations are shown relative to the verification shooting lines in Fig. 4.2. One of the OBHs (OBH-A) was located at 69°55.994'N, 167°3.049'W, directly on the first survey track line. The second OBH was positioned 900 m perpendicular to the track line (and from OBH-A) at 69°56.158'N, 167°4.395'W.

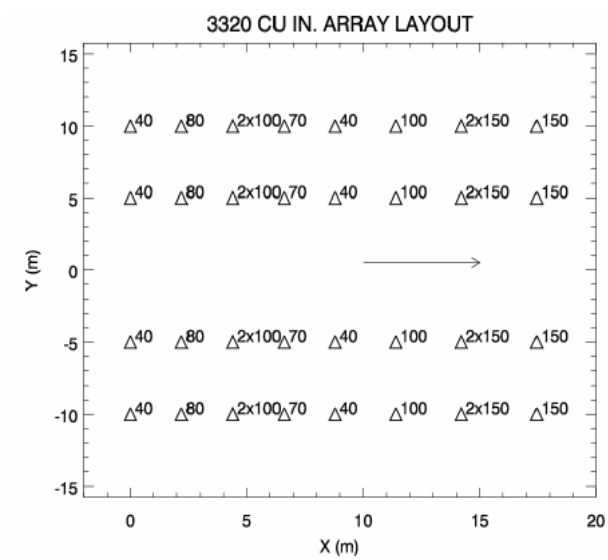

FIGURE 4.1. Plan view layout of GXT's 3320 in^3 airgun array. The front of the array is at the right. Note that the first 150 in^3 gun in each sub-array was a spare.

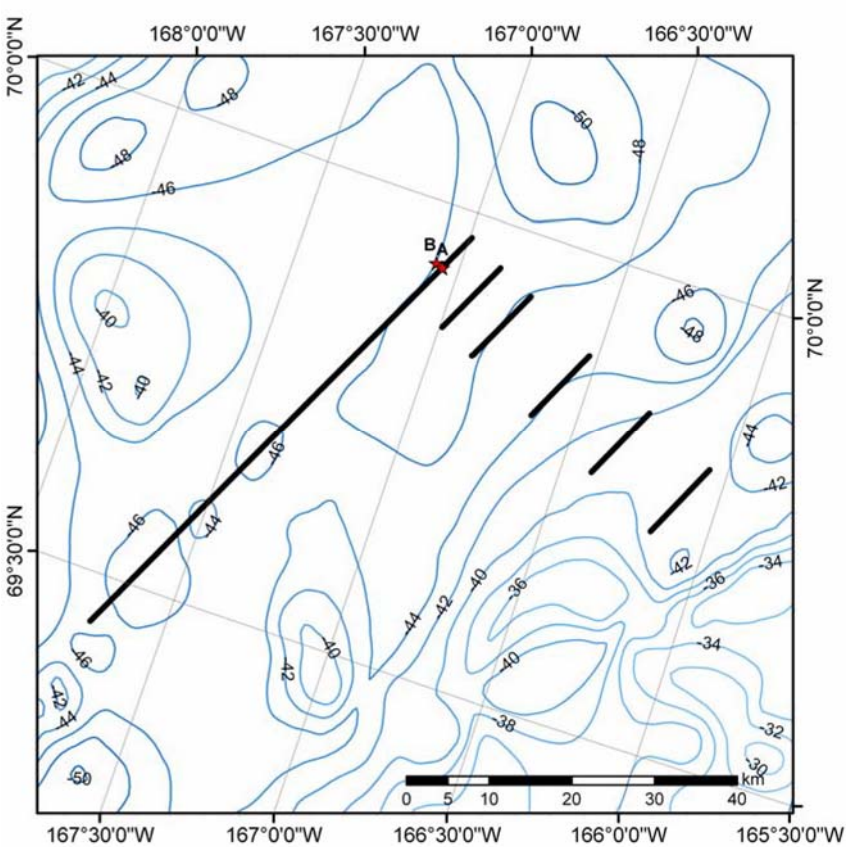

FIGURE 4.2. Discoverer track during verification measurements, and deployment locations of OBH-A and OBH-B (near northernmost end of long track line). Depths are in meters.

The verification shooting track was designed to provide measurements at multiple ranges from the airgun array in both the broadside and endfire directions. The longest survey line provided measurements to a maximum range of 65 km in the endfire direction, and the shorter lines provided measurements of the broadside direction, to a maximum range of 40 km.

The survey started at the southwest end of the long survey track (Line 1) at a range of 65 km from the OBH locations. The *Discoverer* traveled northeasterly toward the OBHs and eventually over top of OBH A (at a broadside range of 900 m from OBH B) and continued to a range of 5 km past OBH A. The *Discoverer* then made a gradual turn of 180 degrees to start southwesterly along Line 2. The *Discoverer* subsequently continued along the more southeast lines, transiting 10 km along each line. This geometry provided broadside aspect measurements at ranges of 5, 10, 20, 30 and 40 km.

Discoverer utilized its array in full capacity throughout the entire survey and there were no dropped guns or missed shots reported.

STUDY AREA AND ENVIRONMENT

Location

The acoustic measurement study area was located approximately 100 km offshore of the North coast of Alaska in the Chukchi Sea (Fig. 4.3). Water depth was uniform, with depth always between 40 to 46 m.

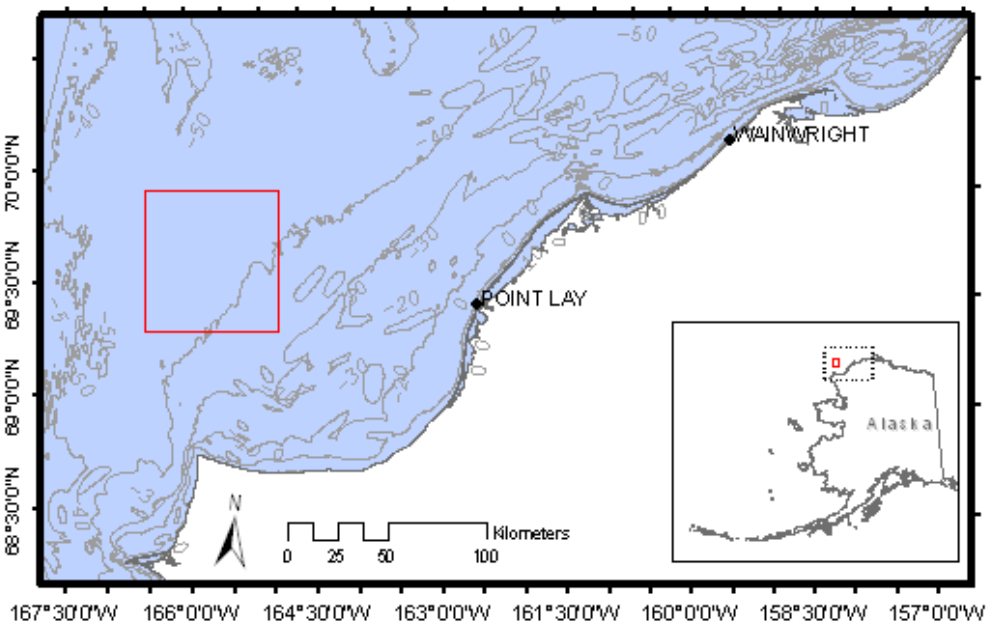

FIGURE 4.3. Acoustic measurement study location indicated with a red square off the North coast of Alaska in the Chukchi Sea.

Water Sound Speed Profile

Water column temperature and salinity profile measurements were taken during the field measurement program using a Seabird SBE 19 Seacat Profiler lowered by hand over the side of the *Octopus* to a maximum depth of 45 m. Sound speed (c) can be computed from temperature (T), salinity (S), and depth (D) based on the following equation:

$$c = 1449.2 + (4.6 \times T) - (0.055 \times T^2) + (0.00029 \times T^3) + (1.34 - (0.01 \times T)(S - 35)) + (0.016 \times D) \quad (1)$$

The average measured temperature and salinity profiles are presented in Fig. 4.4 with the computed sound speed profile.

Surface temperature was constant at approximately 6 degrees Celsius in the top 14 m. Temperatures below 14 m depth decreased with increasing depth, to about 3 degrees Celsius at 45 m depth. The salinity values increased slightly from 30.5 psu at the surface to 32 psu at 45 m depth. The resulting sound speed profile is most strongly influenced by temperature, showing a constant speed layer with speed 1470 m/s at the surface and then decreasing by 10-12 m/s at the bottom. This sound speed variation causes a slightly downward refracting acoustic environment.

METHODS

Acoustic Equipment

JASCO Research's OBH recording systems were used to make the airgun pulse noise recordings. The OBHs recorded high-resolution 24-bit digital audio at a sample rate of 32 kHz. They were deployed on the seabed using an expendable anchor weight that is fastened to the OBH by an acoustic release. The weight is released by the acoustic release when the system is pinged using a coded signal sent from the surface. A schematic of the OBH systems is shown in Fig. 4.5.

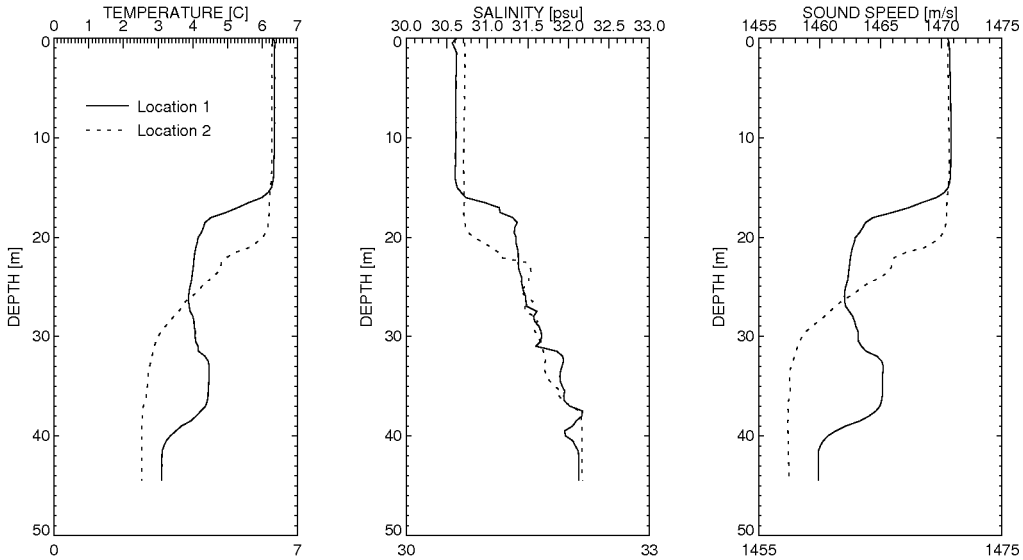

Figure 4.4. Average temperature (left), salinity (center), and computed sound speed (right) profiles measured within the acoustic measurement field study area.

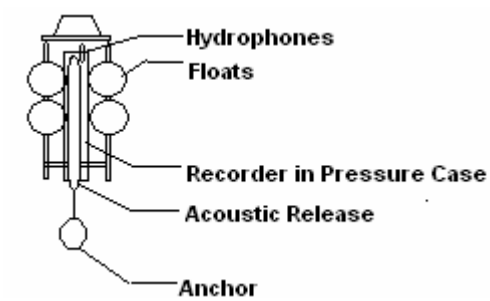

FIGURE 4.5. Schematic diagram of OBH system.

Both OBH systems were set up with two different sensitivity calibrated reference hydrophones for the acoustic recordings:

1. A Reson TC4043, with nominal sensitivity -201 dB re V/μPa.
2. A Reson TC4032, with nominal sensitivity -170 dB re V/μPa.

The higher sensitivity Reson TC4032 was also amplified with an 18.0 dB gain amplifier so the two channels differed in overall sensitivity by 49 dB. This configuration allowed accurate measurements of sound levels over a very wide dynamic range in pressure (from approximately 60 dB re μPa to 210 dB re μPa). This configuration provided near-ideal capture of airgun pulses from distances beyond 60 km (36 miles) to the shots from less than 100 m (330 feet) from the OBH systems. The more sensitive hydrophone (TC4032) was saturated by the high pressure signals at ranges less than approximately 4.5 km. The signals from both hydrophones were fed to a Sound Devices model 722 digital hard-disk recorder housed within the OBH pressure case. The hydrophone signals were digitized in 24-bit samples at a sample rate of 32 kHz and stored directly on hard-drives. The 40GB hard drives were capable of storing up to 60 hours of 2-channel audio data at this sample rate.

All hydrophones were calibrated to NIST traceable standards. Voltage sensitivities and frequency responses of the hydrophone preamplifiers, amplifiers, and digitizer were calibrated in the lab prior to the

measurements using the Reson hydrophone's insert-cal feature; a reference signal of varying frequency was fed directly into the hydrophone preamplier and recorded with all components connected. This approach tested the end-to-end voltage response of the systems.

Recording Procedures

The OBH systems were deployed four hours prior to the start of the verification shooting using a crane from the *Octopus* (see photo in Fig. 4.6). The OBH systems were left on the seafloor to record continuously throughout the test program, acquiring an approximate total of 24.5 hours of data each. At the end of the program, release codes were transmitted to drop the anchors, allowing the OBHs to float to the surface for retrieval. The data recordings were copied from the internal hard drives of the recorders onto laptop computers for processing and all data were backed up on 250GB external hard drives. Shot logs containing GPS data for each airgun event were delivered from the *Discoverer* to the *Octopus*.

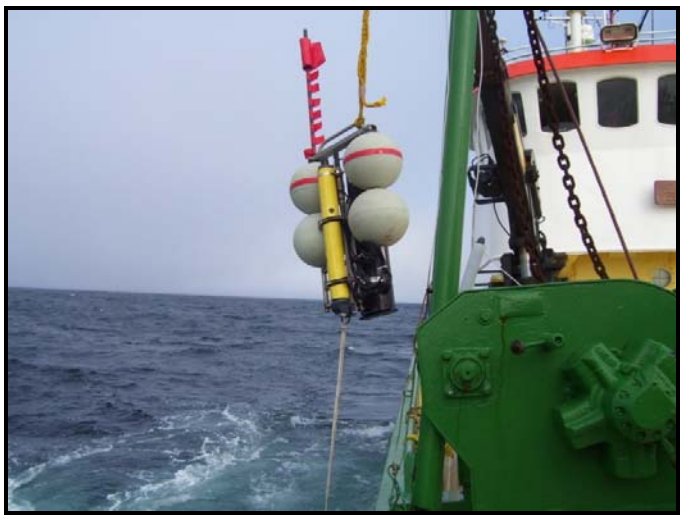

FIGURE 4.6. OBH system being deployed from the M/V *Octopus*.

Underwater sound metrics

Airgun (impulsive) noise

The sound field is described in terms of a time-varying pressure $p(t)$. Since measured sound intensities typically vary over many orders of magnitude, sound levels are usually expressed in logarithmic decibel (dB) units. The decibel scale is a relative scale that indicates the sound level relative to a pre-defined reference level.

By convention, noise underwater is measured in decibels relative to the reference pressure 1 μPa. Several sound level metrics (i.e., different ways of quantifying sound level) are commonly used to evaluate the loudness of impulsive noises. The three most commonly used sound level metrics are peak sound pressure level (PSPL), *rms* sound pressure level (SPL) and sound exposure level (SEL).

The peak sound pressure level (symbol L_{pk}) is the maximum instantaneous sound pressure level attained by an impulse, $p(t)$:

$$L_{pk} = 20\log_{10}\left(\max\left|p(t)\right|\right) \qquad (2)$$

The rms sound pressure level or SPL (symbol L_p) is the mean square pressure level over a time window, *T*, containing the impulse:

$$L_p = 10\log_{10}\left(\frac{1}{T}\int_T p(t)^2\,dt\right) \qquad (3)$$

For impulsive sounds, the rms pressure depends strongly on the choice of the time window *T* over which the rms level is computed. For computing airgun safety radii, the time interval, *T*, is most often taken to be the "90% energy pulse duration" rather than over a fixed time window. Here the SPL is defined so that the time window, T_{90}, is taken to be the interval containing 90% of the pulse energy — this is commonly referred to at the 90% *rms* SPL (symbol L_{p90}).

The sound exposure level or SEL (symbol L_E) is the time-integral of the square pressure over a fixed time window, *T*, long enough to include all parts of the signal:

$$L_E = 10\log_{10}\left(\int_T p(t)^2\,dt\right) \qquad (4)$$

Strictly speaking, SEL has units of μPa·√s rather than μPa and is not actually a measure of sound pressure but of sound energy[6] or exposure. Nonetheless, this metric is closely related to the *rms* sound pressure level since the two are computed in a very similar fashion. Sound exposure is a cumulative metric: total sound exposure may be computed by summing together (in the dB sense) the SEL's of many individual airgun shots. SEL's presented in this report represent the sound exposure from single airgun shots.

Current NOAA National Marine Fisheries Service thresholds for exposure of marine mammals to seismic noise are cast in terms of the 90% *rms* level: 190 dB for pinnipeds, 180 dB for cetaceans. Note, however, that the acoustic modeling techniques used by JASCO for estimating pre-season airgun array safety radii were based on SEL calculations, and these were converted to 90% *rms* SPL by accounting for the difference in the respective integration times. If the pulse duration, T_{90}, is known (or may be estimated) then the SEL is related to the 90% *rms* level via the following equation:

$$L_E = L_{p90} + 10\log(T_{90}) + 0.458 \qquad (5)$$

The last term in *Equation (5)* accounts for the 10% of energy that falls outside the T_{90} integration time period.

M-weighting

The potential for seismic survey noise to impact marine wildlife is dependent on how well the wildlife can hear the sounds produced. Noises are less likely to disturb animals if they are at frequencies the animal cannot hear well. The exception is when the noise pressure is so high as to cause physical injury (whether temporary or permanent). For non-injurious sound levels, frequency weighting curves based on audiograms may be applied to bias the importance of sound levels at particular frequencies in a manner reflective of the receiver's sensitivity to those frequencies.

A NMFS-sponsored Noise Criteria Committee has devised standard frequency weighting curves — so called "M-Weighting" filters — for use with marine mammal species (Gentry et al. 2004). M-

[6] Sound exposure is computed in the same way as energy flux density (EFD). EFD, however, is generally expressed in energy units directly rather than in decibels relative to the energy of a pressure wave with rms amplitude 1 μPa..

weighting filters are band-pass filter networks that are designed to reduce the importance of inaudible frequencies for four broad classes of marine mammals:

1. Mysticetes
2. Mid-frequency odontocetes
3. High-frequency odontocetes
4. Pinnipeds

The amount of discount applied by M-weighting filters for less-audible frequencies is not as great as would be indicated by the corresponding audiograms for these groups of species. The rationale for applying a smaller discount is that these frequencies, though inaudible, could still cause physical impacts because of their high pressure levels. The M-Weighting filters therefore are designed for use in primarily Level-A harassment assessment. They could be considered conservative (in the sense of overestimating the potential for impact) if applied to gauging mainly behavioral impacts.

Fig. 4.7 shows the decibel frequency response of the four standard underwater M-weighting filters. These filters have unity gain (0 dB) through the pass band and their high and low frequency roll off is approximately –12 dB per octave. The amplitude response of the M-weighting filters is defined in the frequency domain by the following function:

$$G(f) = -20\log_{10}\left[\left(1+\frac{f_{lo}^2}{f^2}\right)\left(1+\frac{f^2}{f_{hi}^2}\right)\right] \qquad (6)$$

The roll off and pass band of these filters are controlled by the two parameters f_{lo} and f_{hi}; the parameter values that are used for the four different standard M-weighing curves are given in Table 4.1.

M-weighting filters were applied to the airgun data in this study by filtering in the frequency domain using the Fast Fourier Transform (FFT) algorithm. After M-weighting was applied, the airgun data were transformed back to the time domain for calculating the M-weighted SPL's. The M-weighting filters applicable to marine mammals commonly encountered in the Alaskan Chukchi Sea are as follows:

1. Bowhead whales (*Balaena mysticetus*) and Gray whales (*Eschrichtius robustus*): low frequency mysticete M-weighting.
2. Beluga whales (*Delphinapterus leucas*): mid-frequency odontocete M-weighting.
3. Spotted seals (*Phoca largha*), ringed seals (*Phoca hispida*), ribbon seals (*Phoca fasciata*), bearded seals (*Erignathus barbatus*), Pacific walruses (*Odobenus rosmarus*): pinniped underwater M-weighting.

Band pressure levels

A convenient way of expressing the frequency content of a broadband signal is in terms of 1/3-octave band pressure levels (symbol L_{bp}). In 1/3-octave band analysis, sound is band-pass filtered into several adjacent frequency bins, and the mean-square pressure level in each bin is computed. The resultant 1/3-octave band levels give the frequency distribution of sound energy within the signal. The acoustics community has adopted standard 1/3-octave frequencies in order to facilitate comparisons between studies; the center frequencies (f_c) of these standard pass-bands are given by the following formula:

$$f_c = 10^{i/10} \qquad i = 1,2,3... \qquad (7)$$

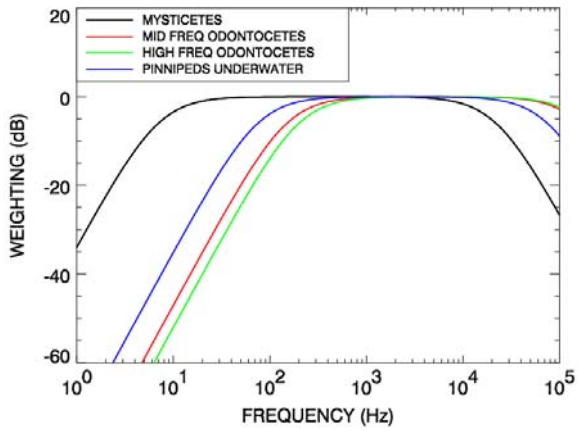

FIGURE 4.7. Plot of standard M-weighting curves for mysticetes, odontocetes (mid and high-frequency), and pinnipeds.

TABLE 4.1. Low frequency and high frequency cutoff parameters for standard marine mammal M-weighting curves.

M-weighting filter	f_{lo} **(Hz)**	f_{hi} **(Hz)**
Mysticetes	7	22,000
Mid-frequency odontocetes	150	160,000
High-frequency odontocetes	200	180,000
Pinnipeds underwater	75	75,000

Note that the bandwidth of a single 1/3-octave band is ~23% of band center frequency so, for example, the width of the 1/3-octave band at 1 kHz is 230 Hz. 1/3-octave band analysis may be applied to both continuous noise and impulsive noise.

Data Analysis

The pressure waveform data from the airgun test recordings were processed using customized analysis software according to the following steps:

1. Identify individual airgun pulses.
2. Determine source receiver separation ranges for each airgun pulse by correlating the shot times with the navigation logs obtained from the *Discoverer*.
3. Convert waveform data to units of microPascals (µPa) by applying hydrophone sensitivity, preamplifier, amplifier and digital conversion gains to digital recording units.
4. Determine the maximum sound pressure level (L_{pk}) for each pulse in dB/µPa.
5. Compute cumulative square pressure (L_E) through each pulse's duration. This step is performed both with and without applying the m-weighting filters to the data.

6. Determine times at which 5% and 95% of the cumulative square pressure for each pulse was received.
7. Compute the *rms* level (L_p) for each pulse by dividing the cumulative square pressure (L_E) between the 5% and 95% times by the number of samples in this period, and taking the square root. This step is performed both with and without applying the m-weighting filters to the data.
8. Transform each airgun pulse to the frequency domain, via the Fast Fourier Transform, to obtain 1-Hz spectral power levels in 1 second steps.
9. Integrate the spectral power levels inside standard 1/3-octave bands to obtain band sound pressure levels (L_{bp}) for bands from 10 Hz to 2 kHz.

Some of the data files contained airgun shots that did not correspond to the shot times when the *Discoverer* was firing its guns. These signals were attributed to third party seismic programs that were operating concurrently in the Chukchi Sea. This was most notable in the data files where the source receiver separation was large, and thus the GXT airgun signal levels were comparable to the external airgun signals also received from long ranges. Care was taken in data processing to ensure that these extraneous airgun signals were not included in the calculations.

RESULTS

Peak, rms and SEL

Peak, 90% *rms*, and SEL values as a function of range from the array were computed for each airgun pulse. The sound levels produced by an array of airguns typically exhibits a certain amount of horizontal directivity, dependant on the array layout, and the sound level will vary with source-receiver orientation. Typically the sound signature will be greatest in the broadside direction where the signatures from the individual airguns add coherently. The pressure waveform data were thus separated into shots that were received from the endfire aspect of the array and those that were received broadside of the array. Endfire shots were all computed from the data received at OBH A as the *Discoverer* traversed Line 1, also including data received at OBH B at ranges greater than 20 km. Scatter plots of the received levels versus range are presented in this section; endfire pulses are presented in Fig. 4.8, and broadside pulses are presented in Fig. 4.9.

The broadside levels were observed to be greater than the endfire levels by an amount that increased with increasing range. For example, the broadside levels were approximately 5 dB greater than the endfire levels at 5 km range and were 12 dB greater than the endfire levels at 40 km range. The broadside and endfire pulses will differ in their frequency compositions and this indicates that the dominant frequency components of the broadside pulses are better supported by the propagation environment than the dominant frequencies in the endfire aspect pulses. This characteristic is discussed further in the sections that follow.

The following general transmission loss equation can be fit to data to approximate received sound level at a location a distance *r* from an underwater sound source:

$$RL = SL - n\log r - \alpha r \qquad (8)$$

In Equation *(8)*, *RL* is the received level in dB re μPa, *SL* is the source level in dB re μPa, *n* is a geometric spreading constant, *r* is the source-receiver separation, and α is an absorption coefficient. A least-squares fit to this general equation was established for the measured 90% *rms* data to provide

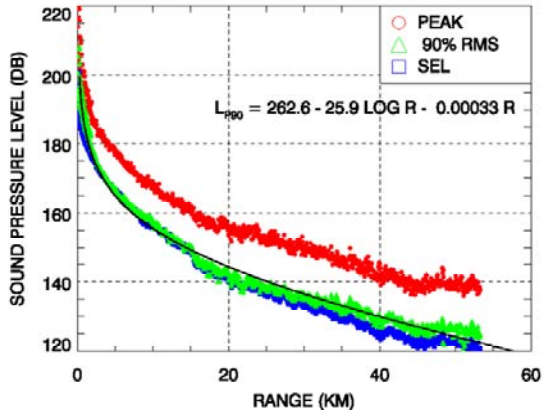

FIGURE 4.8. Peak, 90% *rms*, and SEL values for individual airgun pulses as a function of range in the endfire direction. Equation shown defines the transmission loss curve (plotted in solid black) fit to the 90% *rms* data.

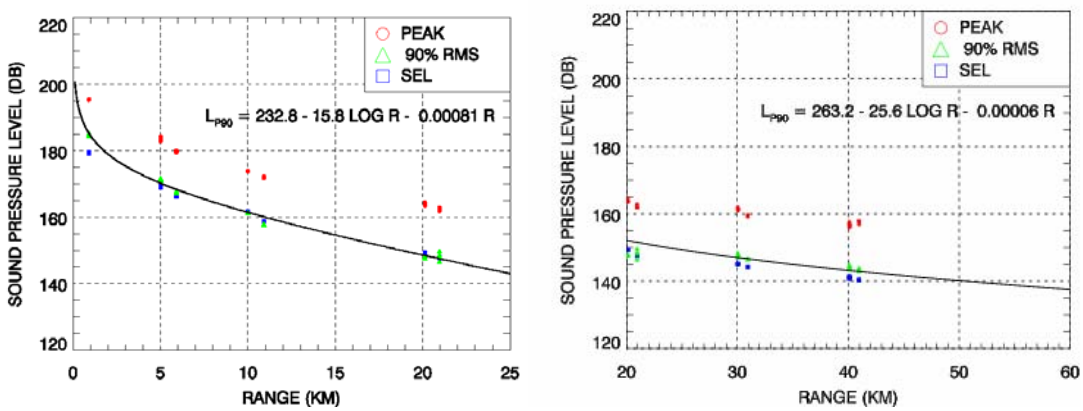

FIGURE 4.9. Peak, 90% *rms*, and SEL values for individual airgun pulses as a function of range in the broadside direction. Equation shown defines the transmission loss curve (plotted in solid black) fit to the 90% *rms* data. Left hand plot shows close range data (<20 km), right hand shows long range data (>20 km).

estimated ranges to specific received sound levels that are provided in Table 4.2. The coefficients that provide the best fit with the 90% rms data are labeled on the plots, and the equations are plotted as solid black curves in Fig. 4.8 and Fig. 4.9. The scarce broadside data were not well fit at all ranges by a single empirical transmission loss curve. Thus a separate trend-line was used to extrapolate radii from the broadside data received only at ranges less than 20 km that was used to fit the data at ranges greater than 20 km. These curves are separately indicated in the left and right hand plots of Fig. 4.9.

TABLE 4.2. Ranges to 90% *rms* sound pressure level thresholds from 190 to 120 dB re µPa, in 10 dB steps for the 3320 in^3 array.

90% *rms* SPL (dB re µPa)	Endfire Range (km)	Broadside Range (km)
190	0.62	0.48
180	1.46	1.77
170	3.36	5.11
160	7.28	10.97
150	14.35	23.7
140	25.27	50.66
130	39.89	97.55
120	57.53	166.96

At long ranges (greater than 20 km) the endfire data exhibits stronger transmission loss than is observed in the broadside data. It is also noted that the absorption coefficient (α) for the TL curve fit with the endfire data is much larger than the value used in the fit for the long-range, broadside data.

The broadside *rms* radii exceed the enfire *rms* radii at all levels except for the 190 dB threshold. This is again due to the different characteristics of the broadside and endfire pulses and the corresponding transmission losses incurred by the pulses propagating in the shallow-water environment. This effect is not apparent for the 190 dB radius since at this close range the received signal is composed of steeply propagating sound rays and the horizontal directivity effects are less important.

Airgun pulse duration

The pulse shape of each individual airgun event contains contributions from many different frequency components of the signal. Modal dispersion causes different frequencies to travel at different speeds in this environment. This results in a spreading-out in time of the signal with distance from the source. Understanding changes of the pulse shape as a function of range is important to understanding the corresponding changes in the length of the time window containing 90% of the energy of a pulse, and thus changes in the 90% *rms* level. This is particularly important when considering estimates of marine mammal safety radii which are often estimated using computer models of the sound field. Computer models such as that used by JASCO Research to establish pre-season estimates of safety radii deal with SEL values, however current regulations are based on *rms* levels. The modeled SEL values must thus be converted to 90% *rms* levels using the relationship defined previously in *Equation (5)*, which depends on the pulse length, T_{90}.

Fig. 4.10 presents a scatter plot of the length of the time window containing 90% of the airgun pulse energy (T_{90}) as a function of range, and as a function of the 90% *rms* level. These plots present data received at all aspects from the array. At close range (less than 5 km) the pulse length is seen to increase with increasing range as expected due to frequency dispersion. For ranges between 5 and 20 km there is more scatter in the data which is due to the directivity of the source, and the pulse length becomes nearly constant for a given azimuthal direction from the source. In some azimuthal directions the pulse length is greater than 1 second and this is why at ranges between 5 and 20 km the SEL value is very close to, and in fact sometimes greater than the 90% *rms* value in the plots in Fig. 4.8 from the previous section. At ranges greater than 20 km, a gradual, progressive shortening of the pulse length is observed in the endfire data. This could be due to a changing seafloor composition to areas with a softer bottom, a hypothesis that is supported by a change in the modal composition of the pulse spectrograms presented in the next section. A softer bottom removes some of the low-frequency content of the airgun pulse, where dispersion effects are more pronounced, thus shortening the length of the pulse.

Frequency Analysis

Spectrograms

Spectrogram plots of pulses received at various broadside ranges from the airgun array are presented in Fig. 4.11. At close range (1 km) the pulse is characterized as a narrow packet that is fairly evenly distributed throughout the frequencies. As the range increases, the modal structure becomes more evident (indicated as bands that sweep through frequencies in time) and the pulse shape spreads out temporally. The modal structure observed in the plots for 10 km and 20 km show that the environment at the study location supports low frequency propagation, indicating a low cut-off frequency (the frequency below which sound energy will not propagate through the environment) due to a hard bottomed seafloor with a high sound speed.

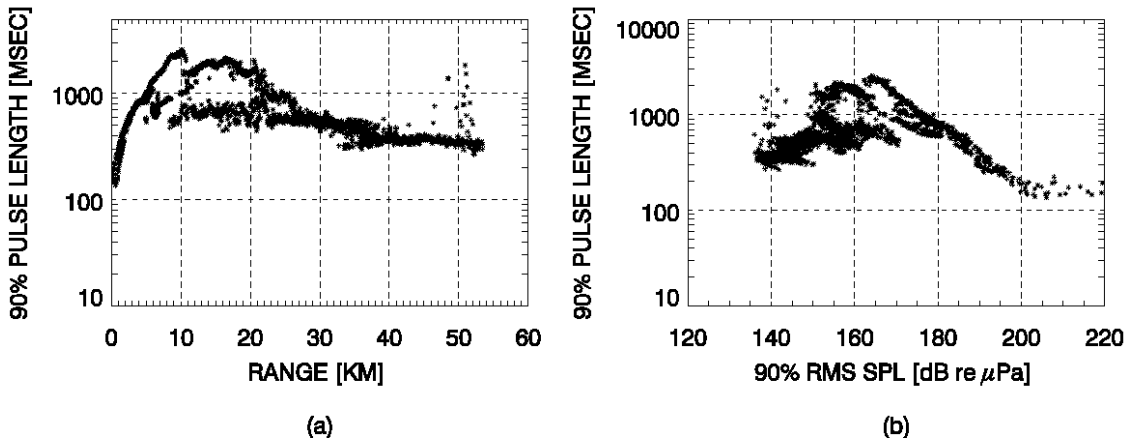

FIGURE 4.10. Pulse length containing 90% of total pulse energy for 3320 in^3 airgun array plotted (a) versus range from the source, and (b) versus 90% *rms* sound pressure level.

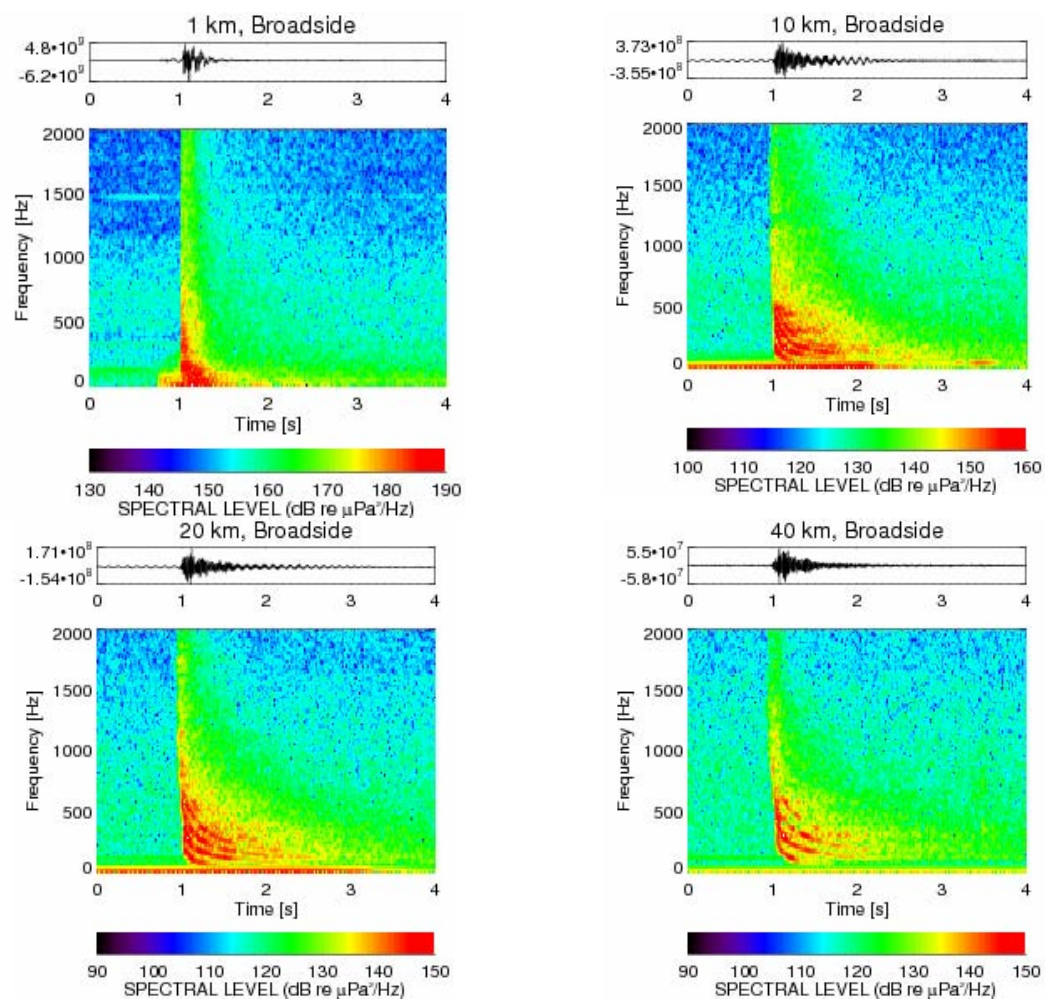

FIGURE 4.11. Spectrogram plots showing spectral levels as a function of frequency and time for airgun pulses received at four different broadside ranges: 1, 10, 20, and 40 km.

At the 10 km range and greater, the arrival of a 10 Hz band is clearly observed before the arrival of the pulse peak. This is due to low frequency energy that traveled through the ground before reaching the receiver, at a faster speed than the sound that traveled through the water.

Spectrograms were also generated for pulses received at long ranges in the endfire direction (Fig. 4.12). The spectrogram at the 20 km range looks similar to the broadside pulse received at the same range, however at the 40 km range it is noted that more of the lower frequency energy has been stripped out of the arrival pulse and the 'tails' of the modal bands have been shortened. A soft bottomed waveguide will have a higher cut-off frequency and the modes will not be supported to as low frequencies as would be supported in the hard bottom case. Therefore these plots seem to indicate that the endfire pulses may encounter a changing bottom type from hard to soft at long ranges, as also evidenced by the previously discussed reduction of the 90% *rms* pulse length (T_{90}). This is also reflected by the different transmission loss trends exhibited in the SPL data for endfire versus broadside data.

Band Pressure Levels

Contour plots of 1/3-octave band pressure levels as a function of source-receiver separation range are presented in Fig. 4.13. These plots present the changing nature of the frequency distribution of the energy in the pulses as a function of range. It is observed that the propagation environment best supports frequencies between 100-700 Hz, and there is also a strongly supported notch at 10 Hz. The different frequency distributions of the levels received broadside compared to those received from the endfire aspect are noted in these contours. The closest range that truly broadside pulses were received was 900 m (at OBH-B as the source passed over OBH-A).

Directivity

Estimated 1/3-octave band source levels of the array signature were obtained by back-propagating the band level data under the assumption of spherical spreading (i.e. that sound attenuates with range by the factor 20*log*R). It is noted that these estimates do not compensate for the signal cancellation from the surface reflected 'ghost' and therefore the source level estimates likely underestimate the true array source levels. Fig. 4.14(b) presents the directivity pattern - that is the airgun array source levels as a function of angle, where 0 degrees is directly broadside of the array and +90 degrees is the bow aspect of the array. As expected for an array of airguns, the levels are greatest within a 30 degree lobe directly broadside of the array, where the levels exceed those outside of the broadside lobe by approximately 5 dB. The bow aspect levels also appear to be 1 or 2 dB greater than the aft aspect levels.

M-weighting

M-weighted filters were applied to the received 90% *rms* levels (endfire and broadside pulses were considered separately) to investigate the impact of m-weighting on the marine mammal safety radii calculations. Three different m-weighting filters were separately applied: a low-frequency filter applicable for considerations relating to mysticetes, a mid-frequency filter applicable for odontocete hearing, and a filter applicable for pinnipeds underwater. For each of these filters the data were again fit to an empirical transmission loss curve based on *Equation (8),* using a least-squares approach. The broadside data were again fit separately for ranges less than 20 km in the same manner as was used for the flat-weighted data presented previously. The m-weighted 90% *rms* levels and the corresponding curve fits for endfire and broadside data are indicated in Fig. 4.15 and Fig. 4.16, respectively.

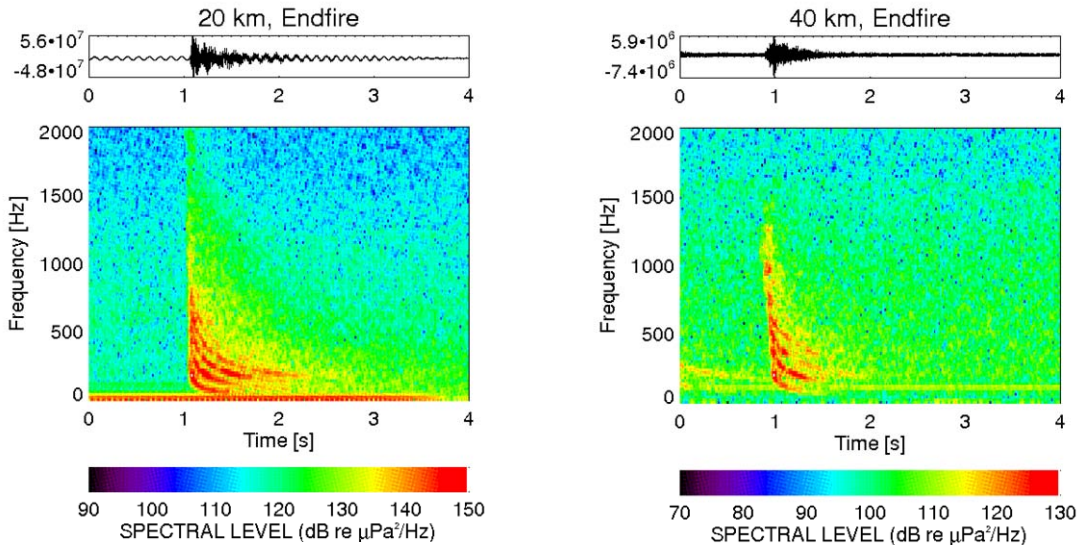

FIGURE 4.12. Spectrogram plots showing spectral levels as a function of frequency and time for airgun pulses received at two different endfire ranges: 20 km and 40 km.

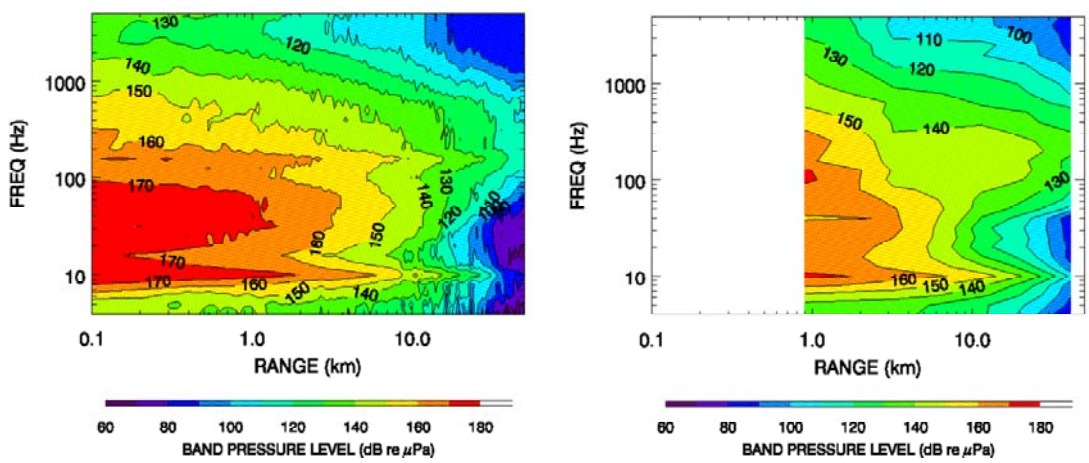

FIGURE 4.13. Contour plots of 1/3-octave band pressure levels versus range and frequency for the 3320 in^3 airgun array. Endfire levels are on the left, broadside levels are on the right.

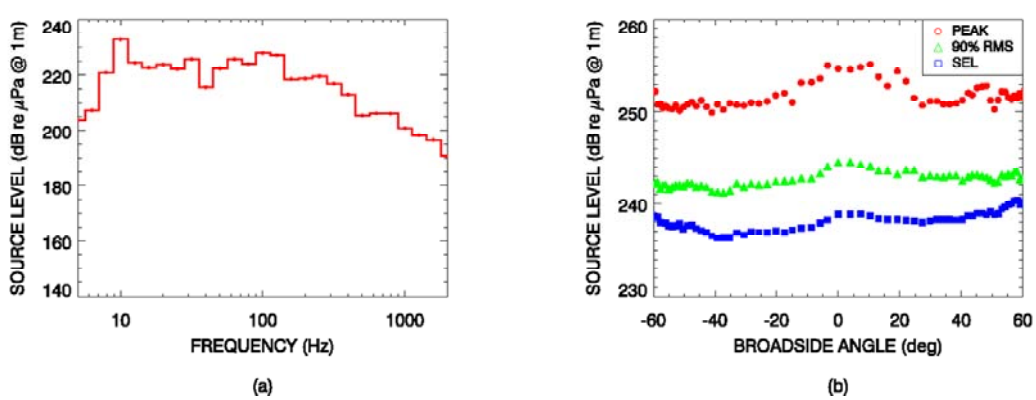

FIGURE 4.14. Plots of back-propagated airgun source level estimates: (a) 1/3-octave band source levels configurations and (b) peak, 90% *rms* and SEL source levels as a function of beam angle (array broadside is 0 degrees, bow aspect is +90 degrees).

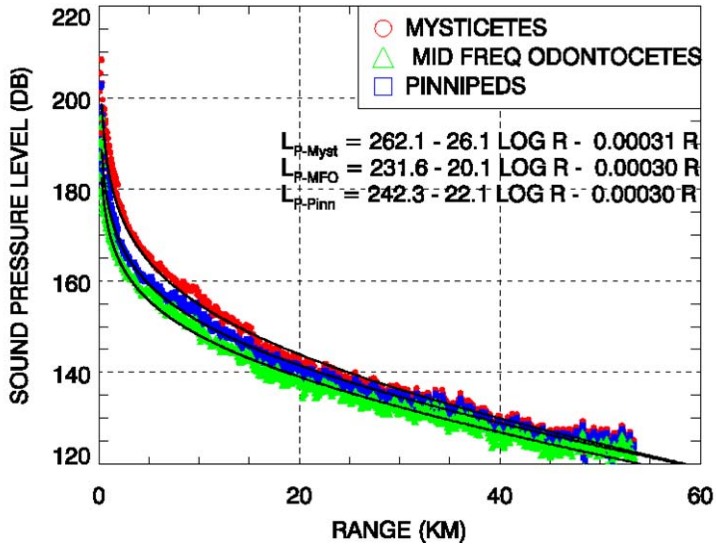

FIGURE 4.15. M-weighted 90% *rms* levels versus range for the 3320 in^3 airgun array for the endfire aspect. Best-fit transmission loss curves are indicated for each m-weighting filter and are plotted as solid black curves.

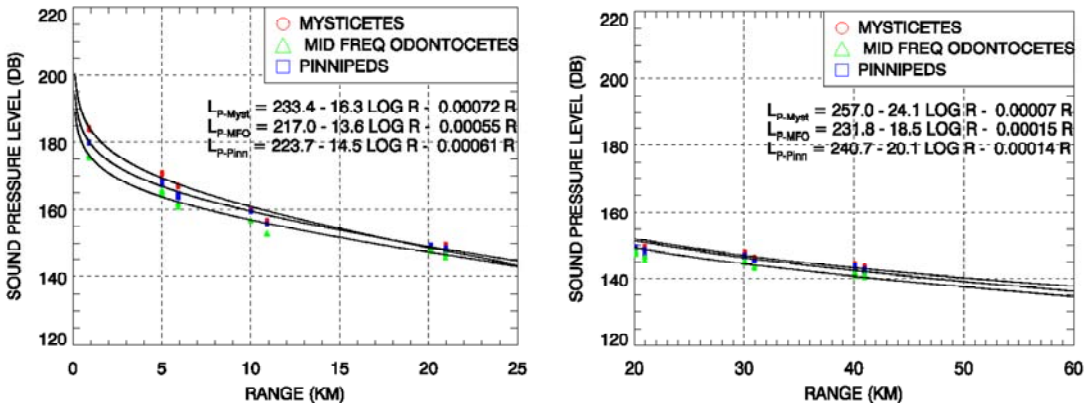

FIGURE 4.16. M-weighted 90% *rms* levels versus range for the 3320 in^3 airgun array for the broadside aspect. Best-fit transmission loss curves are indicated for each m-weighting filter and are plotted as solid black curves. Left hand plot shows close range data (<20 km), right hand shows long range data (>20 km).

Radii to specific 90% *rms* levels, in 10 dB steps, were obtained from the empirical fits to the data. The radii computed for low-frequency mysticetes, mid-frequency odontocetes and for pinnipeds in water are presented in Table 4.3, Table 4.4, and Table 4.5, respectively.

DISCUSSION

Received Level vs Range Relationships and Effect on Safety Radii

The accuracy of the fit of an empirical transmission loss estimate with measured data is very important when estimating the safety radii for the 190 and 180 dB re µPa threshold levels. Due to the steepness of the transmission loss (TL) curve at these close ranges, a difference of only a few decibels between the best-fit curve and the measured data can result in a difference in the radius estimate by tens, or even hundreds, of meters. When there is considerable scatter in the data one could consider using a best-fit

TABLE 4.3. Ranges to low-frequency (mysticete) M-weighted 90% *rms* sound pressure level thresholds from 190 to 120 dB re µPa, in 10 dB steps, for the 3320 in^3 array.

90% *rms* SPL (dB re µPa)	**Endfire Range (km)**	**Broadside Range (km)**
190	0.58	0.44
180	1.37	1.59
170	3.15	4.72
160	6.90	10.60
150	13.83	23.61
140	24.84	50.82
130	39.92	96.28
120	58.42	160.22

TABLE 4.4. Ranges to mid-frequency (odontocete) M-weighted 90% *rms* sound pressure level thresholds from 190 to 120 dB re µPa, in 10 dB steps, for the 3320 in^3 array.

90% *rms* SPL (dB re µPa)	**Endfire Range (km)**	**Broadside Range (km)**
190	0.12	0.09
180	0.36	0.49
170	1.11	2.26
160	3.24	7.50
150	8.48	18.72
140	18.68	42.12
130	34.20	76.82
120	53.93	119.78

TABLE 4.5. Ranges to underwater pinniped M-weighted 90% *rms* sound pressure level thresholds from 190 to 120 dB re µPa, in 10 dB steps, for the 3320 in^3 array.

90% *rms* SPL (dB re µPa)	**Endfire Range (km)**	**Broadside Range (km)**
190	0.23	0.20
180	0.66	0.93
170	1.80	3.52
160	4.67	9.58
150	10.93	22.45
140	22.01	47.25
130	38.00	83.09
120	57.95	127.29

approach, or a precautionary approach where the TL curve would be fit with the maximum received levels at each range. The scatter in the endfire data received at close ranges in this study was minimal and the curve that best-fit the data at all ranges was used. The curve that 'best-fit' the broadside data at all ranges slightly overestimated the close range data and would have grossly overestimated the 190 dB radius calculation. This is the reason that separate fits were used for estimating the broadside radii at close ranges than for long ranges. This approach is justified since the propagation characteristics can be expected to change with range as the shape and frequency content of the airgun pulses also changes with range.

Effect of Frequency Weighting on Safety Radii Calculations

Table 4.6 presents the percentage amount that the safety radii were reduced after applying the m-weighting filters. The radii were most significantly reduced, from flat-weighted radii, by weighting with the mid-frequency odontocete filter and were least affected by the application of the low-frequency, mysticete filter. This is an expected result due to the different cut-off frequencies of the m-weighting filters that are displayed in Fig. 4.7. The filter for low frequency mysticetes is essentially flat-weighted over the frequency ranges that are dominant in the airgun pulses, while the mid-frequency odontocete and the underwater pinniped filters attenuate the important low frequency components of the airgun pulses more severely.

The effect of each filter was most notable for the radii to levels greater than 150 dB while for levels of 150 dB and less, the radii were not significantly altered after m-weighting was applied. This is because the pulses at longer ranges contain less low frequency energy due to propagation losses in the shallow water environment. As well, due to the different frequency compositions of broadside pulses relative to endfire pulses, the broadside radii are generally less affected by m-weighting than the endfire radii, for all three m-filters.

TABLE 4.6. Percentage reduction of marine mammal safety radii after applying m-weighting filters for mysticetes, odontocetes, and pinnipeds in water, for both endfire and broadside data.

***90% rms* SPL (dB re µPa)**	**Percent Reduction of *rms* Radius**					
	Low Frequency (Mysticete)		**Mid Frequency (Odontocete)**		**Pinnipeds in Water**	
	Endfire	**Broadside**	**Endfire**	**Broadside**	**Endfire**	**Broadside**
190	6%	8%	81%	81%	63%	58%
180	6%	10%	75%	72%	55%	47%
170	6%	8%	67%	56%	46%	31%
160	5%	3%	55%	32%	36%	13%
150	4%	0%	41%	21%	24%	5%
140	2%	0%	26%	17%	13%	7%
130	0%	1%	14%	21%	5%	15%
120	-2%	4%	6%	28%	-1%	24%

SUMMARY OF FIELD VERIFICATION MEASUREMENTS

The verification measurements taken in the field on 20-21 August 2006 were used to characterize the sound transmission associated with the 3320 in^3 airgun array employed by GX Technology for their 2006 Arctic Span Seismic Survey. Sound levels propagating broadside of the array were found to be greater than the levels produced in the array's endfire direction. The marine mammal safety radii for the 180 dB re µPa *rms* threshold level were calculated to be 1.46 km in the endfire direction and 1.77 km in the broadside direction. The radii for the 190 dB re µPa *rms* threshold were measured to be 0.62 km in the endfire and 0.48 km in the broadside directions. The broadside lobe was determined to be 40° wide and to contain levels 5 dB greater than the off-broadside levels.

The pulse length of individual airgun pulses was observed to increase with range due to dispersion, out to a range of 10-20 km, after which the pulse length was noted to be mainly influenced by the array directivity.

Spectrograms of the airgun pulses indicated a large number of supported normal modes. This indicates that the seabed at the test location was likely composed of an acoustically reflective sediment bottom. Sound levels at other locations in the Chukchi Sea may decrease more rapidly with distance if bottom types are less reflective.

Broadside band levels were observed to be greater than endfire band levels by up to 10 dB. The greatest differences in the endfire versus broadside band levels were observed at close ranges. At distances beyond 10 km, maximum sound levels at broadside and endfire were dominated by sound energy between 100 Hz and 700 Hz.

M-weighting filters for mysticetes, mid-frequency odontocetes and pinnipeds underwater were applied to the 90% *rms* sound level data. The odontocete M-weighting reduced the received sound levels by the greatest amount. However, the M-weighting filters were less effective at greater distances from the sound source, where there was proportionally more mid-to-high frequency energy in the airgun pulses.

5. MODEL VALIDATION CHAPTER[7]

INTRODUCTION

An acoustic modeling program was performed by JASCO Research Ltd. for GXT to predict sound levels at four locations in the Alaskan Chukchi Sea. The Marine Operations Noise Model (MONM) was used at each site to estimate sound levels as a function of direction at depths spanning the water column. Those modeling results are discussed in Chapter 3 of this report.

Model site C4 corresponded with the location of GXT's Chukchi Sea source verification measurement study (see Chapter 4 in this report). This chapter compares model predictions of broadband and 1/3-octave frequency band sound levels with collected field data.

Model results were also examined to characterize some features of the sound field that were not measured directly in the 2006 verification program; specifically, the measurement program used bottom-deployed recording systems that did not measure sound level variation with depth. Depth variation of model results was examined to characterize this aspect of the sound field that may be important for predicting impacts on marine mammals. The model analysis also tested sound level variations caused by different bottom types; the analysis considered differences in sound level estimates versus range resulting from:

1.) An acoustically non-reflective silt bottom,

2.) an intermediate bottom type (sand) based on the geological description of area sediments at the verification site, and

3.) a more reflective compacted sand bottom.

MODEL VALIDATION

Broadband Levels

Broadband (10 Hz to 2 kHz) sound levels were computed by MONM for the GXT 3320 in^3 airgun array by summing modeled Sound Exposure Levels (SEL) in 1/3-octave bands between 10 Hz and 2 kHz. Model results predicted sound levels at a test receiver positioned 1 m above the seabed, which corresponds with the measurement depth of the bottom-moored OBH systems that were used for source verification measurements. The SEL values are based on the sound energy from single shots from the airgun array.

SEL was used instead of *rms* sound levels for these comparisons because the model outputs SEL directly and SEL is more straightforward to compute from the data because it does not rely on a representative pulse duration. *Rms* levels were as much as 10 dB greater than SEL values at the closest ranges (less than 500 m) and the difference decreased with increasing range to 0 dB at approximately 5 km range and beyond. The numerical difference between the two metrics is related to the effective duration parameter that is inherent in the *rms* calculation. The accepted method for choosing the *rms* duration is based on the times at which 5% and 95% of the cumulative pulse energy has arrived. *Rms*

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[7] Authors of this summary are Mikhail Zykov and David Hannay, JASCO Research Ltd., 2101-4464 Markham Street, Victoria, B.C. Canada, V8Z 7X8.

levels computed this way are often referred to as 90% *rms* levels. At locations close to the source the pulse duration is much shorter than 1 second and the 90% *rms* level as a result is greater than the SEL. As distance increases, reverberation extends the length of the pulse thereby reducing the difference. As the duration approaches 1 second the 90% *rms* level approaches SEL. In some cases the duration exceeded 1 second thereby making 90% *rms* levels slightly less than SEL.

Modeled broadband SEL results as a function of range are plotted with corresponding measured data in the broadside (Fig. 5.1a) and endfire (Fig. 5.1b) directions. SEL levels in the broadside direction are greater than the endfire levels at the same ranges in both the model predictions and measured data. Modeled SEL levels in the broadside direction are in very good agreement with measured data at 1 km range, but underestimate the levels at greater ranges. At 5 km to 20 km the match is still quite good, with differences between 2-5 dB, but at 40 km the broadside model results are almost 10 dB less than measurements.

Endfire model results agree very well with endfire measurements at all ranges (Fig. 5.1b). The model results are within about 3 dB of measurements at ranges out to 3 km, and the difference decreases by 5 km range to about 1 dB, and remains small out to over 50 km range.

Depth Variation

Low frequency sound levels are commonly greater at depth than near the surface. The variation of airgun sound levels with depth was investigated by examining the model predictions of sound level as a function of depth. Figures 5.2 and 5.3 show cross-section plots of SEL, versus range and depth, out to 40 km range from the source for the broadside and endfire directions respectively, from the array. The analysis indicates that sound levels in mid-water depths are predicted to be greater than sound levels near the sea-surface and near the bottom. This feature is important for assessing potential impacts, because measurements made very near the bottom or near the sea surface may not be representative of levels at other depths used by marine mammals.

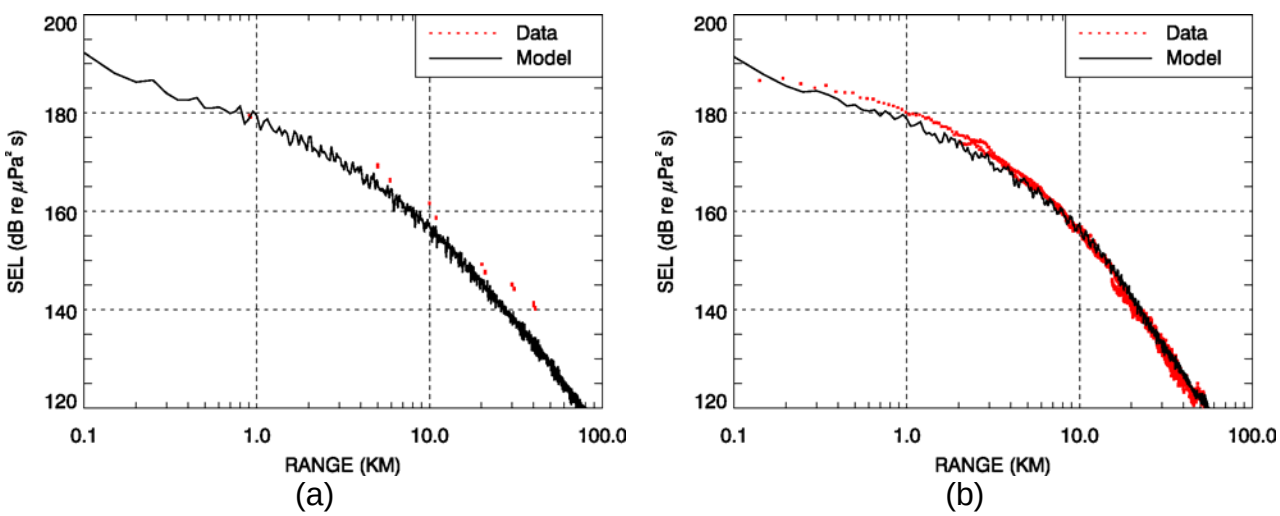

FIGURE 5.1. Modeled and measured SEL from the 3320 in^3 airgun array at (a) broadside and (b) endfire aspects.

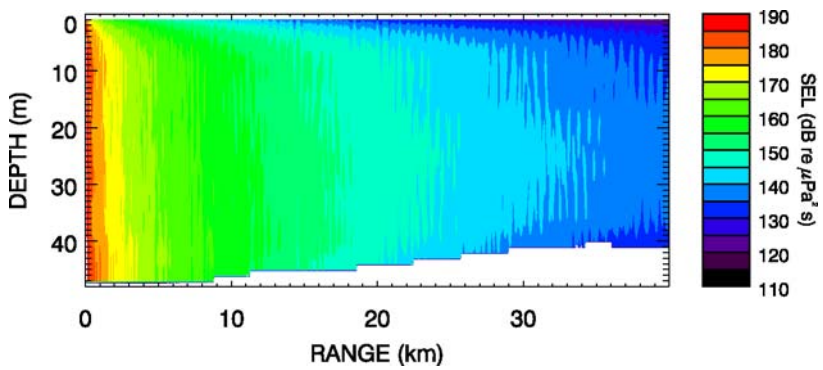

FIGURE 5.2. Modeled broadband SEL versus range depth, showing the distribution of sound energy with depth for the broadside transect.

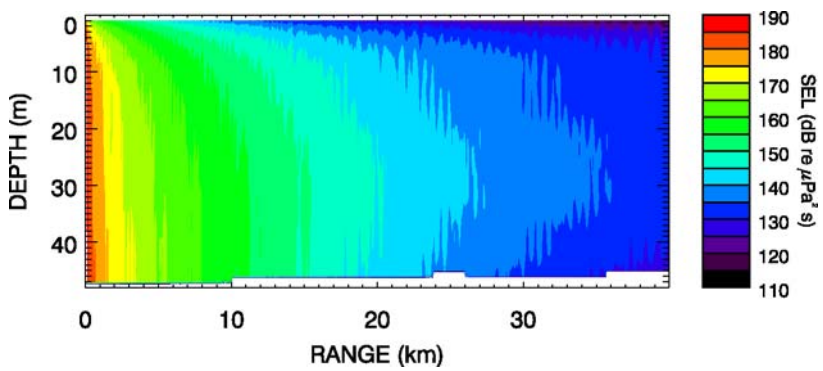

FIGURE 5.3. Modeled broadband SEL versus range depth, showing the distribution of sound energy with depth for the endfire transect.

Threshold Radii

The modeled sound levels for the source verification test site were used to estimate distances from the airgun array at which sound levels reached thresholds between 190 dB and 120 dB re µPa *rms* in the broadside and endfire directions. Because marine mammal exclusion zones are based on the 90% *rms* SPL, it was necessary to convert modeled SEL levels to *rms* SPL levels. SEL to *rms* SPL conversions for array broadside and array endfire directions are given in Table 5.1. These conversions are based on the differences in the two metrics computed from the measured pressure signatures. It is also possible to estimate the SEL to SPL conversion using full waveform modeling when measurements are not available.

TABLE 5.1. SEL to 90% *rms* SPL conversions derived from measurements at the source verification site.

90% rms *level* (dB re µPa)	***Broadside SEL* (dB re µPa^2 s)**	***Endfire SEL* (dB re µPa^2 s)**
190	183	184
180	175	177
170	168	169
160	159	160
150	149	148
140	138	138
130	128	126
120	118	116

Table 5.2 shows a comparison of the modeled and measured threshold radii for the 3320 in^3 airgun array, for 90% *rms* SPL's from 190–120 dB re μPa, in 10 dB steps. The third column for each range shows the ratio between the predicted and measured radii; a value greater than 1.0 indicates that the model overestimated the empirical values. The model estimates for endfire threshold distances match well with measured distances except for ranges beyond 40 km. The agreement is poorer in the array broadside direction, where the model tends to underestimate the measured threshold radii except at the short ranges with levels above 185 dB re μPa.

TABLE 5.2. Modeled and measured 90% *rms* threshold ranges, for broadside and endfire array aspects, at the source verification test site. Greyed cells represent extrapolations from shorter range measurements.

rms **threshold**	***Broadside range***			***Endfire range***		
(dB re μPa)	*Model (km)*	*Data (km)*	*Model/Data*	*Model (km)*	*Data (km)*	*Model/Data*
190	0.4	0.3	1.33	0.3	0.3	1.00
180	1.5	1.8	0.83	1.6	1.6	1.00
170	3.8	4.8	0.79	3.6	3.8	0.95
160	8.8	10.4	0.85	7.8	7.8	1.00
150	16.4	19	0.86	15.6	15.6	1.00
140	31	41	0.76	25	25	1.00
130	56	66	0.85	43.2	37.4	1.16
120	78	98	0.80	72	59	1.22

Comparison of 1/3-octave band levels

Figures 5.4 and 5.5 show plots of modeled and measured 1/3-octave band pressure levels versus range and frequency at array broadside and array endfire for a receiver 1 m above the seabed. These plots are useful for determining the dominant frequencies as a function of distance from the source. It is apparent in comparing the model and data broadside results that the model reproduced the measured frequency distribution well but underestimated sound levels in the dominant 200 Hz frequency band. This difference is the primary reason that the broadband modeled sound levels underestimated long range broadside threshold distances. Overall, the broadside model results are satisfactory for estimating sound levels at ranges less than 1 km. At ranges from 1 km to 10 km the model underestimated broadband levels by approximately 1-5 dB. From 10-40 km the model mismatch increased to approximately 7 dB, assuming a sand bottom type.

Model estimates of frequency distribution in the endfire direction are much better than at broadside; the model predicts the dominant endfire frequency at 150 Hz very well. Sound levels at 200 Hz however are still underestimated, but that has less effect on the broadband levels. It is not known if the lower-than-measured model estimates at frequencies near 200 Hz is caused by a mismatch of the source model or if it is caused by overestimation of transmission loss by the acoustic model. Mismatch of the acoustic model could be caused by incorrectly specified bottom geoacoustic parameters (which would affect low frequencies more than high frequencies). High-resolution measurements made close to the source may be able to check the accuracy of the source model to resolve the origin of the near-200 Hz mismatch. The model results for endfire were found to be suitable for estimating endfire levels at all ranges measured (to over 50 km).

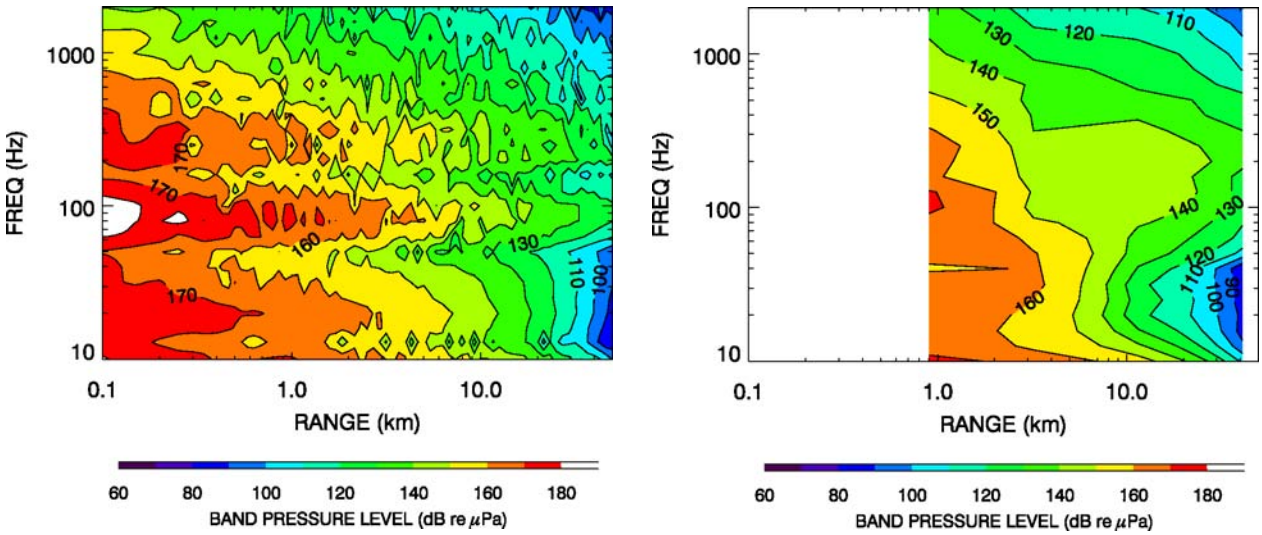

FIGURE 5.4. Modeled (left) and measured (right) 1/3-octave band SEL versus range at array broadside.

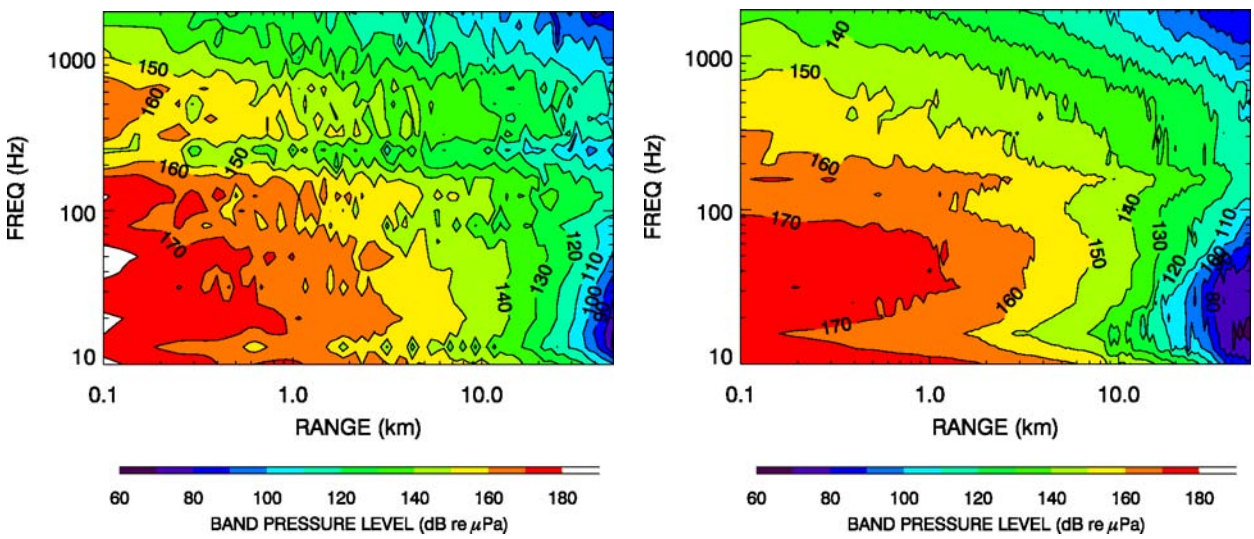

FIGURE 5.5. Modeled (left) and measured (right) 1/3-octave band SEL versus range at array endfire.

Seabed Geoacoustic Parameter Uncertainty

An important source of uncertainty for these acoustic model predictions was the limited knowledge of geoaoustic properties of the seabed for the sites modeled. Seabed parameters were estimated from descriptions of the general geology near the site since no direct measurements of the required parameters were available. Acoustic propagation loss in shallow water is dominated by seabed interactions and so even small variations in the seabed properties can influence estimated sound levels. We investigated the model's sensitivity to incorrectly-specified seabed parameters by comparing results obtained using three bottom type scenarios representing the possible variability in surficial sediments. These were: (1) sand; (2) compacted sand; and (3) silt. The geoacoustic parameters for the sand bottom type are the parameters specified for site C4 modeling. The compacted sand bottom type had increased P-wave velocity and density, and the silt bottom had lower P-wave velocity and density. P-wave attenuations in the silt bottom were also reduced. The important parameters for these three bottom type scenarios are given in Table 5.3.

TABLE 5.3. Geoacoustic parameters for sand (1), compacted sand (2), and silt (3) bottom types. All bottom type scenarios had three layers. Ranges indicate limits of linear parameter gradients within the layers.

Depth (mbsf)	**Density (g/cm^3)**			**P-wave speed (km/s)**			**P-wave attenuation (dB/λ)**			**S-wave speed (m/s)**			**S-wave attenuation (dB)**		
Type →	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
0–2	1.8-1.9	1.9-2.0	1.5-1.6	1.7-1.8	1.8-1.9	1.5-1.6	0.5-0.4	0.4-0.2	0.2						
2-20	1.9-2.0	2.0-2.1	1.6-2.0	1.8-1.9	1.9-2.1	1.6-1.7	0.4-0.1	0.2-0.1	0.2-0.1	0.2	2.5	1.2	4.0	3.0	4.0
20–170	2.0-2.1	2.1-2.2	2.0-2.1	1.9-2.0	2.1-2.2	1.7-2.0									
>170	2.5	2.5	2.5	3.0	3.0	3.0	0.1	0.1	0.1						

Figure 5.6 shows broadband received levels predicted by the model for the three bottom types discussed above. These results demonstrate that increased acoustic impedance, for higher-speed sediments, generally leads to increased sound levels at short-medium distance, but the higher levels at long ranges for the silt bottom show this is not always the case. The enhanced sound propagation at long ranges observed for the lower-speed silt bottom is attributed to the lower P-wave attenuation coefficient; modes that propagate partially in the bottom experience less attenuation so do not decay as rapidly. At short ranges the sound field is dominated by water-borne paths so the bottom attenuation coefficient is less important relative to the P-wave speed which defines the lowest frequency that can propagate as a water-borne mode.

We note that, in addition to the unknown sediment types, the type of acoustic basement and the depth to the basement were also unknown. These parameters could also be expected to influence the long-range sound levels, though changing these parameters was not investigated.

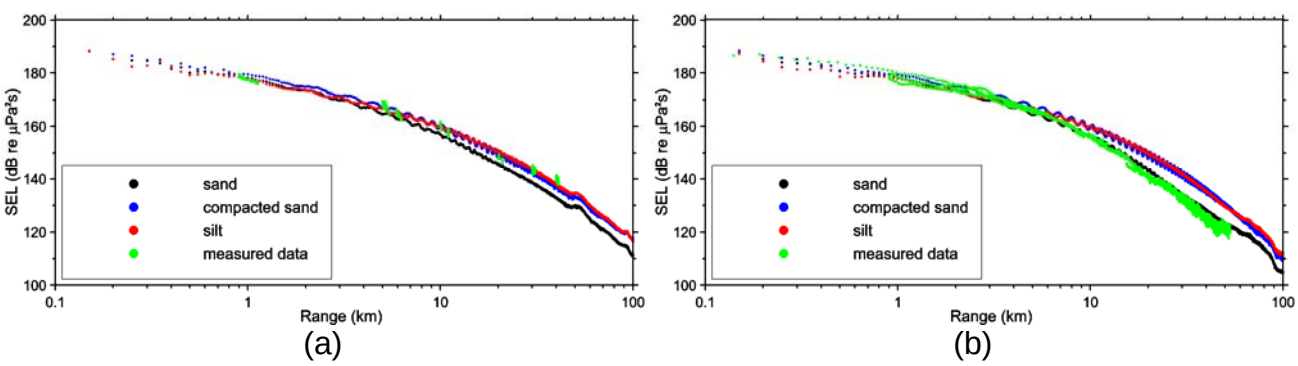

FIGURE 5.6. Broadband model SEL predictions and measured data for sand, compacted sand, and silt bottom types for (a) broadside and (b) endfire aspects.

SUMMARY

A comparison of modeled sound levels with sound level measurement data from GX Technology's 2006 source verification measurement study indicates that model predictions generally agreed well with the measured sound levels. Modeled broadband SEL values were in excellent agreement (less than 3dB at all ranges) with measured data for the endfire aspect using a sand bottom type. The model results for the array broadside aspect agreed well with measurements at close ranges, but results based on a sand

bottom type underestimated sound levels at ranges beyond 1 km. At 30 km the difference was approximately 7 dB. The discrepancy could stem from inaccurate model source level estimation, particularly at frequencies between 100 Hz and 300 Hz that are best supported for sound propagation in this environment, or from improperly defined geo-acoustic model input parameters, or a combination of the two effects. A comparison of the 1/3-octave band level frequency distributions indicated that the model may under-estimate the dominant 200 Hz component of the sound field observed in the data, but overall the frequency distribution is predicted well at all ranges.

A sensitivity analysis of the influence of bottom type selection on model results indicated that model predictions for a sand bottom matched well with measured sound levels in the endfire direction at all ranges. Broadside model results for a sand bottom underestimated measurements at ranges greater than 1 km. The mismatch increased from near 0 dB at 1 km to 7 dB at 40 km. It is quite possible that the broadside mismatch was due to use of the wrong bottom type in that direction. Spatial variability of bottom type was directly observed in the endfire measurements; there was a clear transition to more absorptive bottom type at approximately 12 km distance from the OBHs in the endfire data that caused transmission loss to abruptly increase for source positions at greater distances. Model results using either the compacted sand or silt bottoms matched well the broadside measurements at all ranges.

6. MONITORING AND MITIGATION METHODS [8]

This chapter describes the marine mammal monitoring and mitigation measures implemented for GXT's seismic study in the Chukchi Sea, addressing the requirements specified in the IHAs (Appendices A and B). The section begins with a brief summary of the monitoring tasks relevant to mitigation for marine mammals. The acoustic measurements and modeling results used to identify the safety radii for marine mammals are then described. A summary of the mitigation measures required by NMFS is then presented. The section ends with a description of the monitoring methods implemented for this cruise from aboard the source and support vessels involved in the seismic activities, 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 IHAs issued to GXT by NMFS and USFWS were satisfied, effects on marine mammals were minimized, and residual effects on animals were documented. Tasks specific to monitoring are listed below (also see Appendix A):

- Provide qualified MMOs for the source and support vessels throughout the seismic surveys in the Chukchi Sea.
- Visually monitor the occurrence and behavior of marine mammals near the airguns when the airguns are operating and during a sample of the times when they are not.
- Visually monitor the occurrence and behavior of marine mammals from the various source and support vessels.
- Use support vessels to conduct visual surveys of areas where airgun sound could have received levels ≥160 dB re 1 μPa $_{rms}$.
- Use the primary support vessel to perform passive acoustic monitoring (PAM) in the 160 to 120 dB zones to search for groups of migrating bowhead whales.
- Record (insofar as possible) the effects of the airgun operations and the resulting sounds on marine mammals.
- Use the visual monitoring data as a basis for implementing the required mitigation measures.
- Estimate the number of marine mammals potentially exposed to strong airgun sounds.

Safety and Potential Disturbance Radii

Chukchi Sea—Discoverer

Under current NMFS guidelines (e.g., NMFS 2000), "safety radii" for marine mammals around airgun arrays are customarily defined as the distances within which received pulse levels are ≥180 dB re 1 μPa (rms) for cetaceans and ≥190 dB re 1 μPa (rms) for pinnipeds. The ≥190 dB re 1 μPa (rms) guideline was also employed by the USFWS for the animals under its jurisdiction (polar bears and walruses) in its IHA issued to GXT. These safety criteria are based on an assumption that seismic pulses received at lower received levels will not injure these animals or impair their hearing abilities, but that

[8] Chapter 6 by R. Rodrigues, B. Haley and H. Patterson (LGL).

higher received levels *might* have some such effects. Marine mammals exposed to ≥160 dB (rms) are assumed by NMFS to be potentially subject to behavioral disturbance. However, for certain groups (dolphins, pinnipeds), available data indicate that disturbance is unlikely to occur unless received levels are higher, perhaps ≥170 dB rms for an average animal. For the current seismic project there has also been concern that received pulse levels as low as 120 dB (rms) may have the potential to disturb whales, particularly bowhead cow/calf pairs and/or large groups (composed of 12 or more individuals) of bowhead or gray whales. Monitoring of the 160 and 120 dB zones, which was required in the IHA issued by NMFS, is discussed below in the section on Special Mitigation Measures.

In its application for an IHA, GXT modeled and reported radii for the 190, 180, 170, and 160 dB zones (Table 6.1). Subsequent to submitting its application, GXT contracted with JASCO to model sound source characteristics using a different model (see Chapter 3). The JASCO parabolic equation model was believed by GXT and NMFS to be superior in these waters because it accounted for bathymetry effects, water properties, and the geoacoustic properties of seabed layers. The JASCO-modeled radii (Table 6.1) were based on the worst case model predictions. This model was used by GXT to estimate sound level isopleths and radii for rms sound level thresholds between 120 and 190 dB. These modeled radii estimates were multiplied by a safety margin of 1.5 to obtain conservative exclusion radii for marine mammal safety as well as disturbance radii which were used during determination of actual safety radii based on empirical field measurements of the airgun sound by JASCO. The field work included forward and broadside range measurements and was completed prior to the beginning of seismic data acquisition (see Chapter 4).

In most cases broadside radii verified by measurement were greater than modeled radii (Table 6.1). Forward (or endfire) radii were less than broadside radii and generally less than modeled radii. The field measurements were conducted at a more southerly location than the locations for which modeling had been based, and differences in measured vs. modeled radii resulted in part from JASCO's inability to conduct field measurements in the same location that had been assumed in the model (see Chapter 4 for further details).

Mitigation Measures as Implemented

The primary mitigation measures that were implemented during the seismic activities in the Chukchi Sea included ramp up, power down, and shut down of the airguns. These measures are standard procedures during seismic cruises and are described in detail in Appendix E. Mitigation also included those measures specifically identified in the IHA (Appendix A) as indicated below.

Standard Mitigation Measures

Standard mitigation measures implemented during the study included the following:

1. Safety radii implemented for the seismic activities were determined by sound source verification of modeled values.
2. Power-down or shut-down procedures were implemented when a marine mammal was sighted within or approaching the applicable safety radius while the airguns were operating.
3. 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 sometimes not feasible due to ice conditions and power downs or shut downs were the preferred mitigation measures when mammals were sighted within or about to enter the safety radii.
4. A ramp-up procedure was implemented whenever operation of the airguns was initiated.

5. In order for seismic operations to start up during day or night, the full applicable safety radius must have been visible for at least 30 min.

Table 6-1. Comparison of the size of modeled safety radii with radii size determined during sound source measurements for the 2-string airgun array deployed from the *Discoverer* in the Chukchi Sea, Alaska, 2006 (see Chapter 4 for details).

Received Level (dB re 1 µPa)	Radii based on GXT modeling (km)	Radii based on JASCO modeling (km)	Broadside radii measured by JASCO (km)	Forward radii measured by JASCO (km)
190	0.06	0.45	0.48	0.62
180	0.25	1.81	1.77	1.46
170	1.25	3.69	5.11	3.36
160	6.00	9.58	10.97	7.28
120	N/A	>100	166.96	57.53

The specific procedures applied during power downs, shut downs, and ramp ups are described in Appendix E. Briefly, a ***power down*** as implemented aboard the *Discoverer* involved reducing the number of operating airguns from the full array of 36 airguns to either one or two airguns when a marine mammal was observed approaching or was seen within the safety radius. Power down also occurred when the *Discoverer* was between seismic survey lines to reduce the area of ensonification. The 190 and 180 dB radii around the much-reduced source operated during a power down were 100 m and 250 m, respectively. A ***shut down*** involved suspending operation of all airguns. A shut down was sometimes implemented when a mammal was first sighted within or approaching its safety radius. At other times the airgun array was first powered down, and was later fully shut down if the mammal approached the safety radius around the small source that operated during power downs. A ***ramp up*** involved a gradual increase in the number of airguns operating, with the number of operating guns generally being doubled every 5 min until the full array was operating.

Special Mitigation Measures as Required by NMFS

In addition to the standard exclusion radii of 190 and 180 dB (rms) for pinnipeds and cetaceans, respectively, NMFS, in the IHA, required GXT to monitor the 160 dB radius during all seismic activities. In addition, the IHA required GXT to monitor the 120 dB radius after 25 Sept. in the Chukchi Sea during periods when seismic activity was occurring.

Monitoring of the 120 dB zone was required due to concerns that seismic noise might disturb bowhead whales, particularly cow/calf pairs, within the 120 dB radius. The IHA designated two mechanisms to monitor this large area including (1) the use of survey aircraft to locate cow/calf pairs within the 120 dB radius, and (2) the use of a dedicated passive acoustic monitoring (PAM) system capable of detecting bowhead calls within the 120 dB radius. The IHA required that seismic operations be shut down if 4 or more bowhead cow/calf pairs were recorded within the 120 dB radius during the aerial monitoring, or if the PAM system detected one or more calling bowheads within the 120 dB radius.

The 160 and 120 dB radii extended approximately 12.4 and 55 km, respectively, ahead of the airgun source on the *Discoverer* and were monitored by MMOs onboard the *Octopus*. The *Octopus* was outfitted with a towed PAM system that was capable of locating the position of whale vocalizations. The

Octopus had 2 trained MMOs and 2 PAM system operators on board during all seismic operations. Due to bunk space limitations one of the PAM observers, who had the training and experience of a typical MMO, also served as the second MMO.

Initial clearance of the 160 and 120 dB zones was conducted prior to ramp up of the airgun array and on occasions when the source had been shut down for periods of 10 minutes or more, either due to presence of marine mammals or operational constraints. Clearance of the 160 dB area was conducted by the visual MMOs onboard the *Octopus*. In general, during daylight hours MMOs are able to effectively monitor a distance of ~2.5 – 2.7 km from a vessel. The *Octopus* traveled along a series of three transects centered on the point of the anticipated first shot in the ramp up procedure. The survey lines were ~14 km in length and spaced ~5.4 km apart resulting in a surveyed area ~8.1 km x 7 km centered on the first shot point.

Once the initial 160 dB area had been cleared the chase vessel moved to a position ~55 km ahead of the source vessel to begin monitoring of the 120 dB zone ahead of the seismic vessel. Operational monitoring was conducted on a continuing basis during seismic operations and utilized the combined observations of MMOs onboard the *Discoverer* and the *Octopus*, as well as the PAM system on the *Octopus*. During monitoring of the 120 dB zone, the *Octopus* reduced speed to listen for whales every 30 minutes between periods of increased speed required for sufficient coverage of a relatively large area. The PAM array was monitored continuously, but these slower-speed listening sessions reduced vessel propulsion and water flow noise and improved the ability of the PAM system to detect vocalizing whales.

Periodically, the *Octopus* returned to within 5-10 km of the *Discoverer*. The *Octopus* then followed a track in front of the *Discoverer* to again clear the 160 dB zone. Once the 160 dB zone was cleared, the *Octopus* again moved to the 120 dB isopleth approximately 55 km ahead of the *Discoverer* to continue monitoring of the 120 dB zone. This monitoring pattern was continued throughout the duration of the survey. The 160 dB zone was cleared no less than every 48 hours or three times per 7 days as required by the IHA. Monitoring of the 55 km 120 dB zone stopped on 16 October due to safety concerns as inclement weather increased (at a distance of 55 km, the *Discoverer's* radar did not detect the *Octopus*).

Additional Mitigation Measures Required by USFWS

In addition to the mitigation measures listed above, the USFWS required that

1. The vessels observed an 800 m (0.5 mi.) exclusion zone around walruses and polar bears sighted either on land or ice.
2. All polar bear or walrus sightings be reported to USFWS within 48 h.
3. No seismic operations be conducted within a 64 km (40-mi.) radius of communities to minimize potential interactions with walrus hunters.

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 seismic source and support vessels were as follows: (1) Conduct monitoring and implement mitigation measures to avoid or minimize exposure of cetaceans to airgun sounds with received levels >180 dB re μPa (rms), or of pinnipeds to >190 dB. (2) Conduct monitoring and implement mitigation measures to avoid or minimize exposure of groups of 12 or more bowhead or gray whales to airgun sounds with received levels >160 dB re μPa (rms). (3) Document numbers of marine mammals present, any reactions of marine mammals to seismic activities, and whether there was any possible effect on accessibility of marine mammals to subsistence hunters in Alaska. Results of the monitoring effort are presented in Chapter 7.

Table 6-2. Safety radii for sound levels 190, 180, and 160 dB re 1 μPa (rms) applied by MMOs during GXT's seismic survey in the Chukchi Sea, 2006. Safety radii were derived from JASCO's field measurements (Chapter 4). The observers were stationed 135 m ahead of the airgun array.

Received Sound Level	**Distance of Safety Radius (from observer)**		Mitigation
	Full Array (36 airguns)	Powered Down (1 or 2 airguns)	
≥190 dB	558 m	100 m	power down / shut down for pinnipeds
≥180 dB	1900 m	250 m	power down / shut down for cetaceans
≥160 dB	12400 m	N/A	clear prior to ramp up; power down (if aggregation of >12 baleen whales)

The visual monitoring methods that were implemented during GXT's seismic exploration were very similar to those used during previous cruises involving seismic activities (e.g., Smultea and Holst (2003), MacLean and Haley (2004), Holst (2004), Smultea et al. (2004), Haley and Koski (2004), MacLean and Koski (2005), Smultea et al. (2005), Holst et al. (2005a,b), and Ireland et al. (2005). The standard visual observation methods are described in Appendix E.

In summary, during the seismic survey activities in the Chukchi Sea at least one MMO onboard the source vessel maintained a visual watch for marine mammals during all daylight hours while seismic surveys were underway. Observers focused their search effort forward of the vessel but also searched aft of the vessel while it was underway. Watches were conducted with the naked eye, Fujinon 7 × 50 reticle binoculars, and Zeiss 20 x 60 image stabilized binoculars. MMOs instructed seismic operators to power down or shut down airguns if marine mammals were near or about to enter the appropriate safety radii (Table 6.2).

MMOs onboard the *Octopus* conducted watches similar to those of MMO's onboard the *Discoverer*. The *Octopus* was the chase vessel for the Discoverer and generally traveled approximately 6 to 8 km ahead of the Discoverer to monitor the 160 dB radius which extended approximately 12.5 km from the Discoverer. MMOs onboard the *Octopus* were thus able to notify MMOs onboard the *Discoverer* if 4 bowhead cow/calf pairs entered the 160 dB radius, allowing the *Discoverer* to implement appropriate mitigation. Appendix E provides further details regarding visual monitoring methods.

Passive Acoustic Monitoring Methods

Initial clearance of the 160 dB (*rms*) zone was conducted prior to ramp up of the airgun array and on occasions when the source had been shut down for periods of 10 minutes or more, either due to presence of marine mammals or operational constraints. If the mitigation gun had been operational and MMO and PAM monitoring had been continuing, ramp up could occur on new lines without initial clearance by the PAM. Clearance of this zone was performed by sailing the *Octopus* with PAM along three transects centered on the point of the anticipated first shot in the ramp up procedure (Figure6.1).

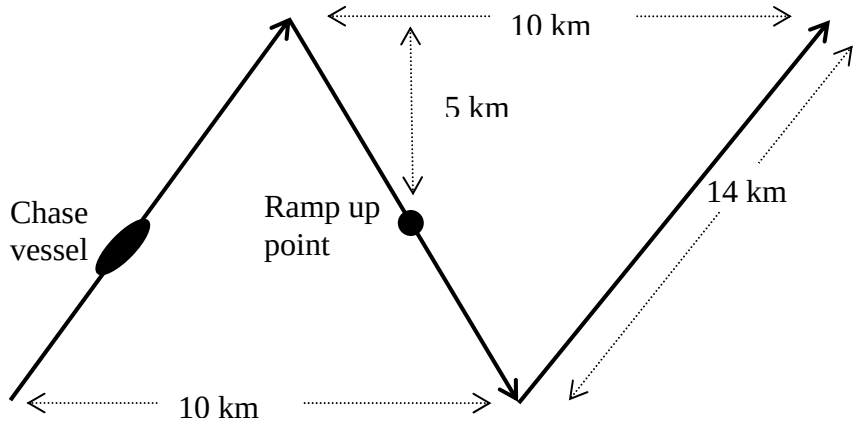

FIGURE 6.1: Transects completed by chase vessel for clearance of 160 dB zone.

After clearing the 160 dB zone area, the chase vessel was required to continuously monitor for vocalizing whales that may be encountered ahead of the survey vessel. For the first two days of surveying the zone monitored by PAM extended to 55 km ahead of the *Discoverer*. This zone was based on the area expected to be ensonified above 120 dB *rms*. In carrying out this monitoring, the PAM vessel followed a saw-tooth pattern in which it sailed at approximately 6 kts speed ahead of the *Discoverer* and to the side of the survey track that would intercept the migration direction of bowhead whales. After the first two days of this approach it was decided for safety reasons, and for optimal practical PAM effectiveness, that the maximum distance the *Octopus* would advance ahead of the *Discoverer* would be limited to 15 km. The reduced distance was employed for the remainder of the seismic survey. If bowhead or gray whale calls were detected by the PAM system, the planned procedure dictated that the MMO was to attempt to locate the whale visually, assisted by bearings provided by the PAM system.

Analyses

Vessel-Based Surveys

Categorization of Data.—Observer effort and marine mammal sightings were divided into several analysis categories related to vessel and seismic activity. The categories were similar to those used during various other recent seismic studies conducted under IHAs (e.g., Haley and Koski 2004; MacLean and Koski 2005; Smultea et al. 2005; Holst et al. 2005a,b; Ireland et al. 2005). These categories are defined briefly below, with a more detailed description provided in Appendix E.

In general, data were categorized as “seismic” or “non-seismic”. “Seismic” included all data collected from the source vessel (*Discoverer*) while the airguns were operating. Non-seismic included all data obtained before the airguns were activated (pre-seismic) or >1 or >2 h (for pinnipeds and cetaceans, respectively) after the airguns were deactivated. Data collected during post-seismic periods from 3 min to 1 h (for pinnipeds) or 2 h (for cetaceans) after cessation of seismic activity were considered either “recently exposed” (3–30 min) or “potentially exposed” (30 min to 1 or 2 h) to seismic sound levels, and were excluded from analyses. Thus, the post-seismic data (3 min to 1 or 2 h after cessation of seismic) were not included in either the “seismic” or “non-seismic” categories. The 3 min cutpoint was considered appropriate because of the relatively slow speed during seismic operations (~4 kt or 7.4 km/h, average).

The 1 and 2 h cutoff periods correspond to the time required to transit to an area in which the received sound level would not be likely to have much (if any) effect on the distributions of pinnipeds and cetaceans, respectively. The chosen sound levels were comparable to those used in other recent seismic cruises (Haley and Koski 2004; MacLean and Koski 2005; Holst et al. 2005a; Ireland et al. 2005). Periods of time during which other vessels were sighted within 1 km of the *Discoverer* (for pinnipeds) and 5 km of the *Discoverer* (for cetaceans) were also excluded. At the time of publishing it was not possible to calculate the specific distance between the *Octopus* and *Discoverer* beyond the usual operating distance of ~3 nm or ~6 km apart. At this distance it is unlikely that the distribution of pinnipeds observed from the *Octopus* would have been affected by the seismic noise generated by the *Discoverer*; thus all pinniped sightings from the *Octopus* are included as 'non-seismic'. The distance at which the distribution of cetaceans may have been affected by the *Discoverer* was greater; therefore we did not classify cetacean sightings from the *Octopus* as either seismic or non-seismic.

This categorization system was designed primarily to distinguish potential differences in behavior and distribution of marine mammals with and without seismic surveys. The rate of recovery toward "normal" during the post-seismic period is uncertain. Marine mammal responses to seismic sound likely diminish with time after the cessation of seismic activity. The end of the post-seismic period was defined as a time long enough after cessation of airgun activity to ensure that any carry-over effects of exposure to sounds from the airguns 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 E.

Line Transect Estimation of Densities.—Marine mammal sightings during the "seismic" and "non-seismic" periods were used to calculate sighting rates (#/km). Sighting rates were then used to calculate the corresponding densities (#/km^2) of marine mammals near the survey and chase ships 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

- periods 3 min to 1 or 2 h after the airguns were turned off (post-seismic), or
- when ship speed was <3.7 km/h (2 kt), or
- with seriously impaired sightability. (This included all nighttime observations, and daytime periods with one or more of the following: visibility <3.5 km, Beaufort sea state (Bf) >5 (Bf >2 for porpoises), or >60º of severe glare between 90º left and 90º right of the bow.)

Correction factors for missed animals, i.e., $f(0)$ and $g(0)$, were calculated for gray whales, bowhead whales, unidentified whales, bearded seals, ringed seals, Pacific walruses, unidentified seals, and unidentified pinnipeds (see Appendix E). Other correction factors were taken from other related studies, as summarized by Koski et al. (1998) and Barlow (1999). This was necessary because of the low number of sightings of any individual species, making estimation of $f(0)$ from project specific data problematic, and because of the inability to assess trackline sighting probability, $g(0)$, during a study of this type.

Densities estimated from non-seismic observations 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.

Estimating Numbers Potentially Affected.—For purposes of the IHA, NMFS assumes that any marine mammal that might have been exposed to airgun pulses with received sound levels ≥160 dB re 1 μPa (rms) may have been disturbed. When calculating the number of mammals potentially affected, we used the measured 160 dB radii with some adjustments based on JASCO's model for situations where specific measurements were not available (Tables 5.1D, 5.2C).

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") involved multiplying the following three values for each airgun configuration in use: (A) km of seismic survey; (B) width of area assumed to be ensonified to ≥160 dB (2 × 160 dB radius); and (C) densities of marine mammals estimated from this study (Appendix I). Thus, areas of water ensonified on more than one occasion, due to overlapping or adjacent tracklines, were counted in the area calculation as many times as they were ensonified.

The second approach ("individuals") involved multiplying the same three values, except that areas ensonified to ≥160 dB on more than one occasion, due to overlapping tracklines, were counted only once. The area of water considered ensonified in this calculation was therefore smaller than in the first calculation. During the Chukchi Sea surveys by the *Discoverer*, many of the tracklines were in close proximity to one another in comparison with the 160 dB distance, leading to much overlap of the areas ensonified to ≥160 dB during transits along the various tracklines. In this situation, the two approaches lead to very different values for the ensonified area, and the estimated number of exposures is much higher than the estimated number of individuals exposed.

The two approaches can be interpreted as providing maximum and minimum (respectively) estimates of the number of marine mammals that would have been exposed to sound levels ≥160 dB re 1 μPa (rms) if they did not show avoidance reactions. The actual number is probably somewhere between these two estimates. This approach was originally developed to estimate numbers of seals potentially affected by seismic surveys in the Alaskan Beaufort Sea conducted under IHAs (Harris et al. 2001). The method has recently been used in estimating numbers of seals and cetaceans potentially affected by other seismic surveys conducted under IHAs (e.g., Haley and Koski 2004; Smultea et al. 2004, 2005; MacLean and Koski 2005; Holst et al. 2005a,b). The methodology is described in detail in these past reports and in Appendix E.

7. RESULTS OF GXT'S MARINE MAMMAL MONITORING PROGRAM[9]

INTRODUCTION

This chapter provides background information on the occurrence of marine mammals in the Chukchi Sea, and describes the results of GXT's 2006 marine mammal monitoring program. In addition, the numbers of marine mammals potentially affected during project operations within the study area are estimated. The study area, for the purposes of marine mammal data analyses, was the actual seismic survey area and transit areas within the Chukchi Sea (see Fig. 2.1).

The marine mammals known to occur along the cruise trackline across the Chukchi Sea belong to four taxonomic groups: odontocetes (toothed whales, including the beluga whale), mysticetes (baleen whales), pinnipeds (seals and walruses), and ursids (polar bear). Nine cetacean species and five species of pinnipeds are known to occur in the survey area, along with the polar bear. Of the total 15 species, three (all cetaceans) are listed under the U.S. Endangered Species Act (ESA) as endangered: the bowhead, humpback, and fin whales. Appendix F summarizes the abundance, habitat, and conservation status of the marine mammal species likely to occur in the cruise area.

CHUKCHI SEA MONITORING

Monitoring Effort and Marine Mammal Encounter Results

This section summarizes the visual monitoring effort and sightings from the *Discoverer* and the *Octopus* during the Chukchi Sea seismic surveys from 7 Oct. to 22 Nov. 2006 and 28 Sept. to 15 Nov. 2006, respectively. Summaries of results of visual monitoring are presented here, with more detailed data presented in Appendix G, including survey effort in both kilometers and hours. A general summary of effort and sightings is shown in Table 7.1 and Appendix Table G.1. Marine mammals observed during transits outside the study area are summarized in Appendix Table G.2.

Seismic survey activities by the *Discoverer* occurred along 1939 km of trackline during daylight, over a total of 240 h. In total, 4719 km and 539 h of visual observations were conducted within the Chukchi Sea study area, including 2664 km and 345 h of observation from the *Discoverer* and 2055 km and 194 h from the *Octopus* (Fig. 2.1; Appendix Table G.1). "Useable" survey conditions occurred during 45.4% (in km; 38.2% in h) of the total visual effort (Appendix Table G.1). "Useable" effort excluded periods 3 min to 1 h (for pinnipeds) or 2 h (for cetaceans) after the airguns were turned off, poor visibility conditions (visibility <3.5 km or extensive glare), and Beaufort Wind force (Bf) >5. Periods of time during which other vessels were sighted within 1 km of the *Discoverer* (for pinnipeds) and 5 km of the *Discoverer* (for cetaceans) were also excluded. At the time of publishing it was not possible to calculate the distance between the *Octopus* and *Discoverer* beyond the usual operating distance of ~6 nm or ~11 km. At this distance it is unlikely that the distribution of pinnipeds observed from the *Octopus* would have been affected by the seismic noise generated by the *Discoverer*, thus all pinniped sightings from the *Octopus* are included as 'non-seismic'. The distance at which the distribution of cetaceans may have been

[9] By Heather Patterson, Andrea Hunter, Meaghan Jankowski, Darren Ireland, Beth Haley.

TABLE 7.1. Detection rates for sightings from the *Discoverer* (7 Oct.–12 Nov. 2006) and *Octopus* (28 Sept.–11 Nov. 2006) during the Chukchi Sea cruise.

	Non-Seismic			Post-Seismic			Seismic			*Total*		
Effort Type	**No. of Detections**	**Effort (km)**	**Detection Rate (No./1000 km)**	**No. of Detections**	**Effort (km)**	**Detection Rate (No./1000 km)**	**No. of Detections**	**Effort (km)**	**Detection Rate (No./1000 km)**	**No. of Detections**	**Effort (km)**	**Detection Rate (No./1000 km)**
A. Discoverer												
Useable[a]												
Cetaceans	0	49	--	N/A	N/A	N/A	1	361	2.8	***1***	***410***	***2.4***
Pinnipeds in water	0	49	--	N/A	N/A	N/A	3	361	8.3	***3***	***410***	***7.3***
Pacific Walrus in water	0	49	--	N/A	N/A	N/A	1	361	2.8	***1***	***410***	***2.4***
Total All Pinnipeds	*0*	*49*	--	*N/A*	*N/A*	*N/A*	*3*	*361*	*8.3*	***3***	***410***	***7.3***
Total Unidentified Pinnipeds	*0*	*49*	--	*N/A*	*N/A*	*N/A*	*0*	*361*	--	***0***	***410***	***--***
Total All Pacific Walrus	*0*	*49*	--	*N/A*	*N/A*	*N/A*	*1*	*361*	*2.8*	***1***	***410***	***2.4***
Total Seals	*0*	*49*	--	*N/A*	*N/A*	*N/A*	*2*	*361*	*5.5*	***2***	***410***	***4.9***
Non-Useable[b]												
Cetaceans	*0*	597	--	0	79	--	0	1578	--	***0***	***2254***	***--***
Pinnipeds in water	*4*	597	6.7	0	40	--	3	1578	1.9	***7***	***2215***	***3.2***
Pacific Walrus in water	*0*	597	--	0	40	--	0	1578	--	***0***	***2215***	***--***
Total All Pinnipeds	*4*	*597*	*6.7*	*0*	*40*	--	*3*	*1578*	*1.9*	***7***	***2215***	***3.2***
Total Unidentified Pinnipeds	*0*	*597*	--	*0*	*40*	--	*0*	*1578*	--	***0***	***2215***	***--***
Total All Pacific Walrus	*0*	*597*	--	*0*	*40*	--	*0*	*1578*	--	***0***	***2215***	***--***
Total Seals	*4*	*597*	*6.7*	*0*	*40*	--	*3*	*1578*	*1.9*	***7***	***2215***	***3.2***
Discoverer Totals												
Cetaceans	***0***	***646***	***--***	***0***	***79***	***--***	***1***	***1939***	***0.5***	**1**	**2664**	**0.4**
Pinnipeds	***4***	***646***	***6.2***	***0***	***40***	***--***	***6***	***1939***	***3.1***	**10**	**2625**	**3.8**
Unidentified Pinnipeds	***0***	***646***	***--***	***0***	***40***	***--***	***0***	***1939***	***--***	**0**	**2625**	**--**
Pacific Walrus	***0***	***646***	***--***	***0***	***40***	***--***	***1***	***1939***	***0.5***	**1**	**2625**	**0.4**
Seals	***4***	***646***	***6.2***	***0***	***40***	***--***	***5***	***1939***	***2.6***	**9**	**2625**	**3.4**
B. Octopus												
Useable[a]												
Pinnipeds in water	55	1734	31.7	N/A	N/A	N/A	N/A	N/A	N/A	***55***	***1734***	***31.7***
Pacific Walrus in water	2	1734	1.2	N/A	N/A	N/A	N/A	N/A	N/A	***2***	***1734***	***1.2***
Total All Pinnipeds	*57*	*1734*	*32.9*	N/A	N/A	N/A	N/A	N/A	N/A	***57***	***1734***	***32.9***
Total Unidentified Pinnipeds	*1*	*1734*	*0.6*	N/A	N/A	N/A	N/A	N/A	N/A	***1***	***1734***	***0.6***
Total All Pacific Walrus	*1*	*1734*	*0.6*	N/A	N/A	N/A	N/A	N/A	N/A	***1***	***1734***	***0.6***
Total Seals	*55*	*1734*	*31.7*	N/A	N/A	N/A	N/A	N/A	N/A	***55***	***1734***	***31.7***
Non-Useable[b]												
Pinnipeds in water	7	321	21.8	N/A	N/A	N/A	N/A	N/A	N/A	***7***	***321***	***21.8***
Pacific Walrus in water	0	321	--	N/A	N/A	N/A	N/A	N/A	N/A	***0***	***321***	***--***
Total All Pinnipeds	*7*	*321*	*21.8*	N/A	N/A	N/A	N/A	N/A	N/A	***7***	***321***	***21.8***
Total Unidentified Pinnipeds	*0*	*321*	--	N/A	N/A	N/A	N/A	N/A	N/A	***0***	***321***	***--***
Total All Pacific Walrus	*0*	*321*	--	N/A	N/A	N/A	N/A	N/A	N/A	***0***	***321***	***--***
Total Seals	*7*	*321*	*21.8*	N/A	N/A	N/A	N/A	N/A	N/A	***7***	***321***	***21.8***
OctopusTotals												
Cetaceans	***0***	***2055***	***--***	***N/A***	***N/A***	***N/A***	***N/A***	***N/A***	***N/A***	***0***	**2055**	**--**
Pinnipeds	***64***	***2055***	***31.1***	***N/A***	***N/A***	***N/A***	***N/A***	***N/A***	***N/A***	**64**	**2055**	**31.1**
Unidentified Pinnipeds	***1***	***2055***	***0.5***	***N/A***	***N/A***	***N/A***	***N/A***	***N/A***	***N/A***	**1**	**2055**	**0.5**
Pacific Walrus	***1***	***2055***	***0.5***	***N/A***	***N/A***	***N/A***	***N/A***	***N/A***	***N/A***	**1**	**2055**	**0.5**
Seals	***62***	***2055***	***30.2***	***N/A***	***N/A***	***N/A***	***N/A***	***N/A***	***N/A***	**62**	**2055**	**30.2**
Overall Totals for Both Vessels												
Cetaceans[c]	***0***	***2701***	***--***	***0***	***79***	***--***	***1***	***1939***	***0.5***	***1***	***4719***	***0.2***
Pinnipeds	***68***	***2701***	***25.2***	***0***	***40***	***--***	***6***	***1939***	***3.1***	***74***	***4680***	***15.8***
Unidentified Pinnipeds	***1***	***2701***	***0.4***	***0***	***40***	***--***	***0***	***1939***	***--***	***1***	***4680***	***0.2***
Pacific Walrus	***1***	***2701***	***0.4***	***0***	***40***	***--***	***1***	***1939***	***0.5***	***2***	***4680***	***0.4***
Seals	***66***	***2701***	***24.4***	***0***	***40***	***--***	***5***	***1939***	***2.6***	***71***	***4680***	***15.2***

Note: N/A means not applicable.
[a] Useable sightings are those made during useable daylight periods of visual observation, as defined in *Acronyms and Abbreviations.*
[b] Includes the "Post-Seismic" category.
[c] Includes only sightings from the *Discoverer.*

affected by the *Discoverer* was greater, therefore we did not classify cetacean sightings from the *Octopus* as either seismic or non-seismic. As such, cetacean sightings from the *Octopus* are described, but *not* included, in analyses. However, the cetacean sightings from the Octopus were used to calculate cetacean densities in the study area.. The project provided data on the fall occurrence, distribution, and abundance of marine mammals in the Chukchi Sea, an area where few systematic survey data had previously been collected.

Visual Survey Effort

Survey effort from the *Discoverer* and *Octopus*, in kilometers and hours, subdivided by seismic activity and Beaufort wind force, is summarized in Table G.1.

Discoverer.—During 4707 km of *Discoverer* operations, 410 km of useable visual observations were made (Appendix Table G.1). The low percentage of useable visual observation is, in most part, due to the decreasing daylight during Oct. and Nov. in the Arctic. MMOs observed exclusively from the

bridge (100% of watch time, eye height 13.32 m). Of the 345 h and 2664 km of visual observation effort, 0.41 h and 3.25 km occurred during nighttime ramp up. One observer was on visual watch aboard the *Discoverer* during 164 h (1285 km), with at least two observers on watch during the remaining 181 h (1380 km).

Beaufort force (sea state) during observations aboard the *Discoverer* ranged from 0 to 9 within the Chukchi Sea, with 1.3% (km) of the observation effort during conditions of Bf = 0-1 (Table G.1). Most (64.5%) of the 2663 km of observation effort occurred with Beaufort force 4 to 6 (wind speed 11-27 kt or 20-50 km/h). Approximately 31% (km) of the total observation effort occurred when the Beaufort force was greater than 5, a condition under which sightings are not considered useable. This is typical for the fall in the study region (Pilot Chart, date unkn.).

Octopus.—Within the Chukchi Sea, the *Octopus* covered a distance of 8230 km, with useable visual observations occurring during 2055 km (Table G.1). All visual observations from the *Octopus* were made from the bridge (eye height ~5 m) and during daytime. One observer was on visual watch aboard the *Octopus* during 194 h (2055 km).

Beaufort force during observations aboard the *Octopus* ranged from 1 to 7 within the Chukchi Sea, with 7.1% (in km) of the observation effort during conditions of Bf = 1 (Table G.1). Most (52.5%) of the 2055 km of observation effort occurred with Beaufort Force 2 to 3 (wind speed 4-10 kt or 7-19 km/h).

Visual Sightings of Marine Mammals and Other Vessels

Numbers of Marine Mammals Seen.—An estimated 111 individual marine mammals were seen in 75 groups through the Chukchi Sea study area (Table 7.2). Five marine mammal species were identified. Pinnipeds were far more abundant that cetaceans with bearded seals being the most commonly identified species (n = 44 individuals in 19 groups), followed by spotted seals (n = 6 in 6 groups; Table 7.3). Ringed seals and Pacific walrus were also observed within the project area. Only three Pacific walruses were observed during the study period. There were many sightings of unidentified seals (n = 54 individuals in 44 groups); most of these were likely ringed seals, given the known occurrence of this species throughout the study area.

Only one unidentified mysticete whale was recorded from the *Discoverer* during the survey (Table 7.2, 7.3). Fifteen groups of 25 cetaceans were sighted from the *Octopus.* We were not able to classify cetacean sightings from the *Octopus* as seismic or non- seismic due to time constraints. Because the *Octopus* typically worked within ~6 – 10 km of the *Discoverer*, the distribution of cetacean sightings from the *Octopus* might have been influenced by seismic operations. Therefore, the cetacean sightings from the *Octopus* are not included in the following analyses (Tables 7.2, 7.3). However, the *Octopus* cetacean sighting data were used to calculate cetacean densities in the survey area. These data will be further analyzed and presented as seismic vs. non-seismic in a forthcoming comprehensive report.. All pinniped sightings from the *Octopus* are considered non-seismic because the *Octopus* was typically ~6 – 10 km away from seismic operations, outside the distance within which pinnipeds are likely to be disturbed by the *Discoverer's* seismic activities. A detailed list of sightings is provided in Appendix Table G.3.

Most of the 75 sightings of marine mammals (81.3% or 61 groups) made within the study area were "useable" (Table 7.2, 7.3). These "useable" sightings, along with the corresponding effort data, are the basis for the ensuing analyses comparing sighting rates and behaviors of marine mammals during seismic and non-seismic periods.

Table 7.2. Numbers of sightings and of individual marine mammals, both (A) total, and (B) useable, observed in the study area from the Discoverer (7 Oct.–12 Nov. 2006) and from the Octopus (28 Sept.–11 Nov. 2006), during the Chukchi Sea cruise.

	Octopus		*Discoverer*								*Total*	
	Non-Seismic		Non-Seismic		Post-Seismic		Seismic		*Discoverer Total*			
Species	**Sightings**	**Indiv.**	**Sightings**	**Indiv.**	**Sightings**	**Indiv.**	**Sightings**	**Indiv.**	**Sightings**	**Indiv.**	**Sightings**	**Indiv.**
A. All Sightings												
Cetaceans												
Unidentified Mysticete Whale	N/A	N/A	0	0	0	0	1	1	*1*	*1*	***1***	***1***
Total Cetaceans	*N/A*	*N/A*	*0*	*0*	*0*	*0*	*1*	*1*	1	1	**1**	**1**
Pinnipeds in Water												
Unidentified Pinniped	1	1	0	0	0	0	0	0	*0*	*0*	***1***	***1***
Odobenids												
Pacific Walrus	1	2	0	0	0	0	1	3	*1*	*3*	***2***	***5***
Phocids												
Bearded Seal	17	42	0	0	0	0	2	2	*2*	*2*	***19***	***44***
Ringed Seal	2	2	0	0	0	0	0	0	*0*	*0*	***2***	***2***
Spotted Seal	6	6	0	0	0	0	0	0	*0*	*0*	***6***	***6***
Unidentified Seal	37	47	4	4	0	0	3	3	*7*	*7*	***44***	***54***
Total Pinnipeds	*64*	*100*	*4*	*4*	*0*	*0*	*6*	*8*	10	12	**74**	**112**
Total Unidentified Pinnipeds	*1*	*1*	*0*	*0*	*0*	*0*	*0*	*0*	0	0	**1**	**1**
Total Pacific Walrus	*1*	*2*	*0*	*0*	*0*	*0*	*1*	*3*	1	3	**2**	**5**
Total Seals	*62*	*97*	*4*	*4*	*0*	*0*	*5*	*5*	9	9	**71**	**106**
B. Useable[a] Sightings												
Cetaceans												
Mysticetes												
Unidentified Mysticete Whale	0	0	0	0	N/A	N/A	1	1	*1*	*1*	***1***	***1***
Total Cetaceans	*0*	*0*	*0*	*0*	*N/A*	*N/A*	*1*	*1*	1	1	***1***	***1***
Pinnipeds in Water												
Unidentified Pinniped	1	1	0	0	N/A	N/A	0	0	*0*	*0*	***1***	***1***
Odobenids												
Pacific Walrus	1	2	0	0	N/A	N/A	1	3	*1*	*3*	***2***	***5***
Phocids												
Bearded Seal	16	41	0	0	N/A	N/A	0	0	*0*	*0*	***16***	***41***
Ringed Seal	2	2	0	0	N/A	N/A	0	0	*0*	*0*	***2***	***2***
Spotted Seal	6	6	0	0	N/A	N/A	0	0	*0*	*0*	***6***	***6***
Unidentified Seal	31	39	0	0	N/A	N/A	2	2	*2*	*2*	***33***	***41***
Total Pinnipeds	*57*	*91*	*0*	*0*	*N/A*	*N/A*	*3*	*5*	3	5	**60**	**96**
Total Unidentified Pinnipeds	*1*	*1*	*0*	*0*	*N/A*	*N/A*	*0*	*0*	0	0	**1**	**1**
Total Pacific Walrus	*1*	*2*	*0*	*0*	*N/A*	*N/A*	*1*	*3*	1	3	**2**	**5**
Total Seals	*55*	*88*	*0*	*0*	*N/A*	*N/A*	*2*	*2*	2	2	**57**	**90**

Note: N/A means not applicable.
[a] Useable sightings are those made during useable daylight periods of visual observation, as defined in *Acronyms and Abbreviations*.

No deaths or injury of animals were observed during the seismic program, and no carcasses of whales, seals, and walruses were sighted (Appendix Table G.3).

Sightings with Airguns On.—Of the total 11 marine mammal sightings from the *Discoverer*, seven were made while the airguns were operating, four were made during non-seismic periods, and no sightings were noted during "post-seismic" periods (Tables E.1, 7.2).

A shut down mitigation measure was requested on one occasion when a group three walruses was sighted in the water approaching the 190 dB re 1 μPa $_{rms}$ safety radius around the operating airguns. Further details on this encounter are provided later in this chapter (see *Mitigation Measures Implemented*).

Sighting Rates.—Sighting rates (# groups sighted per unit effort) during various types of MMO effort are presented in Table 7.1. Sighting rates for all categories of pinnipeds from the *Octopus* were much greater than sighting rates from the *Discoverer* during non-seismic periods. This may have resulted in part from *Octopus* activities near the ice edge where marine mammal densities may have been greater than in open water areas where the *Discoverer* typically operated. Marine mammal sightings from the *Discoverer* may also have been reduced due to avoidance of airgun sound by marine mammals in the immediate area of the *Discoverer*.

TABLE 7.3. Number of marine mammal sightings from the *Discoverer* (7 Oct.–12 Nov. 2006) and *Octopus* (28 Sept.–11 Nov. 2006) during the Chukchi Sea cruise, and number that were "useable" in analyses. Numbers in parentheses are numbers of individuals.

	Discoverer Sightings (Individuals)		***Octopus*** Sightings (Individuals)		***Total*** Sightings (Individuals)	
Species	**All**	**Useable[a]**	**All**	**Useable[a]**	**All**	**Useable[a]**
Cetaceans						
Unidentified Mysticete Whale	1(1)	1(1)	0	NA	***1(1)***	***1(1)***
Total Cetaceans	***1(1)***	***1(1)***	0	NA	**1(1)**	**1(1)**
Pinnipeds						
Unidentified Pinniped	0	0	1(1)	1(1)	***1(1)***	***1(1)***
Pacific Walrus	1(3)	1(3)	1(2)	1(2)	***2(5)***	***2(5)***
Bearded Seal	2(2)	0	17(42)	16(41)	***19(44)***	***16(41)***
Ringed Seal	0	0	2(2)	2(2)	***2(2)***	***2(2)***
Spotted Seal	0	0	6(6)	6(6)	***6(6)***	***6(6)***
Unidentified Seal	7(7)	2(2)	37(47)	31(39)	***44(54)***	***33(41)***
Total Pinnipeds	***10(10)***	***3(5)***	***64(100)***	***57(91)***	**74(110)**	**60(96)**
Total Seals	*9(9)*	*2(2)*	*62(97)*	*55(88)*	**71(106)**	**57(90)**
Total Marine Mammals	***11(11)***	***4(6)***	***64(100)***	***57(91)***	**75(111)**	**61(97)**

Note: N/A means not applicable.
[a] Useable sightings are those made during useable daylight periods of visual observation, as defined in *Acronyms and Abbreviations.*

Based on the number of groups seen per kilometer from the *Discoverer*, sighting rates for cetaceans were greater during seismic operations than during non-seismic conditions (Table 7.1, 7.2). The reverse was true for pinniped sighting rates from the *Discoverer*; pinniped sighting rates were ~2 times greater during non-seismic than seismic periods. This trend was true for both useable and non-useable data (Table 7.1, 7.2). The highest sighting rate occurred for pinnipeds during non-seismic periods (8.3 detections/1000 km) although the sample size of "useable" detections was small.

When all data are considered (i.e., data from the *Octopus* and the *Discoverer*), sighting rates are greater for pinniped groups during non-seismic rather than seismic or post-seismic periods (Table 7.1). This is largely due to the high sighting rates from the *Octopus* which were all considered to be unaffected by seismic activities. Pooling these data with the sighting rate data from the *Discoverer* results in an overall higher sighting rate for all groups during non-seismic periods.

The presence of fog (visibility <3.5 km) was the most common reason that sightings were considered non-useable. During the surveys from the *Discoverer*, the detection rate during non-useable periods was generally reduced compared to that during useable periods, consistent with what would be expected during periods of poor vs. good visibility (Table 5.1). For the *Octopus*, sighting rates were higher for all groups for useable rather than non-useable data

Other Vessels.—While the *Discoverer* and *Octopus* worked in tandem, the vessels were typically within ~10 km of each other and often as close as ~5 km of each other. The location and proximity of the *Octopus* was extremely variable, and probably had some effect on the number of sightings and the behavior of marine mammals that were sighted. This effect, however, was not apparent to the MMOs in real time when they were observing marine mammals. The seismic vessel *Patriot* was also operating in the area but was never close enough to be seen by the MMOs. There were also rare observations within

the study area of other vessels at anchor when the *Discoverer* approached port, which had no affect on the distribution and behavior or marine mammals in the area of the *Discoverer's* seismic activities.

Passive Acoustic Monitroing Effort and Acoustic Detections of Marine Mammals

PAM monitoring carried out during seismic activities totaled 173 hr. This does not include hours of effort during testing and transit periods which totaled 16.5 hr.

Ship noise from the Octopus itself was the most common background noise heard during the survey. These sounds consisted of low pitched noise from the propeller and the engine. Airguns shots were audible when firing, but lasted only a small fraction of a second every 20 seconds.

No PAM sound detections were attributed to marine mammal vocalizations during either system testing or seismic survey monitoring. The fact that no marine mammal vocalizations were identified and no cetaceans were observed in the seismic survey area indicates that marine mammals were likely not present in the vicinity of the seismic operations. However, it is also possible that whales stopped vocalizing when exposed to airgun noise at levels existing further away from the seismic vessel than PAM monitoring was performed, or that they moved to avoid the sounds produced by the seismic survey.

Distribution of Marine Mammals

Observations during the Chukchi Sea study indicate that bearded seals were the most abundant marine mammals in the area (Tables 7.2, 7.3). We expect that several bearded seal identifications were incorrect. Several of the recorded bearded seal observations are likely observations of ringed seals, which is the more abundant species in the area (Bengston 2005), The majority of unidentified seals are expected to be ringed seals because bearded seals would be more easily confused with Pacific walrus (because of their size) and therefore classified as unknown pinnipeds. Pacific walruses were more abundant than ringed seals. Only half of the pinniped species were seen during both seismic and non-seismic periods. Ringed and spotted seals were seen only during non-seismic periods. The single, useable, cetacean sighting (unidentified mysticete whale) occurred during a seismic period (Table 7.2).

Marine Mammal Behavior

The data collected during visual observations provide information about behavioral responses of marine mammals to the seismic survey. The relevant data include estimated closest observed points of approach (CPA) to the airgun array, movement relative to the vessel when the airguns were and were not firing, and observed behavior of animals at the time of the initial sightings.

Closest Observed Point of Approach

No meaningful comparison of seismic vs. non-seismic sightings from this survey was possible due to the low number of seismic marine mammal observations. There were only three useable sightings of pinnipeds during seismic activity and 57 useable sightings during non-seismic periods (Tables 7.4 and 7.5).

Although the sample sizes are small, the trend in sighting-distance data from this study are consistent with those from many previous seismic studies. In those studies, marine mammals were usually observed at greater distances from the vessel and lower sighting rates when the airguns were operating than when the airguns were silent (e.g., Smultea et al. 2004; Haley and Koski 2004; MacLean and Koski 2005; Holst et al. 2005a,b).

TABLE 7.4. Closest observed points of approach (CPA) of useable marine mammal sightings from the *Discoverer* to the airguns during non-seismic and seismic periods during the Chukchi Sea survey (7 Oct.–12 Nov. 2006). There were no "useable" sightings during non-seismic periods.

		Seismic			
Taxonomic Group	**# Sightings**	**Mean CPA (m)**	**s.d.**	***n***	**Range (m)**
Cetaceans					
Mysticete	1	4275	N/A	1	N/A
Odontocete	N/A	N/A	N/A	N/A	N/A
Pinnipeds in Water					
Unidentified Pinnipeds	N/A	N/A	N/A	N/A	N/A
Pacific Walrus	1	235	N/A	1	N/A
Seals	2	686	91	2	622 - 750

[a] Includes only useable sightings as defined in *Acronyms and Abbreviations.*

TABLE 7.5. Closest observed points of approach (CPA) of useable marine mammal sightings to observers on board the *Octopus* during non-seismic periods in the Chukchi Sea from (28 Sept.–11 Nov. 2006).

		Non-seismic		
Taxonomic Group[a]	**# Sightings**	**Mean CPA (m)**	**s.d.**	**Range (m)**
Pinnipeds in Water				
Pacific Walrus	1	40	N/A	N/A
Seals	55	161	150	5 - 800
Unidentified Pinnipeds	1	20	N/A	N/A

[a] Includes only useable sightings as defined in *Acronyms and Abbreviations.*

Categories of Behavior

Marine mammal behavior is difficult to observe, especially from a seismic vessel, because individuals and/or groups are often at the surface only briefly, and there may be avoidance behavior. This causes difficulties in re-sighting those animals, and in determining whether two sightings some minutes apart are repeat sightings of the same individual(s). Only limited behavioral data were collected during this project because marine mammals were often seen at a distance from the vessel, and they were typically not tracked for long distances or durations while the vessel was underway. The two variables that were examined quantitatively to assess potential seismic effects on behavior were the categories of movement and behavior when the animal(s) were first observed (see Appendix Table E.1 for variables and definitions). The CPA distance recorded for each sighting was also an indicator of behavior (see above and Appendix Table G.3 for details on sightings). Results regarding movement and behavior are presented in Tables 7.6 and 7.7. (In those tables, cetacean data include only useable sightings from the *Discoverer*; however, seal, unidentified pinniped, and Pacific walrus data include useable sightings from both the *Discoverer* and the *Octopus*.)

TABLE 7.6. Numbers of useable sightings of marine mammals by movement category during seismic and non-seismic periods from the *Discoverer* (7 Oct.–12 Nov. 2006) and the *Octopus* (28 Sept.–11 Nov. 2006) within the Chukchi Sea. See Appendix E for definitions of movement categories

	Movement Relative to Vessel[a]									
Taxonomic Group[b]	**Mill**	**Flee**	**Swim Perpen-dicular**	**Swim Away**	**Swim Parallel**	**Swim Toward**	**No Movement**	**Total of Known/Recorded Movement**	**Unknown/ Not Recorded**	***Total***
Cetaceans										
Non-seismic	0	0	0	0	0	0	0	0	0	***0***
Seismic	0	0	0	0	0	0	0	0	1	***1***
Total	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***1***	**1**
Seals										
Non-seismic	2	1	1	7	14	2	28	55	0	***55***
Seismic	1	0	0	0	1	0	0	2	0	***2***
Total	***3***	***1***	***1***	***7***	***15***	***2***	***28***	***57***	***0***	**57**
Unidentified Pinnipeds										
Non-seismic	0	0	1	0	0	0	0	1	0	***1***
Seismic	0	0	0	0	0	0	0	0	0	***0***
Total	***0***	***0***	***1***	***0***	***0***	***0***	***0***	***1***	***0***	**1**
Pacific Walrus										
Non-seismic	0	0	0	1	0	0	0	1	0	***1***
Seismic	0	0	0	1	0	0	0	1	0	***1***
Total	***0***	***0***	***0***	***2***	***0***	***0***	***0***	***2***	***0***	**2**

[a] Includes only useable sightings as defined in *Acronyms and Abbreviations*.
[b] Cetacean sightings include only those from the *Discoverer*. Seals, unidentified pinnipeds, and Pacific walrus include those from the *Discoverer* and the *Octopus*. See text for explanation.

TABLE 7.7. Comparison of first observed behaviors of useable marine mammal sightings during non-seismic and seismic periods from the *Discoverer* (7 Oct.–12 Nov. 2006) and the *Octopus* (28 Sept.–11 Nov. 2006) within the Chukchi Sea. See Appendix E for definitions of behavior categories.

	First-observed Behavior[a]								
Taxonomic Group[b]	**Blow**	**Dive / Forward Dive**	**Swim / Travel**	**Porpoise/ Surface Active Travel**	**Spyhop / Look**	**Surface Active**	**Total of Known/Recorded Behavior**	**Behavior Unknown/Not Recorded**	***Total***
Cetaceans									
Non-seismic	0	0	0	0	0	0	0	0	***0***
Seismic	1	0	0	0	0	0	1	0	***1***
Total	***1***	***0***	***0***	***0***	***0***	***0***	***1***	***0***	**1**
Seals									
Non-seismic	0	6	4	1	43	0	54	1	***55***
Seismic	0	1	0	0	1	0	2	0	***2***
Total	***0***	***7***	***4***	***1***	***44***	***0***	***56***	***1***	**57**
Unidentified Pinnipeds									
Non-seismic	0	0	1	0	0	0	1	0	***1***
Seismic	0	0	0	0	0	0	0	0	***0***
Total	***0***	***0***	***1***	***0***	***0***	***0***	***1***	***0***	**1**
Pacific Walrus									
Non-seismic	0	0	0	0	0	1	1	0	***1***
Seismic	0	0	1	0	0	0	1	0	***1***
Total	***0***	***0***	***1***	***0***	***0***	***1***	***2***	***0***	**2**

[a] Includes only useable sightings as defined in *Acronyms and Abbreviations*.
[b] Cetacean sightings include only those from the *Discoverer*. Seals, unidentfied pinnipeds, and Pacific walrus sightings include those from the *Discoverer* and the *Octopus*. See text for explanation.

Movement.—There was only one useable cetacean sighting from the *Discoverer*, which occurred during a seismic period. However, the movement for this cetacean during the sighting was unknown (Table 7.6). A total of 57 useable seal sightings had movement records (Table 7.6). Of those seal sightings, 55 sightings were during non-seismic periods and only two sightings were made during seismic periods. During non-seismic periods, those seals for which movement was recorded were most often seen not moving relative to the vessel (51%; Table 7.6). Swimming parallel (25%) and swimming away (13%) were the next most frequently-observed movements in relation to the vessel for seals, during non-seismic periods. During seismic periods, the two seal sightings had recorded movements of milling and swimming parallel in relation to the vessel. The only record of an animal 'fleeing' from the vessel was

for a seal sighting which occurred during a non-seismic period (Table 7.6). There was one useable unidentified pinniped sighting, during a non-seismic period. The recorded movement was swimming perpendicular to the vessel (Table 7.6).

Two useable sightings of Pacific walruses had recorded movements. One walrus sighting occurred during a non-seismic period while the other sighting occurred during a seismic period. Both sightings had recorded the walrus movement as swimming away from the vessel (Table 7.6).

First Observed Behavior.—The "first observed behavior" for the one useable cetacean sighting was blowing (Table 7.7). For observations of seals with known behavior during non-seismic periods, looking (80%; Table 7.7) was the most common "first observed behavior", followed by diving/forward diving (11%), and swimming/traveling (7%). Similarly, the first observed behavior for seal sightings during seismic periods was looking and diving/forward diving. The only record of porpoising/surface active travel was for a seal sighting and occurred during a non-seismic period (Table 7.7). The first recorded behavior for the unidentified pinniped sighting which occurred during a non-seismic period, recorded the first behavior as swimming/traveling (Table 7.7). Behavior was recorded for two sightings of Pacific walrus, one was surface active during a non-seismic period, and the other was swimming/traveling during a seismic period (Table 7.7).

Mitigation Measures Implemented

There was only one mitigation measure requested, which was a shut down of the airguns due to a Pacific walrus sighting, where three walruses were approaching the pinniped safety radius applied during the Chukchi Sea survey. The applied "190 dB rms" safety radii for pinnipeds were 558 m for a power down and 100 m for a shut down (Tables 6.1, 6.2). The power down safety radius was within the range of measured 190 dB rms distances, which was 620 m ahead of the vessel and 480 m beside the vessel (Table 6.1). When assessing the likelihood of exposure to ≥190 dB rms, it is important to also account for the fact that sound levels are not uniform with depth (Greene and Richardson 1988; Tolstoy et al. 2004a,b), so animals need to dive well below the surface to encounter sound levels ≥190 dB rms near the measured sound level distances.

On October 14, 2006 at 23:31:26 GMT, three Pacific walruses (two adults and one juvenile; sighting 3, Appendix Table G.3) were sighted swimming 493 m ahead of the MMO, off the starboard bow. The MMO immediately called for a shut down of the 35 operating airguns (3280 in^3; the full array includes 36 airguns with a total volume of 3320 in^3) and the array was immediately shut down. Therefore, the three animals only came within 622 m of the 35 operating airguns before the shut down occurred. The measured 190 dB rms distance ahead of the full 36-airgun array was 620 m (Table 6.1), so the three walruses were initially sighted very near the edge of the measured 190 dB rms zone ahead of the vessel. After the shut down, the walruses dove as a group and re-surfaced 317 m from the MMO, off the starboard bow. They proceeded to dive again and re-surfaced 100 m from the MMO, but off the port bow. The group was last observed to the stern of the vessel at a distance of 606 m from the MMO (487 m from the shut down airguns), leisurely swimming perpendicularly away from the vessel's trackline. There were no other sightings of pinnipeds for which mitigation measures were needed, so the only observed pinnipeds possibly ensonified at ≥190 dB rms were the three Pacific walruses.

No power downs or shut downs were implemented for cetaceans. A power down was required when cetaceans approached within the "180 dB rms" safety radius of 1900 m from the *Discoverer*'s airgun array. A full shut down was required if cetaceans approached within 250 m of the powered-down array, or if the animal was first detected within the shut down safety radius of the powered-down

configuration). The single, useable cetacean sighting was of an unidentified mysticete whale >4 km away from the *Discoverer*. Therefore, no cetaceans appeared to have been ensonified to ≥180 dB rms.

Estimated Number of Marine Mammals Present and 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, source depth, water-mass and bottom conditions, and—for directional sources—aspect (Chapter 3 and 4; see also 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) and further reduced for animals that are on the ice.

Disturbance and Safety Criteria

Table 6.1 shows the preliminary distances at which various sound levels were estimated to be received from the *Discoverer's* 3320 in^3 36-airgun array. The predicted 160 and 170-dB radii are assumed behavioral disturbance criteria. The prelimimary 180 and 190 dB rms broadside distances were used as the safety radii for determining when mitigation measures were required. During this and many other recent projects, NMFS has required that mitigation measures be applied to avoid or minimize the exposure of cetaceans and pinnipeds to impulse sounds with received levels ≥180 dB and ≥190 dB, respectively. NMFS commonly assumes that cetaceans and seals exposed to pulsed sounds with received levels ≥160 dB (rms) might be disturbed, although there is little evidence that most pinnipeds or delphinids exposed to airgun sounds with levels just above 160 dB are disturbed. The safety and disturbance radii summarized in Table 6.1 were used after the field season to estimate numbers of marine mammals exposed to various received sound levels.

This section applies two methods to estimate the number of pinnipeds and cetaceans exposed to seismic sound levels strong enough that they might have caused disturbance or other effects. The procedures include ***(A)*** minimum estimates based on direct observations, and ***(B)*** estimates based on pinniped and cetacean densities obtained during this study. The actual number of individuals exposed to, and potentially affected by, strong seismic survey sounds likely was between the minimum and maximum estimates provided below.

Estimates from Direct Observations

The number of marine mammals observed close to the *Discoverer* during the Chukchi Sea survey provides a minimum estimate of the number potentially affected by seismic sounds. This is likely an underestimate of the actual number potentially affected. Some animals probably moved away before coming within visual range, and not all of those that remained would have been seen by observers. No polar bears were observed during GXT's 2006 project.

Pinnipeds Potentially Exposed to Sounds ≥160 dB re 1 μPa (rms).—During this project, there was only one sighting involving three Pacific walruses (two adults and one juvenile) that resulted in the implementation of a shut down (see previous section entitled Mitigation Measures Implemented). In this case, the walruses were sighted very near the 190 dB rms distance of 620 m ahead of the vessel, so it is

possible (given the movement of the animals away from the vessel and local variation in sound propagation) that these three animals were exposed to sounds ≥190 dB rms before they surfaced and were detected. Based on direct observation and the measured dB rms distances (Table 6.1), the number of pinnipeds "taken" at the ≥160 dB rms level includes a total of five seals (three unidentified seals and two bearded seals) and three Pacific walruses (the same animals which precipitated the only shut down), for a total of eight pinnipeds. If pinnipeds were assumed to only be harassed at noise levels ≥170 dB rms, the number of pinnipeds "taken" would be the same as the number "taken" at the ≥160 dB rms level.

Cetaceans Potentially Exposed to Sounds ≥160 dB re 1 μPa (rms).—There were no sightings involving cetaceans that resulted in the implementation of mitigation measures. In fact, there was only one useable sighting of a cetacean from the source vessel, an unidentified mysticete whale, when the airguns were operating (sighting 4, Appendix Table G.3). This single whale was exposed to sounds ≥160 dB rms, so the total number of cetaceans "taken" at the ≥160 dB rms level based on direct observations is one whale.

Estimates Extrapolated from Density

The numbers of marine mammals directly sighted during the Chukchi Sea study no doubt under-estimated the actual numbers present because some animals present near the trackline were likely not seen by the MMOs. During daylight, animals are missed if they are below the surface when the ship is nearby. Some other mammals, even if they surface near the vessel, are missed because of limited visibility, intervening ice, glare, or other factors limiting sightability. High sea state (Bf) was a significant factor during limited periods of this cruise. Also, sound levels were estimated to be ≥160 dB (rms) out to 12.5 km. This distance was well beyond that at which MMOs can detect even the more conspicuous animals under favorable sighting conditions during daylight. Furthermore, marine mammals could not be seen effectively during periods of darkness, which occurred for increasing numbers of hours per day after October, and nighttime observations were generally not required or attempted.

Some animals may have avoided the area near the seismic vessel while the airguns were firing (see Richardson et al. 1995, 1999; Stone 2003; Gordon et al. 2004; Smultea et al. 2004). Within the assumed 160–170 dB radii around the source (i.e., ~6−12.5 km), and perhaps farther away in the case of the more sensitive species and individuals, the distribution and behavior of pinnipeds and cetaceans may have been altered as a result of the seismic survey. This could occur as a result of reactions to the airguns, or as a result of reactions to the *Discoverer* or the *Octopus* themselves. The extent to which the distribution and behavior of pinnipeds might be affected by the airguns is uncertain, given the variability of previous study results (Thompson et al. 1998; Harris et al. 2001; Moulton and Lawson 2002; Miller et al. 2005). However, it is safe to assume that some pinnipeds that were on the ice as the two ships approached would have gone into the water in response to the *Octopus* before they were in view of observers on the *Discoverer*. Likewise, it is safe to assume that some cetaceans when approached by the seismic survey would have moved away before they were in view.

The methodology used to estimate the areas exposed to received levels ≥160, ≥170, ≥180 and ≥190 dB (rms) was described briefly in Chapter 6 *Monitoring and Mitigation Methods* and in more detail in Appendix E. Densities were based on data collected from the two vessels (*Discoverer* and *Octopus*) during GXT's seismic operations in the Chukchi Sea. The density data are summarized in Appendix Table H.1.

The aforementioned densities were used to estimate both the number of total *exposures* of marine mammals to 160, 170, 180, and 190 dB (rms), and the number of exposures of different *individual* marine

mammals to these sound levels. These numbers provide estimates of the number of animals potentially affected by seismic operations, as described in Chapter 6 and Appendix E.

The estimates provided here are based on the actual amount of seismic surveying completed during this project. In contrast, the estimates provided in the IHA applications for this project (LGL 2006a,b) were based on the then-anticipated amount of survey trackline, with an allowance for the possibility that some lines would not be surveyed due to poor weather. The estimates in the IHA applications assumed that there would be more seismic surveying than actually occurred (5302 km vs. 4707 km). The present estimates are lower than those in the IHA application, because the actual observed densities were sometimes lower than those used to estimate takes in the IHA application and because the size of the surveyed area was ~89% of the pre-season goal. In addition, the following estimates assume that all mammals present were well below the surface where they would be exposed to the sound levels predicted in Table 6.1 at a given distance. In fact, some pinnipeds and cetaceans in the water might remain close to the surface, where sound levels would be reduced by pressure-release effects (Greene and Richardson 1988), and some pinnipeds and cetaceans may have moved away from the path of the *Discoverer* before it arrived, either because the *Octopus* frequently traveled in front of *Discoverer*, or because of an avoidance response to the approaching *Discoverer* and its airguns. Thus, the following estimates are likely to overstate actual numbers exposed to various received sound levels.

Estimates of the densities of pinnipeds and cetaceans are given in Table H.1, including approximate corrections for sightability biases. These corrected densities were used to estimate the number of marine mammals that were exposed to various received levels of airgun sound, and thus potentially affected by seismic operations (Tables 7.8, 7.9).

Pinnipeds.—Table 7.8 summarizes the estimated numbers of pinnipeds that might have been exposed to received sounds with various levels relative to the number of "takes" requested in GXT's IHA application for the Chukchi Sea (LGL 2006a). These estimates are based on the ensonified area figures from Appendix Table E.2 and the density data from Appendix Table H.1. The latter Appendix table gives the density estimates derived from vessel-based surveys during both non-seismic and seismic periods. Note that the estimated numbers in Table 7.8, based on density data from non-seismic periods, represent the pinnipeds that would have been exposed had the animals not shown localized avoidance of the airguns or the ship itself, and assume that all pinnipeds present were in the water. Some of the animals calculated (based on density) to be within the ≥190 dB zone would in fact move away before being exposed to sounds that strong.

(A) ≥160 dB (rms): We estimate that there would have been ~1.45 exposures to each of ~12,298 different individual seals to airgun pulses with received levels ≥160 dB (rms) during the survey if all seals were in the water and showed no avoidance of the ≥160 dB zone (Table 7.8). Based on the available densities, 1,061 of the individuals would have been spotted seals, 6,516 bearded seals, and 410 ringed seals. We estimate that 112 Pacific walruses would have been exposed to ≥160 dB. The number of unidentified seals and unidentified pinnipeds were 4,311 and 117, respectively. Unidentified pinnipeds were more likely to be bearded seals or Pacific walruses as their size is similar and markedly larger than ringed or spotted seals, which were more likely to be classified as unidentified seals.

The numbers of different exposures of seals and walruses to levels ≥160 dB (rms) calculated from sighting rates during non-seismic periods, was ~1.45 times the number of individual animals exposed, suggesting that each animal was exposed ~1.45 times. The lower numbers of individuals than of

TABLE 7.8. Estimated numbers of individual pinnipeds, and exposures per individual, within the Chukchi Sea that might have been exposed to received levels of sounds at levels shown, divided into *(1)* seals and *(2)* Pacific walrus. Requested takes for the Chukchi Sea are also shown. Estimates are based on "corrected" densities of pinnipeds calculated from sighting effort.

Exposure level in dB re 1μPa (rms)	Based on Non-seismic density[a]		Based on Seismic density[a]		*Requested Take*
	Individuals	Exposures per Individual	Individuals	Exposures per Individual	
1. Seals					
≥160	12,298	1.45	1,102	1.45	19,397
≥170	6,354	1.24	570	1.24	
≥180	2,409	1.19	216	1.19	
≥190	724	1.07	65	1.07	
2. Unidentified Pinniped[b]					
≥160	117	1.45	0	-	NA
≥170	60	1.24	0	-	
≥180	23	1.19	0	-	
≥190	7	1.07	0	-	
3. Pacific Walrus					
≥160	112	1.45	798	1.45	2,359
≥170	58	1.24	411	1.24	
≥180	22	1.19	156	1.19	
≥190	7	1.07	48	1.07	

[a] These density estimates are presented in Appendix Table H.1

[b] Includes Pacific walrus and bearded seal (see text in Chapter 6 for details).

exposures is a result of the fact that many areas were ensonified repeatedly to ≥160 dB as the seismic vessel moved slowly along seismic lines. Most animals that lingered in the area would have been exposed to levels ≥160 dB a few times as the vessel passed by.

(*B) ≥170 dB (rms):* If the disturbance criterion for seals is considered to be ≥170 dB (rms), then the estimated number of exposures would be ~52% of the corresponding estimates for ≥160 dB (rms), based on the proportionally smaller areas exposed to ≥170 dB (Appendix Table E.2). Overall, there would have been ~6,354 seals and 58 walruses each exposed ~1.24 times to seismic sounds ≥170 dB (Table 7.8).

(C) ≥180 dB (rms): Some pinnipeds no doubt were within the 180 dB radius (estimated as being up to 1.77 km, Table 7) around the operating airguns but were missed by the observers even during airgun operations conducted in good visibility conditions. It was estimated that there were 1.12 exposures to each of 2,409 individual seals and 22 individual walruses to sounds ≥180 dB (Table 7.8). These figures assume that there was no effective avoidance by pinnipeds of the 180 dB radius around the approaching airguns.

TABLE 7.9. Estimated numbers individual cetaceans, and exposures per individual, within the Chukchi Sea that might have been exposed to received levels of sounds at levels shown. Requested takes for the Chukchi Sea are also shown. Estimates are based on "corrected" densities of cetaceans calculated from sighting effort.

Exposure level in dB re 1μPa (rms)	Based on Non-seismic density[a]		Based on Seismic density[a]		*Requested Take*
	Exposures	Exposures per Individual	Exposures	Exposures per Individual	
≥160	696	1.45	106	1.45	1396
≥170	359	1.24	55	1.24	
≥180	136	1.19	21	1.19	
≥190	41	1.07	6	1.07	

[a] These density estimates are presented in Appendix Table H.1

(D) ≥190 dB (rms): Based on densities calculated from sighting rates during non-seismic periods, we estimated that there would have been 1.07 exposures to each of 724 different seals and 7 different walruses to airgun sounds at ≥190 dB (rms) if there was no avoidance of the seismic vessel (Table 7.8). Even the smaller of these estimates is higher than the number of seals (*n* = 5) and walruses (n = 3) that direct observations indicated were possibly exposed to ≥190 dB (Mitigation section;. Some pinnipeds within the 190 dB radius presumably were missed during times when MMOs were on watch as well as at night when MMOs generally were not on watch. Even during times when MMOs were on watch, some seals at the surface were likely missed due to brief surface times, poor visibility, rough seas, and other factors related to sightability. Because of this, density-based estimates of exposures and exposed individuals were higher than those based on direct observation. However, estimates based on densities during non-seismic periods may be overestimates. The *Octopus* might be expected to displace some pinnipeds from the trackline before the *Discoverer* arrived, and some additional pinnipeds likely swam away in response to the approaching *Discoverer* to avoid exposure to such strong seismic sound. Therefore, the actual number exposed to ≥190 dB rms was probably lower than the above estimates.

Estimates Based on Densities during Seismic Periods: The estimates quoted in the above paragraphs are all based on densities recorded during non-seismic periods. Densities of seals recorded during seismic periods were lower than those recorded during non-seismic, but the only sighting of Pacific walruses was recorded during seismic operations (Appendix Table H.1). Lower densities might be expected during seismic periods, either because of displacement (to the extent it occurs) or the tendency of seismic activity to take place further away from pack ice where pinniped densities may be lower. (Arctic pinnipeds tend to concentrate near ice in summer.) On the other hand, locally abundant food resources near seismic track lines may be responsible for patchy walrus distribution and for occasional high densities in the open water areas where the seismic activities occurred. The numbers of exposures per individual and minimum numbers of individuals exposed, based on the corrected densities recorded during seismic periods, are summarized in Table 7.8.

Overall, these minimum figures are somewhat lower than those based on densities during non-seismic periods. Again, the minimum estimates of the numbers of individuals exposed are lower than the minimum estimates of numbers of exposures to various received levels. In other words, some of the

individual pinnipeds exposed to a given sound level were exposed to that level multiple times. This reflects the degree of overlap in the ensonified areas around different seismic lines.

Cetaceans.—The estimated numbers of cetaceans that might have been exposed to various levels of received sounds, relative to the number of "takes" requested in the IHA application, are summarized in Table 7.9. The density data used to calculate these numbers, for non-seismic as well as seismic periods, are presented in Table H.1. Note that the estimated numbers in Table 7.9 represent the cetaceans that would have been exposed had the animals not shown localized avoidance of the airguns or the ship itself. Many of the animals calculated (based on density) to be within the ≥180 or ≥190 dB zones would in fact have moved away before being exposed to sounds ≥180 or ≥190 dB. This is presumably at least part of the reason for the fact that estimates based on sightings during seismic periods were much lower than those during non-seismic periods (Table 7.9).

(A) ≥160 dB (rms): We estimate that 696 individual cetaceans would each have been exposed ~1.45 times to airgun pulses with received levels ≥160 dB (rms) during the survey if all cetaceans showed no avoidance of the seismic vessel (Table 7.9). Based on the available densities, 203 of the individuals would have been bowhead whales, 292 gray whales, 23 unidentified mysticete whales, 24 unidentified whales, and 154 harbor porpoises. Minimum estimates of the numbers of different individuals exposed to ≥160 dB were lower than were the estimated number of individual exposures to that level. This reflects the overlap in the ensonified areas around different seismic lines, and the fact that an animal remaining in the area would have been exposed repeatedly to ≥160 dB.

(B) ≥170 dB (rms): On average, some odontocete species may be disturbed only if exposed to received levels of airgun sounds ≥170 dB (rms). If so, then the estimated number of exposures would be ~52% of the corresponding estimates for ≥160 dB, based on the proportionally smaller areas exposed to ≥170 dB. Overall, ~359 individual cetaceans would have each been exposed ~1.24 times to seismic sounds ≥170 dB (Table 7.9).

(C) ≥180 dB (rms): If there was no avoidance of airgun noise by cetaceans, it was estimated that there would have been ~1.2 exposures to each of ~136 individual cetaceans to seismic sounds ≥180 dB (Table 7.9). However, most of these cetaceans probably moved away before the airguns were close enough to create a received level ≥180 dB. As noted earlier, there was only 1 cetacean sighting from *Discoverer* when airguns were operating. It is possible that some additional cetaceans were present within the 180 dB radius and not seen by the MMOs during good visibility conditions. However, under those conditions, most cetaceans present probably were seen.

Estimates Based on Densities during Seismic Periods: Only the unidentified mysticete whale category had a useable sighting sufficient for the calculation of a density applicable to periods of seismic activity (Appendix Table H.1). No cetacean was sighted from the *Discoverer* during non-seismic periods, however if all mysticete whale sightings from both the *Discoverer* and *Octopus* are pooled, the number of sightings during non-seismic periods is greater than the number during seismic periods. Given the small number of sightings, these results should be interpreted with caution. Based on the corrected densities recorded during seismic periods, the minimum numbers of exposures and minimum numbers of individuals exposed are summarized in Table 7.9.

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APPENDIX A:
INCIDENTAL HARASSMENT AUTHORIZATION ISSUED TO GX TECHNOLOGY BY THE NMFS FOR MARINE SEISMIC EXPLORATION ACTIVITIES IN THE CHUKCHI SEA, 2006

DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NATIONAL MARINE FISHERIES SERVICE

Incidental Harassment Authorization

GX Technology, Inc. of Houston Texas (GXT) 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 conducting a marine seismic survey program in the Chukchi Sea in Arctic Ocean waters under the jurisdiction of the United States, contingent upon the following conditions:

1. This Authorization is valid from the date of this Authorization through December 31, 2006.

2. This Authorization is valid only for activities (including support vessels and aircraft) associated with the *M/V Discoverer* conducting seismic survey programs in the Chukchi Sea, as specified in GXT's March 31, 2006 application.

3. (a) The species authorized for takings, by Level B Harassment only, are: Bowhead whales (*Balaena mysticetus*), gray whales (*Eschrichtius robustus*), beluga whales (*Delphinapterus leucas*), ringed seals (*Phoca hispida*), spotted seals (*Phoca largha*), and bearded seals (*Erignathus barbatus*).

(b) The taking of any marine mammal in a manner prohibited under this Authorization must be reported within 24 hours of the taking to the Alaska Regional Administrator (907- 586-7221) or his designee in Anchorage (907-271-3023), NMFS and the Chief of the Permits, Conservation and Education Division, Office of Protected Resources, NMFS, at (301) 713-2289, ext 110, or his designee.

4. The holder of this Authorization is required to cooperate with the National Marine Fisheries Service and any other Federal, state or local agency monitoring the impacts of the activity on marine mammals. The holder must notify the Chief of the Permits, Conservation and Education Division, Office of Protected Resources at least 48 hours prior to the start of collecting seismic data (unless constrained by the date of issuance of this Authorization in which case notification shall be made as soon as possible) and whenever not conducting seismic for more than 48 hours.

5. Prohibitions

(a) The taking, by incidental Level B harassment only, is limited to the species listed under condition 3(a) above. The taking by Level A harassment, serious injury, or death of these species or the taking by behavioral harassment, injury or death of any other species of marine mammal is prohibited and may result in the modification, suspension or revocation of this Authorization.

(b) The taking of any marine mammal whenever the required seismic vessel marine mammal observer (condition 7(a)(i)) is not underway in conformance with condition 7(a)(i), or the coastal or offshore aerial, and/or the dedicated vessel and passive acoustic monitoring programs have not been fully implemented as required by this Authorization is prohibited.

(c) The taking of any marine mammals by seismic sounds when the seismic vessel is within 15 miles of another operating seismic vessel is prohibited.

(d) In accordance with the U.S. Fish and Wildlife Service stipulations (i) seismic surveys are not permitted within the Ledyard Bay spectacled eider critical habitat area; and (ii) seismic-survey support aircraft must avoid overflights of Ledyard Bay critical habitat area after July 1, unless aircraft were at an altitude in excess of 1,500 feet or human safety requires deviation (e.g. a medical emergency).

6. Mitigation.

(a) General Mitigation: The holder of this Authorization is required to:

(i) (A) Ensure that all vessels and aircraft under the direction of GXT avoid concentrations or groups of whales. Operators of support vessels and aircraft should, at all times, conduct their activities at the maximum distance possible from such concentrations of whales. Under no circumstances, other than an emergency, should aircraft operate at an altitude lower than 1,000 feet when within 500 lateral yards of groups of whales. Helicopters may not hover or circle above such areas or within 500 lateral yards of such areas; and (B) When weather conditions do not allow a 1,000-ft flying altitude, such as during severe storms or when cloud cover is low, aircraft may be operated below the 1,000-foot altitude stipulated above. However, when aircraft are operated at altitudes below 1,000 feet because of weather conditions, the operator must avoid known whale concentration areas and should take precautions to avoid flying directly over or within 500 yards of groups of whales.

(ii) take every precaution to avoid harassment of whale concentrations when a vessel is operated near these animals. Vessels must reduce speed when within 300 yards of whales and vessels capable of steering around such groups must do so. Vessels may not be operated in such a way as to separate members of a group of whales from other members of the group.

(iii) avoid multiple changes in direction and speed when within 300 yards of whales. In addition, operators should check the waters immediately adjacent to a vessel to ensure that no whales will be injured when the vessel's propellers (or screws) are engaged.

(iv) operate small boats at a speed that would make collisions with whales unlikely.

(v) when weather conditions require, such as when visibility drops, vessels must adjust speed accordingly to avoid the likelihood of injury to whales.

(vi) operate in full compliance with the agreed-upon Conflict Avoidance Agreement.

(b) Seismic Vessel Mitigation: The holder of this Authorization is required to:

(i) Reduce the volume of the airgun array during vessel turns while running seismic lines.

(ii) To the extent practical, whenever a marine mammal is detected outside the exclusion zone radius, and based on its position and motion relative to the ship track is likely to enter the safety radius, an alternative ship speed or track will be calculated and implemented.

(iii) Exclusion and Monitoring-Safety Zones:

(A) Establish and monitor with trained observers a preliminary exclusion zone for cetaceans surrounding the airgun array where the received level would be 180 dB re 1 :Pa rms. For purposes of the field verification test, described in condition radius is estimated to be 0.85 km from the seismic source.

(B) Establish and monitor with trained observers a preliminary exclusion zone for pinnipeds surrounding the Bolt seismic airgun array where the received level would be 190 dB re 1 :Pa rms. For purposes of the field verification test this radius is estimated to be 0.23 km from the seismic source.

(C) Immediately upon completion of data analysis of the field verification measurements required under establish and monitor new 180-dB and 190-dB marine mammal exclusion zones.

(D) Cetacean Monitor (Safety) Zones:

(1) Whenever the support “chase” vessel monitoring program described in condition 7(b) below detects an aggregation of 12 or more non-migratory balaenopterid whales within an acoustically verified 160-dB rms zone ahead of, or perpendicular to, the seismic vessel track, the holder of this

Authorization must: (a) Immediately power-down the seismic airgun array and/or other acoustic sources to ensure that sound pressure levels atthe shortest distance to the aggregation do not exceed 160 dB rms; and (b) Refrain from powering up the seismic airgun array until biological observers on board the support "chase" vessel(s) or survey aircraft confirm that no balaenopterid aggregations have been detected within the 160-dB zone based upon ship course, direction and distance from last sighting and the last aggregation sighting;

(2) Whenever the aerial monitoring program cow/calf pairs within an acoustically-verified 120-dB monitoring zone, the holder of this Authorization must: (a) Immediately power-down or shut-down the seismic airgun array and/or other acoustic sources to ensure that sound pressure levels are reduced by at least 50 percent; and (b) Refrain from ramping up the seismic airgun array until two consecutive aerial or support vessel surveys confirm that there are no more than 3 bowhead cow/calf pairs within the area to be seismically surveyed within the next 24 hours.

(3) (a) If an aerial monitoring program cannot be implemented due to human safety concerns and vessel surveys are used to monitor the 120-dB monitoring zone as described in a dedicated passive acoustic monitoring program that is capable of locating the position of the vocalization, must be employed and monitored at all times that seismic is operating on the vessel.

(b) If the passive acoustic system detects one or more bowhead vocalizations within the 120-dB zone, the holder of this Authorization must: (a) Immediately shut-down the seismic airgun array and/or other acoustic sources; and (b) not proceed with ramping up the seismic airgun array until the passive acoustic monitoring program confirms that bowhead whales are not within the eastern portion of the 120-dB zone ahead of the ship's trackline over the next 24 hours.

(iv) Power-down/Shut-down.

(A) Immediately shut-down or power-down the seismic airgun array and/or other acoustic sources, whenever any cetaceans are sighted approaching close to or within the area delineated by the 180 dB (re 1:Pa_{rms}) isopleth, or pinnipeds are sighted approaching close to or within the area delineated by the 190 dB re 1 :Pa rms isopleth established under condition 6(b)(iii).

(B) Not proceed with ramping up the seismic airgun array unless the safety zones described in condition 6(b)(iii) are visible and no marine mammals are detected within the appropriate safety zones; or until 15

minutes (for small odontocetes, pinnipeds) or a minimum of 30 minutes (for mysticetes/large odontocetes) after there has been no further visual detection of the animal(s) within the safety zone and the trained marine mammal observer on duty is confident that no marine mammals remain within the appropriate safety zone.

C) Emergency shut-down. If observations are made or credible reports are received that one or more marine mammals are within the area of the seismic survey are in an injured or mortal state, or are indicating acute distress due to seismic noise, the seismic airgun array will be immediately shut down and the Chief of the Permits, Conservation and Education Division, Office of Protected Resources or a staff member contacted. The airgun array will not be restarted until review and approval has been given by either the Alaska Regional Administrator or the Director, Office of Protected Resources or their designees.

(v) Ramp-up

(A) Prior to commencing ramp-up described in condition 6 (b)(v)(C), conduct a 30-minute period of marine mammal observations by at least one trained marine mammal observer (1) at the commencement of seismic operations and (2) at any time electrical power to the airgun array is discontinued for a period of 10 minutes or more and the marine mammal observer watch has been suspended;

(B) If the safety radii are not completely visible for at least 30 minutes prior to ramp-up in either daylight or nighttime, do not commence rampup unless the seismic source has maintained a sound pressure level of at least 180 dB re 1 :Pa rms during the interruption of seismic survey operations.

(C) If the complete 180 dB safety range is visible and no marine mammals are observed while undertaking pre-ramp-up monitoring under conditions 6(b)(v)(A) and (B), ramp-up airgun arrays at a rate no faster than approximately 6 dB per 5-minute period starting with the smallest airgun in the array and then adding additional guns in sequence, until the full array is firing: (1) At the commencement of seismic operations, and (2), anytime after the airgun array has been powered down for more than 10 minutes;

(D) Do not proceed with ramp-up whenever the entire 180 dB safety zone is not visible and more than 2 power-downs due to marine mammal presence within the 180 dB safety zone had occurred within the past 12 hours.

7. Monitoring.

(a) Seismic Vessel Monitoring

(i) The holder of this Authorization must designate biologically-trained, on-site marine mammal observers (MMOs) to be onboard the *M/V Discoverer*, and designated support vessels conducting marine mammal observations or surveys, approved in advance by National Marine Fisheries Service (one may be an Inupiat), to conduct the visual monitoring programs required under this Authorization and to record the effects of seismic surveys and the resulting noise on marine mammals. The minimum number of MMOs required are:

(A) Between July 15th and September 15th, there must be at least 4 trained MMOs (one may be an Inupiat) aboard the *M/V Discoverer* at any one time during all seismic operations.

(B) From September 16 to the end of the survey, there must be at least be at least 3 MMOs onboard the *M/V Discoverer* at any time during all seismic operations.

(ii) MMOs must not be on duty for more than 4 consecutive hours, although more than one 4-hour shift per day is acceptable.

(iii) MMOs will monitor to: (A) ensure that no marine mammals enter the appropriate safety zone whenever the seismic array is on, and (B) record marine mammal activity as described in condition 7(f) below. At least two observers must be on watch during ramp ups and the 30 minutes prior to full ramp ups, and for as large a fraction of the other operating hours as possible. At all other times, at least one observer must be on active watch whenever the seismic airgun array is operating during all daytime airgun operations, during any nighttime power-ups of the airguns and at night, whenever that day's monitoring resulted in one or more power-downs due to marine mammal presence.

(iv) The crew also must be instructed to keep watch for marine mammals at all times. If any are sighted, the bridge watch-stander must immediately notify the MMO on-watch.

(v) MMOs will record the following: (A) the species, group size, age/size/sex categories (if determinable), the general behavioral activity, heading (if consistent), bearing and distance from seismic vessel, sighting cue, behavioral pace, and apparent reaction of all marine mammals seen near the seismic vessel and/or its airgun array (e.g., none, avoidance, approach, paralleling, etc) and; (B) the time, location, heading, speed, and activity of the vessel (shooting or not), along with sea state, visibility, cloud cover and sun glare at (1) any time a marine mammal is sighted, (2) at the start and end of each watch, and (3) during a watch (whenever there is a change in one or more variable); and, (C) the identification of all vessels that are visible within 5 km of the seismic vessel whenever a marine mammal is sighted, and the time observed, bearing, distance, heading, speed and activity of the other vessel(s).

(vi) All MMOs must be provided with and use appropriate night-vision devices, Big Eyes, and reticulated and/or laser range finding binoculars.

(b) Chase Boat Monitoring

(i) At least one "chase boat" will assist in monitoring the exclusion and monitoring safety zones described in condition 6(b)(iii) during active seismic survey operations. The chase boat will have at least two MMOs onboard to collect marine mammal observations.

(ii) During all active seismic survey activity, the chase boat will conduct marine mammal surveys no less than every 48 hours or 3 times per 7 days, of the 160-dB area to be seismically surveyed over the next 24 hours. MMOs will search for aggregations of bowhead and gray whale feeding utilizing a survey design approved in advance by the National Marine Fisheries Service.

(iii) The MMOs on the chase boat will immediately contact the seismic survey ship if marine mammals are sited within the 180/190-dB safety zone or aggregations of 12 or more non-migratory bowhead whales or gray whales are sited within the surveyed 160-dB zone.

(iv) The MMOs onboard chase boats will be limited to shifts of 4 hrs in length and 12 hrs total in a 24 hr period.

(c) Aerial Surveys

(i) In addition to the coastal aerial monitoring program mentioned in condition 8(a)(ii), the holder of this Authorization must implement an aerial monitoring program in the Chukchi Sea upon the earliest of the following conditions: (i) the research vessel monitoring program mentioned in condition 8(a)(iii) has detected 4 migratory cow/calf pairs at the surface during a vessel transit (ii) bowhead whale hunters have determined that the "pulse" of cow/calf pairs are passing Barrow AK in significant numbers (and NMFS has been so notified by the Alaska Eskimo Whaling Commission) or (iii) September 25, 2006.

(ii) Once initiated, aerial monitoring will take place daily (weather permitting), concentrating on the area (A) ahead of the vessel track, (B) upstream of bowhead whale migration, and (C) east of the vessel, whenever GXT's seismic vessel is conducting seismic surveys and is operating within an area of the Chukchi Sea that can be aerially surveyed safely.

(iii) If the biological observers onboard the aircraft see 4 or more migratory bowhead whale cow/calf pairs within the surveyed portion of the 120-dB isopleth from the seismic survey vessel, the lead observer of his/her designee will contact the MMO on watch onboard the seismic vessel of the observation. The location, bearing and approximate speed of the migratory bowhead whales will be recorded.

(iv) Following the suspension of seismic surveys after sighting 4 or more migratory cow/calf pairs, aircraft surveys should initiate new surveys in the area surveyed the previous day.

(d) Field Source Verification Using an autonomous ocean bottom hydrophone system, the Holder of this Authorization is required to measure and report on the distances from the airgun array to broadband received levels of 190, 180, 170, 160, and 120 dB (rms) re 1 Pa. at the beginning of the survey in the Chukchi Sea.

8. Research

(a) The holder of the Authorization, in cooperation with other Authorization holders conducting seismic surveys in the Chukchi Sea during 2006, must conduct all research described in the "Final Monitoring Plan for Seismic Exploration in the Alaskan Chukchi Sea, 2006." Monitoring will include establishment of:(i) an acoustic program to measure sounds produced by seismic vessels (required under condition 7(d)), (ii) an aerial monitoring and reconnaissance of marine mammals available for subsistence harvest along the Chukchi Sea coast; (iii) research ship surveys of the Chukchi Sea, including a towed hypdrophone passive acoustic monitoring system to collect data on the distribution and abundance of marine mammals; and (iv) deployment, and later analysis of data from, bottom-founded autonomous acoustic recorder arrays along the coast of the Chukchi Sea to record ambient sound levels, vocalizations of marine mammals, and received levels of seismic operations should they be detectable.

9. Reporting.

(a) Field Source Verification and the distances to the various radii are to be reported within 72 hours of completing the measurements. In addition to reporting the radii of specific regulatory concern, distances to other sound isopleths down to 120 dBrms (if measurable) will be reported in increments of 10 dB.

(b) Seismic Vessel Monitoring Program: A draft report will be submitted to the National Marine Fisheries Service within 90 days after the end of GXT's seismic survey program in the Arctic Ocean. The report will describe in detail (i) the operations that were conducted, (ii) the results of the acoustical measurements to verify the safety radii, (iii) the methods, results, and interpretation pertaining to all monitoring tasks; (iv) the results of the 2006 shipboard marine mammal monitoring;; (v), a summary of the dates and locations of seismic operations, including summaries of power downs, shut downs, and ramp up delays; (vi) marine mammal sightings (species, numbers, dates, times and locations; age/size/gender, environmental correlates, activities, associated seismic survey activities), (vii) estimates of the amount and nature of potential take (exposure) of marine mammals (by species) by harassment or in other ways to industry sounds; (viii) an analysis of the effects of seismic operations (e.g., on sighting rates, sighting distances, behaviors, movement patterns of marine mammals); (ix) provide an analysis of factors influencing detectability of marine mammals; and (x) provide summaries on communications with hunters and potential effects on subsistence uses.

(c) The draft report will be subject to review and comment by the National Marine Fisheries Service. Any recommendations made by the National Marine Fisheries Service must be addressed in the final report prior to acceptance by the National Marine Fisheries Service. The draft report will be considered the final report for this activity under this Authorization if the

National Marine Fisheries Service has not provided comments and recommendations within 90 days of receipt of the draft report.

(d) A draft comprehensive report describing the acoustic, vessel-based, and aerial monitoring programs will be prepared and submitted within 240 days of the effective date of this Authorization. The comprehensive report will describe the methods, results, conclusions and limitations of each of the individual data sets in detail. The report will also integrate (to the extent possible) the studies into a broad based assessment of all industry activities and their impacts on marine mammals in the Arctic Ocean during 2006.

(e) The draft comprehensive report will be reviewed by participants at the 2007 Open Water Scientific Meeting to be held in Anchorage AK in April, 2007. The draft comprehensive report will be accepted by the National Marine Fisheries Service as the final comprehensive report upon incorporation of recommendations by the workshop participants.

10. Activities related to the monitoring described in this Authorization do not require a separate scientific research permit issued under section 104 of the Marine Mammal Protection Act.

11. The Plan of Cooperation/Conflict Avoidance Agreement outlining the steps that will be taken to cooperate and communicate with the native communities to ensure the availability of marine mammals for subsistence uses, must be implemented.

12. A copy of this Authorization must be in the possession of the operator of all vessels and aircraft engaging in the activity operating under the authority of this Incidental Harassment Authorization.

_____ _____

James H. Lecky Date Aug 15, 2006
Director, Office of Protected Resources
National Marine Fisheries Service

APPENDIX B:
INCIDENTAL HARASSMENT AUTHORIZATION ISSUED TO GXT BY THE USFWS FOR MARINE SEISMIC EXPLORATION ACTIVITIES IN THE CHUKCHI SEA, 2006

AFES/MMM

Mr. Joe Gagliardi
Data Acquisition Manager
GX Technology Corporation
2101 City West Boulevard
Building III, Suite 900
Houston, TX 77042

Dear Mr. Gagliardi:

This responds to your request dated, February 15, 2006 for an incidental take authorization (IHA) for the incidental take of polar bears and Pacific walrus in the Chukchi Sea in association with the 2006 GX Technology Corporation (GXT) open-water seismic data acquisition program. This letter is to transmit the final IHA and its relevant operational conditions, monitoring and reporting requirements to GXT.

This incidental take authorization is issued in accordance with provisions of the Marine Mammal Protection Act, as amended, described in the USFWS publication listed at 71 FR 26770, dated May 8, 2006. Should you have any further questions contact Mr. Craig Perham of our Marine Mammals Management Office at (907) 786-3800 or 786-3810.

Sincerely,

Thomas O. Melius
Regional Director

Enclosure

cc: FFWFO
LE
Rance Wall, Minerals Management Service

ISSUED: June 29, 2006
EXPIRES: November 30, 2006

INCIDENTAL TAKE AUTHORIZATION
(IHA-06-03)

GX Technology Corporation (GXT) is hereby authorized to take small numbers of polar bears and Pacific walrus incidental to conducting seismic exploration activities in the Chukchi Sea identified within your IHA request (February 15, 2006). This IHA (IHA-06-03) allows GXT to take small numbers of Pacific walrus and polar bears incidental to oil and gas exploration activities in association with the Chukchi Sea open-water seismic data acquisition program. A description of the project is presented in 71 FR 26770.

Authorization is subject to the following conditions:

1. The polar bear/walrus interaction plan is approved and all provisions unless noted specifically are incorporated into the IHA by reference.

2. The Operations Manager will be fully aware, understand, and capable of implementing the conditions of this authorization.

3. Intentional take is prohibited.

4. This authorization is valid only for those activities identified in the request for an IHA dated February 15, 2006.

5. Conditions that will be required to minimize the potential for harassment include the following:
(1) Seismic and support vessels must observe a 0.5-mile (800-m) exclusion zone around walrus and polar bears observed on land or ice during travel status.

(2) Aircraft will be required to maintain a 1,000-ft (300-m) minimum altitude within 0.5 mile (800-m) of hauled out walrus and polar bears.

(3) Seismic operations will cease if walrus or polar bears are sighted within a 190 dB acoustical safety radius.

(4) Ice management mitigation measures, i.e., ‘‘ice scouting,’’ such as radar, satellite imagery, and reconnaissance flights using scheduled aircraft to monitor ice movement in the projected survey areas 24 to 48 hours prior to seismic activity, should be considered in response to ice movement. They will serve to limit the distance to ice due to seismic program protocols and thus limit the potential for walrus and polar bear encounters.

6. No seismic activities will occur within a 40-mile radius of affected communities. This condition will limit potential interactions with walrus hunters in near-shore environments.

7. Polar bear and walrus monitoring, reporting, and survey activities will be conducted in accordance with those outlined in 71 FR 26770. The basic monitoring and reporting requirements follow:

   - Cooperate with the Fish and Wildlife Service, and other designated Federal, State, or local agencies to monitor the impacts of oil and gas seismic activities on polar bears and Pacific walrus;

   - A Service-approved site-specific polar bear and walrus interaction plan will be on file with the USFWS and on-site for company personnel. These plans outline the contingency steps that the applicant will take, such as the chain of command for reporting and responding to polar bear or walrus sightings.

   - Designate a qualified individual or individuals to observe, record, and report the effects of the activity on Pacific walrus and polar bears; a FWS-approved monitoring plan requires ship-board trained marine mammal observers. During seismic operations, on-board marine mammal observers will monitor the zone of ensonification for polar bears and walrus. If a polar bear or walrus is sighted in the ensonification zone, operations will cease until animals move out of the zone.

   - At the discretion of the Fish and Wildlife Service, allow the Fish and Wildlife Service to place an observer on the site (vessels and aircraft) to monitor the impacts of the activity on Pacific walrus and polar bears;

   - Report all observations of Pacific walrus and polar bears to the Marine Mammals Management Office, Fish and Wildlife Service within 48 hours;

   - Submit a report to the Marine Mammals Management Office within 90 days after completion of activities.

8. This authorization expires November 30, 2006.

_____ _____

Regional Director, USFWS

Date

APPENDIX C:
DEVELOPMENT AND IMPLEMENTATION OF SAFETY RADII

This appendix provides additional background information on the development and implementation of safety radii as relevant to the GXT seismic exploration activities discussed in this report. It is not known whether exposure to a sequence of strong pulses of low-frequency underwater sound from marine seismic exploration actually can cause hearing impairment or non-auditory injuries in marine mammals (Richardson et al. 1995:372*ff*; Finneran et al. 2002). There has been considerable speculation about the potential for injury to marine mammals, based primarily on what is known about hearing impairment to humans and other terrestrial mammals exposed to impulsive low-frequency airborne sounds (e.g., artillery noise). The 180-dB criterion for cetaceans was established by NMFS (1995) based on those considerations, before any data were available on temporary threshold shift (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 root-mean-square (rms). The corresponding NMFS criterion for pinnipeds is 190 dB re 1 μPa (rms).

Finneran et al. (2002) have 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 $\mu Pa^2 \cdot s$. 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 pressure 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.

The above-mentioned 180 dB re 1 μPa level is measured on an rms basis. The rms pressure is an average over the duration of the seismic pulse (Greene 1997; Greene et al. 1998). This is the measure commonly used in recent studies of marine mammal reactions to airgun sounds. The rms level of a seismic pulse is typically about 10 dB less than its peak level (Greene 1997; McCauley et al. 1998, 2000a,b). Rms level is affected by duration of the received pulse, which depends on propagation effects between the source and the receiving animal. The greater the temporal dispersion of (i.e., the longer) the received pulse, the lower the expected rms level. Biological effects probably are more closely related to energy content of the received pulse than to its rms pressure, but we consider rms pressure because current NMFS criteria are based on that method.

Radii within which received levels from the airgun array were expected to diminish to various values relevant to NMFS criteria mentioned above were estimated by GXT. Prior to entering the Chukchi Sea, GXT contracted with JASCO to model the sound source characteristics using JASCO's airgun array source model (to estimate the source and near-field properties) and JASCO's implementation of a parabolic equation model to predict received levels at various distances in each direction. The models, in combination, account for airgun array characteristics, bathymetry effects, water properties, and the geoacoustic properties of seabed layers. JASCO's modeling procedures and results are summarized in Chapter 3, 4 and 5. Empirical data to determine actual sound levels produced by the airgun array were obtained shortly after the *Discoverer* entered the Chukchi Sea and new radii based on these measurements were determined within 72 h. The results of the empirical measurements are reported in Chapter 4. Subsequent analysis of the empirical data in combination with model characteristics, which is reported in Chapter 5, produced a refinement of the initial (72 h) analysis.

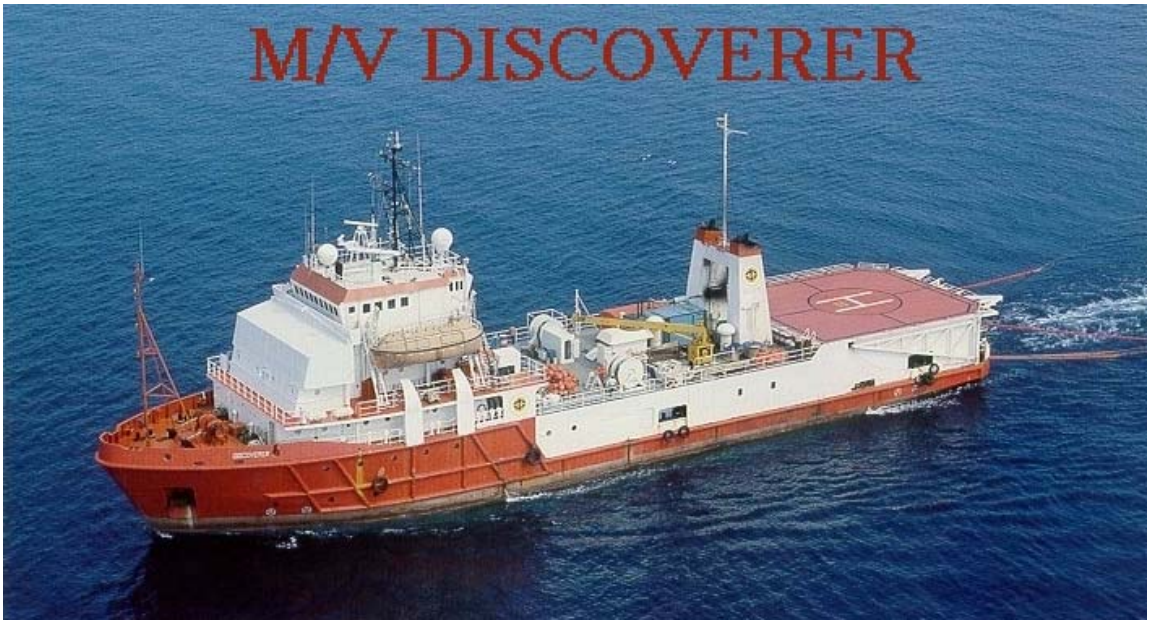
The radius at which received levels diminish to 160 dB re 1 μPa (rms) is considered by NMFS to be a possible criterion of behavioral disturbance for cetaceans. The data on which this 160 dB criterion is based pertain to baleen whales, and many of the odontocetes (e.g., delphinids) do not appear to be as responsive to seismic sounds as are baleen whales (Richardson et al. 1995; Gordon et al. 2004). In this report, the numbers of all species exposed to ≥160 dB are estimated. However, for certain taxa (e.g., pinnipeds), the 170 dB radius is considered as an alternative and more realistic estimate of the outer bounds of the area within which animals are likely to be disturbed significantly. For those taxa, the numbers exposed to ≥170 dB are also estimated.

APPENDIX D:
DESCRIPTION OF VESSEL AND EQUIPMENT

Vessel

M/V *Discoverer*

GXT's seismic source vessel, the *Discoverer*, is capable of doing both 2D and 3D seismic data acquisition work. For 3D seismic work the vessel can perform dual source/dual streamer or dual source/three streamer operation providing high quality 2D and 3D seismic data. Features include a SYNTRAK 960-24 system configurable for multiple streamers. Options include real-time seismic processing, acoustic/laser source positioning, acoustic streamer positioning and onboard navigation. The following are general specifications for the vessel and seismic equipment on board.



REGISTRATION	
Built	1980-Converted 1988 (new seismic installation 1999)
Type	Seismic survey vessel, 2D or 3D
Official Number	711122
Owner	***Shanghai Offshore Petroleum Bureau***
Port of Registry	Nassau, Bahamas
Classifications	DNV + IAI SV SF ICE-C

DIMENSIONS	
Length	72.07m (236 feet)
Beam	16.0m (52 feet)
Draft	5.25m (17 feet)
Call Sign	C6CZ2
Tonnage	2747 Gross 689 Net (registered)
PROPULSION + CAPACITIES	
Main Engine	MLW-ALCO 251 V12x2 Total 5480 BHP
Propulsion	Direct drive, variable pitch propellers, 2 ea. (Liaaen/Hjelset ACG 77/600 CP.)
Bow Thruster	1 x 600 BHP Brunvoll, 1 X 450 BHP Brunvoll
Stern Thruster	2 x 600 BHP Brunvoll
Generators	BBC 485KVA x three 440/220V, 60 Hz driven by three Caterpillar 3412; TA 445 HP
Fuel Capacity	700 tons, approx. 50 days endurance
Water Capacity	350 tons, plus 2 tons / day water maker
Maximum Speed	12 knots
Cruising Speed	10 knots
Number of Berths	43 plus 1 hospital
COMMUNICATIONS	
INMARSAT- C MMSI	430966610
DSC ID	309666000
INMARSAT- A	Sperry Marine MCS2A Communication System Voice / Telex 1570326 Fax 1570735
INMARSAT-M	Voice 762309120/762309121 Fax 762309122 Data 762309123
Radios	406 EPIRB VHF DSC Radios MF/HF DSC Radios Portable VHF Helicopter Radios Radar Transponder
Navtex	ALDEN NavTex Receiver AE-900

BRIDGE/NAVIGATION EQUIPMENT	
Radar	Furuno FR 2110 (ARPA Display) Furuno FR 2010 (remote display)
Auto-pilot	Robertson AP9 MK II
Gyro-compass	Robertson RGC 11 Robertson RGC 11 (either used for survey)
Navigation	MX412 Professional DGPS Navigator
Echo-sounder	Simrad EA
LIFEBOATS / AUXILIARY CRAFT	
Lifesaving Equipment	2 x Harding Fully Enclosed Motor Lifeboats (total 120 persons) 4 x Life-rafts (total 62 persons)
Seismic Work Boat	
FRC	
HELIDECK	
Helideck	16m Diameter

Airgun Description: Discoverer

The *Discoverer* towed a 36-airgun array with a total discharge volume of 3320 in^3, as well as a hydrophone streamer 9 km in length along predetermined lines. Seismic pulses were emitted at intervals of ~20 s and recorded. The 20 s spacing corresponded to a shot interval of ~46 m at the anticipated typical cruise speed of ~4-5 knots (8.3 km/h). The array was towed at ~50 m from the stern of the *Discoverer* at a depth of ~8.5 m. As the airgun array was towed along the survey line, the towed hydrophone array received the reflected signals and transferred the data to the on-board processing system.

The 36-airgun array consisted of 36 sleeve airguns (Fig. D.1). The total discharge volume was 3320 in^3.

<u>36-Airgun Array Specifications</u>

Energy source	36-sleeve airguns (8 × 40 in^3, 4 × 70 in^3, 4 × 80 in^3, 12 × 100 in^3, 8 × 150 in^3) firing every 20 s
Source output (downward)[10]	0-pk is 79.9 bar-m (258 dB re 1 μPa-m); pk-pk is 173 bar-m (265 dB re 1 μPa-m)
Towing depth of energy source	~8.5 m
Air discharge volume	3320 in^3
Dominant frequency components	0–256 Hz

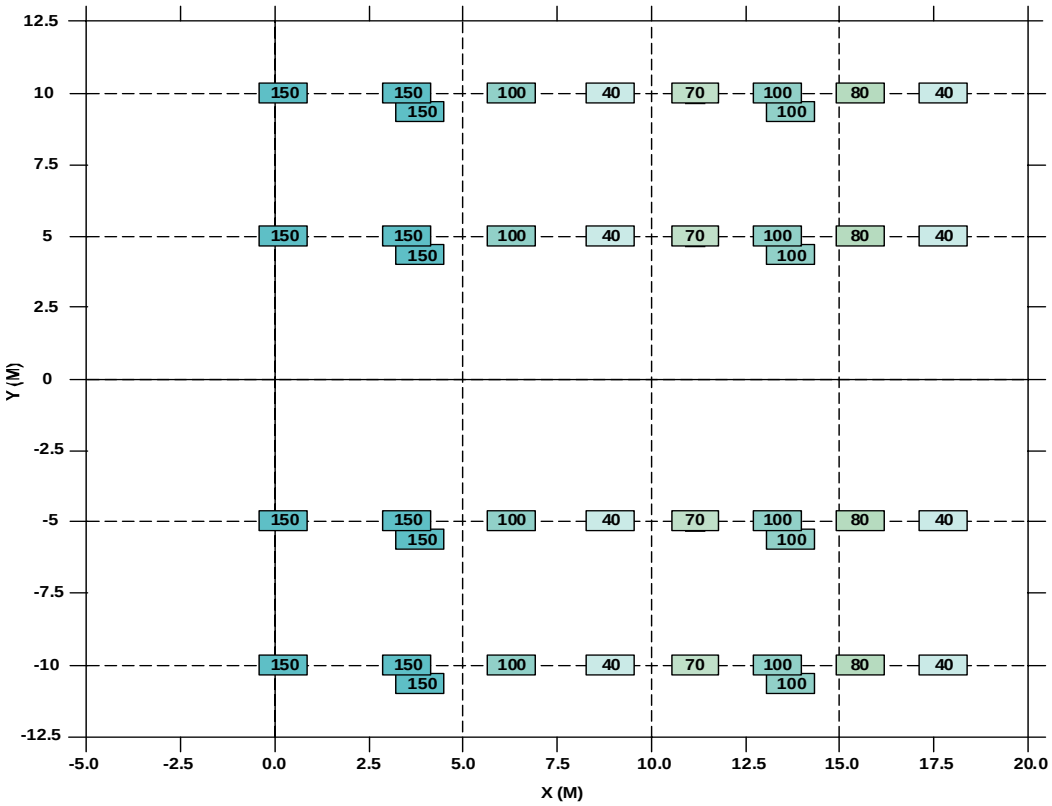


Figure D-1. The spacing and configuration of the 36-airgun array to be towed behind the *Discoverer* during the proposed Chukchi Sea Survey, between 15 June and 30 November 2006. Total discharge value is indicated within each airgun symbol. Measurements are in meters.

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

This appendix provides details on the standard visual and acoustic monitoring methods and data analysis techniques implemented for this project and previous seismic studies. Three marine mammal observers (MMOs) were aboard the *Discoverer* throughout the cruise. Two MMOs were biologists experienced in marine mammal identification and observation methods. The third MMO was an Inupiat with experience living and hunting in the Arctic. In addition to the MMOs onboard the *Discoverer*, GXT placed 3 marine mammal monitoring personnel on the *Octopus*. Two of these MMO's operated the passive acoustic monitoring (PAM) system that was used for mitigation during the seismic activities. The third monitor was a visual MMO. One of the PAM operators was also a trained visual MMO who could assist with MMO duties.

MMOs and PAM operators participated in safety training and a review meeting before the start of the field season, 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 Operations Manager and Head Airgun Operator aboard the vessel during a meeting prior to seismic operations. MMO duties included

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

Visual Monitoring for Marine Mammals

Vessel-based observers monitored marine mammals from the seismic source vessel (*Discoverer*) during all daytime seismic operations, and during any nighttime start ups of the airgun(s), as specified in the IHA and *Federal Register* Notice (NMFS 2006b). MMOs onboard the chase vessel (*Octopus*) also monitored marine mammals during much of the time that seismic operations were occurring. Seismic operations were suspended or amended when marine mammals were observed within, or about to enter, designated safety zones (see above) where there was a possibility of significant effects on hearing or other physical injury. In general, vessel-based observations for marine mammals were conducted using the following guidelines:

- MMOs on the seismic vessel observed during daylight periods while seismic surveys were conducted and, to a similar or lesser extent determined by the Lead MMO, while production activities were not being conducted.
- Two dedicated MMOs observed for 30 min prior to the planned start of seismic operations after an extended shut down.
- The entire safety radius was required to be visible for 30 min prior to start up from a prolonged shutdown during either daylight or nighttime.

- At least one MMO was on stand-by during ongoing seismic operations at night, but was not necessarily on active duty.
- Bridge personnel watched for marine mammals during seismic operations at night and were required to call for the airgun(s) to be shut down if necessary. Bridge personnel also notified the MMO on stand-by if marine mammals were observed in or about to enter the safety radii.
- Observations during daylight hours were conducted in good and poor visibility whenever the airgun(s) were operating and as specified in the IHA, and by two observers if possible, unless safety reasons precluded such observations. During darkness MMOs would be on watch prior to and during ramp-ups observing with NVDs.
- MMOs observed during transit periods without airgun operations, and at the discretion of the Lead MMO, to obtain baseline data on marine mammal distribution and (in the case of less experienced observers) to become familiar with observation protocols.
- MMOs also recorded locations and movements of vessels when on watch; information regarding vessels as well as marine mammals was recorded in a database.

The MMOs used the bridge of the *Discoverer* as an observation platform, where the observer's eye level was ~**14.2 m** above sea level (ASL). When two MMOs were on duty on the bridge simultaneously, they worked on opposite sides of the bridge unless safety or weather conditions precluded such observations.

From the duty station, MMO(s) systematically scanned the area around the vessel in a left to right sweep pattern, usually alternating scan sweeps between reticle binoculars (e.g., Fujinon 7 × 50) and the naked eye during the daytime. Observations were focused and centered forward of the vessel in an arc of ~210º, but MMOs also regularly checked for the presence of marine mammals astern of the vessel. Night vision devices were available for use by MMOs during non-daylight hours.

MMOs were generally on duty for shifts up to 4-hr, with a 2–4 hr break between shifts, depending on the number of observers available and the number of daylight hours. Each individual MMO was generally on duty for ~8-10 hrs per day. The duration of a single visual shift was no longer than 4 hours to avoid observer fatigue. Two MMOs were on watch during the 30 min periods preceding start up of the airgun(s), if possible. Use of two observers simultaneously was desirable and was scheduled when possible to increase detection of marine mammals near the source vessel. In addition to the dedicated MMOs, bridge personnel were instructed and assisted in detecting marine mammals, implementing mitigation requirements, and collecting data as possible before the start of the seismic survey.

While on watch, MMOs kept systematic written records of the vessel's position, activity, and environmental conditions using codes that were entered into a tablet PC and later transcribed onto a Microsoft Excel® spreadsheet. Data were recorded onto the datasheet every 30 min. Additional data were recorded when marine mammals were observed. For all records, the date and time, vessel position (longitude and latitude), and environmental conditions were recorded. Environmental conditions were also recorded whenever the conditions changed and with each marine mammal sighting.

The following information was recorded for each marine mammal sighting: species, number of individuals, bearing relative to the vessel's heading, direction of movement relative to the vessel, distance

from the vessel, vessel position and type of activity, sighting cue, behavior when first sighted, behavior after initial sighting, behavioral pace, and species identification reliability using the codes on Table E.1. On the seismic vessel, distance to marine mammals was measured from the MMO's location on the bridge rather than from the nominal center of the seismic source. The distance of the animal from the airgun was calculated during the analyses. However, for sightings near or within the safety radius in effect at the time, the distance from the marine mammal to the nearest airgun was estimated and recorded for the purposes of implementing power downs or shut downs. The bearing from the vessel to individual or groups of marine mammals was estimated using positions on a clock face, with the bow of the vessel considered to be 12 o'clock and the stern 6 o'clock.

Operational activities that were recorded by MMOs onboard the seismic vessel included the number of airguns in use, total volume of the airguns, and the type of vessel/seismic activity. The position of the vessel was logged every 60 sec by the ships navigational system. These data were copied from an electronic database and pasted into the marine mammal database. Specific information regarding the seismic activities (number of guns and air volume) was collected in the gunner's log. Inter-ship communication between seismic technicians and MMOs was conducted via radio or telephone and used to alert MMOs of any changes in operations, and to request power or shut downs by MMOs.

All data were initially recorded into a tablet PC with customized software (Study Participant Ver. 2.0) in the field and were entered into a Microsoft Excel® database at the end of the day. The database was constructed to prevent entry of out-or-range values and codes. Data collected by MMOs were also checked against the navigation and shot logs collected automatically by the vessel's computers.

Visual and Passive Acoustic Monitoring (PAM) for Marine Mammals in the 160 and 120 dB Zones

Special mitigation tasks in the IHA for GXT's seismic surveys in the Chukchi Sea required monitoring of the 160 and 120 dB zones. The 160 and 120 dB radii extended approximately 7.3 and 57.5 km, respectively, ahead of the airgun source on the *Discoverer*. MMOs onboard the *Octopus* monitored the 160 dB zone, but the 120 dB zone was too large to be monitored visually. Instead, PAM using equipment onboard the *Octopus* was used to monitor the 120 dB zone. Activities related to visual monitoring of the 160 dB zone alternated with PAM mitigation for the 120 dB zone during GXT's seismic exploration activities and PAM, as it related to visual monitoring of the 160 dB zone, is discussed below.

The *Octopus* was outfitted with a towed PAM system that was capable of locating the position of whale vocalizations. The *Octopus* had 1 trained MMOs and 2 PAM system operators onboard during all seismic operations. Due to bunk space limitations one of the PAM observers, who had the training and experience of a typical MMO, also served as the second MMO.

Initial clearance of the 160 and 120 dB zones was conducted prior to ramp up of the airgun array and on occasions when the source had been shut down for periods of 10 minutes or more, either due to presence of marine mammals or operational constraints. Clearance of the 160 dB area was conducted by the visual MMOs onboard the *Octopus*. In general, during daylight hours MMOs were able to effectively monitor a distance of ~2.5 – 2.7 km from a vessel. The *Octopus* traveled along a series of three transects centered on the point of the anticipated first shot in the ramp-up procedure. The survey lines were ~14 km in length and spaced ~5.4 km apart resulting in a surveyed area ~8.1 km x 7 km centered on the first shot point.

TABLE E.1. List of codes used by MMOs during seismic exploration activities in the Chukchi Sea, 2006.

WS	Watch Start
WE	Watch End

LINE
Enter Line ID or leave blank

SEISMIC ACTIVITY

LS	Line Shooting
SH	Shooting Between/Off.Lines
ST	Seismic Testing
SZ	Safety Zone Shut-Down
SD	Shut-Down
OT	Other (comment and describe)

 # GUNS
Enter Number of Operating Airguns, or

88	Varying (e.g., ramp-up)
99	Unknown

ARRAY VOLUME
Enter operating volume, or

99	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

99	Variable (vessel turning)

WATER DEPTH
In meters

Marine Mammal Species

Baleen Whales

BHW	Bowhead Whale
BLW	Blue Whale
FW	Fin Whale
GW	Gray Whale
SW	Sei Whale
HW	Humpback Whale
MW	Minke Whale
UMW	Unidentified **Mysticete Whale**
UW	Unidentified Whale

Large Toothed Whales

BW	Beluga Whale
KW	Killer Whale
NW	Narwhal
NBW	Northern Bottlenose Whale
SPW	Sperm Whale
LFPW	Long-finned Pilot Whale
UTW	Unidentified Tooth Whale

Dolphins

UD	Unidentified Dolphin

Porpoises

HP	Harbor Porpoise

Pinnipeds

BS	Bearded Seal
HBS	Harbor Seal
HDS	Hooded Seal
HPS	Harp Seal
RS	Ringed Seal
SS	Spotted Seal
US	Unidentified Seal
UP	Unidentified Pinniped
PWA	Pacific Walrus

Carnivora

PB	Polar Bear

MOVEMENT

PE	Across Bow
ST	Swim Toward
SA	Swim Away
FL	Flee
SP	Swim Parallel
MI	Mill
NO	No movement
DE	Dead
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
RE	Resting
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

Once the initial 160 dB area had been cleared the *Octopus* moved to a position ~55 km ahead of the source vessel to begin monitoring of the 120 dB zone ahead of the seismic vessel. Operational monitoring was conducted on a continuing basis during seismic operations and utilized the combined observations of MMOs onboard the *Discoverer* and the *Octopus*, as well as the PAM system on the *Octopus*. During monitoring of the 120 dB zone, the *Octopus* reduced speed to listen for whales every 30 minutes between periods of increased speed required for sufficient coverage of a relatively large area. The PAM array was monitored continuously, but these slower-speed listening sessions reduced vessel propulsion and water flow noise and improved the ability of the PAM system to detect vocalizing whales.

Periodically, the *Octopus* returned to within 5-10 km of the *Discoverer*. The *Octopus* then followed a track in front of the *Discoverer* to again clear the 160 dB zone. Once the 160 dB zone was cleared, the *Octopus* again moved to the 120 dB isopleth approximately 55 km ahead of the *Discoverer* to continue monitoring of the 120 dB zone. This monitoring pattern was continued throughout the period while monitoring of the 160 and 120 dB radii was required. The 160 dB zone was cleared no less than every 48 hours or three times per 7 days as required by the IHA.

Marine Mammal Mitigation During Operations

The following mitigation measures were adopted for marine mammal sightings during the proposed seismic program, provided that doing so did not compromise operational safety requirements: course alteration, power downs, shut downs, and ramp ups.

Course Alteration

If a marine mammal was detected outside the safety radius and, based on its position and direction of travel, was likely to enter the safety radius, one possible mitigation measure is to adjust the ship track and/or speed to avoid close approach to the mammal. However, given the presence of the streamer and airgun(s) behind the vessel, the turning rate of the vessel while this gear is deployed is limited, and course alteration is generally not a practical mitigation method for a seismic vessel. Instead, the marine mammal's activities and movements relative to the seismic vessel were closely monitored. If the mammal appeared likely to enter the safety radius, further mitigation actions was taken, i.e., power or shut down of the airgun(s).

Power-down Procedures

If marine mammals were detected outside the safety radius but were likely to enter the safety radius (i.e., if the mammals were moving towards the vessel or if the vessel was moving in the direction of the mammals, even if the mammals dove out of sight, or if the mammals were unable to move out of the path of the vessel), and if the vessel's course or speed could not be changed to avoid having the mammals enter the safety radius, the airgun array was powered down to one gun before the mammals were within the safety radius. Likewise, if a mammal was already within the safety zone when first detected, the airguns were powered down immediately. For the power-down procedure, one airgun was maintained at a Sound Pressure Level (SPL) of at least 180 dB (rms) during the interruption of seismic survey operations. *Shut-down* (see below) normally was implemented only if a marine mammal was detected within or about to enter the safety zone around the remaining operating airgun. Power-downs were achieved by calling the airgun operators by radio or phone.

Full airgun activity did not resume (via a ramp up) until the marine mammal has cleared the safety zone. The mammal was considered to have cleared the safety zone if it had not been seen within the zone for **15 min** (small odontocetes, pinnipeds) or **30 min** (mysticetes and large odontocetes).

Shut-down Procedure

If a cetacean or pinniped was detected within the applicable safety radius, the airgun(s) were shut down. Shut-down was accomplished by calling the airgun operators via the radio or phone for a shut down. If the gunners were unavailable, the **bridge** was called to implement the airgun shut down.

After a shut down, the animal must have cleared the safety zone (see above for definitions) before start up procedures could begin. If the airgun(s) was/were shut down and no observer was on duty, then at least 30 min of observation was necessary prior to start up.

MMOs informed the bridge when start up of the airgun(s) could proceed. If a marine mammal was observed within the safety radii during the 30-min observation period, the airgun operators were informed and the start up was postponed. Start up commenced following a marine mammal sighting when the marine mammal was observed to exit the safety radii, or if no marine mammals were seen in the safety radii for **15 min** (small odontocetes, pinnipeds) or **30 min** (mysticetes and large odontocetes).

Ramp-up Procedure

Daytime Ramp-up Procedure—During daylight hours, a ramp up was required when the airgun array began operating after a specified duration of power down or shut down. Under normal operating conditions (vessel speed ~3.5 knots = ~6.5 km/h), a ramp up was required if the airguns were not in operation for **>11 min**. If the airguns had been shut down or powered down because of the presence of a marine mammal in or near the safety radii, ramp up could not begin until the safety radii were clear of marine mammals, as described below.

If at least one airgun had been operating, a ramp up could be initiated at any time provided two MMOs were on active watch during the ramp up. If a shut-down (no operating airguns) has lasted for **>11 min** and no MMOs had been on duty during that time, a 30-min observation period was required before ramp up could proceed. If the entire safety radius for the full array was not visible for the 30-min pre-ramp up observation period (because of fog or darkness, etc.), a ramp-up coulod not commence unless at least one airgun with an SPL of at least 180 dB had been operational during the interruption of seismic survey operations with the full airgun array.

Ramp up of the airgun array began with one airgun. The number of airguns was then increased at a rate sufficient to produce an increase of ~6 dB per 5-min period when going from one airgun to the full array, which is the normal rate of ramp up for large airgun arrays. During the ramp up, the safety zone for the **full airgun array** was maintained even though fewer aiguns were operating until the ramp up was completed.

MMOs informed the bridge or the airgun operators in advance when ramp up could proceed. If a marine mammal was observed within its applicable safety radius during the 30-min observation period, or during the ramp up, the bridge and airgun operators were informed, as usual, of any necessary mitigation measures (power down, shutdown). Following a marine mammal sighting, ramp up commenced when the marine mammal was observed to exit its safety adius, or if no marine mammals were seen in the safety radii for **15 min** (small odontocetes, pinnipeds) or **30 min** (mysticetes and large odontocetes).

Nighttime Ramp-up Procedure—In addition to the requirements for daytime ramp-ups, during nighttime hours, ramp up could commence **only if the following conditions were met**:

a. The entire safety radius for the full-sized array was visible to MMOs using night-vision devices, (unlikely with very large safety radii)

or

b. At least one airgun had been operating during the interruption of production seismic survey activities.

Under (b), if at least one airgun remained operational during the interruption of production seismic activities (e.g., there had been a power down to one airgun due to a marine mammal sighting beyond the safety radius for a single airgun), ramp up could proceed even if the outer part of the safety zone around the full-array was not visible.

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 and estimate the number of marine mammals potentially exposed to seismic sounds associated with the seismic survey. Sightings of marine mammals hauled out on the ice were included with sightings of marine mammals in the water for the density estimates. To calculate exposures, all the animals calculated in the density estimates were assumed to be in the water. Only marine mammals observed in the water were included in the direct estimates of animals exposed to seismic pulses. The analysis categories that were used were identified in Chapter 6. The primary analysis categories used to assess potential effects of seismic sounds on marine mammals were the "seismic" (airguns operating with shots at <3 min spacing) and "non-seismic" categories (periods before seismic started or >1 or >2 h after airguns were turned off, for pinnipeds and cetaceans, respectively). The analyses excluded the "post-seismic" period 3 min to 2 h after the airguns were turned off. The justification for the selection of these criteria is based on the size of the array in use and is provided below. These criteria were discussed in earlier cruise reports (see Haley and Koski 2004; Smultea et al. 2004, 2005; MacLean and Koski 2005; Holst et al. 2005a,b):

- The period up to 3 min after the last seismic shot is ~3× 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 vessel between 3 min and 30 min after the cessation of seismic activities would have been "recently exposed" (i.e., within the past 30 min) to sounds from the seismic survey. During at least a part of that period, the distribution and perhaps behavior of the marine mammals may still be influenced by the (previous) sounds.
- For some unknown part of the period from 30 min to 1 or 2 h post-seismic, it is possible that the distribution of the animals near the ship, and perhaps the behavior of some of those animals, would still be at least slightly affected by the (previous) seismic sounds.
- By 1 or 2 h after the cessation of seismic operations, the distribution and behavior of pinnipeds and cetaceans, respectively, 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 thus the MMOs. Given those considerations, plus the limited observed responses of most marine mammals to seismic surveys (e.g., Stone 2003; Smultea et al. 2004; Haley and Koski 2004; MacLean and Koski 2005; Holst et al. 2005a,b), it is unlikely that the distribution

or behavior of marine mammals near the vessel > 1 or 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 >1 or 2 h after cessation of seismic operations to be unaffected by the (previous) seismic sounds.

As summarized in Chapter 6, 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 surveys were followed. To allow for animals missed during daylight, we corrected our visual observations for missed cetaceans by using correction factors.

The formulas for calculating densities using this procedure were briefly described in Chapter 6 and are described in more detail 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 a trackline are detected.

f(0), the reduced probability of detecting an animal with increasing distance from a trackline.

The *g*(0) values used in the analysis were calculated for gray whales, bowhead whales, unidentified whales, bearded seals, ringed seals, Pacific walrus, unidentified seals, and unidentified pinnipeds. Where species specific values did not exist values for similar species were used. The *g*(0) values for gray whales and bowhead whales were taken from previously calculated values for gray whales and right whales respectively. The *g*(0) values for pinniped species observed during this study were taken from values calculated previously for pinniped species off California.. Other correction factors were extracted from species specific *g*(0) tables produced for previous studies. The *f*(0) factors used in the analysis were calculated from observations made during this study. The sightings from all four vessels involved in this study were combined to keep the sample sizes adequately high and to minimize the number of *f*(0)s calculated. Only sightings that were during non-exposed seismic periods, that had useable effort, that had useable sightings and that were observed in seastates less than 6 were used. These sightings were imported into Distance 4.1 where the *f*(0) values were calculated separately for each species. The default analysis method used was conventional distance sampling with a half-normal model and cosine expansion but with no stratification. As very few of the sightings were in large groups we simply used the ratio of f(0)s between group sizes of 1-16,17-60 and >60 in previous studies to estimate the appropriate f(0)s for the two larger group sizes in this study from the *f*(0) calculated for the smallest group size in our sightings (1-16).

Number of 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 total area of water ensonified to that degree by the density of marine mammals estimated by line transect methods. The density estimates include all marine mammals, in the water or on ice. The exposure estimates assume that the numbers of animals estimated from those densities are all in the water. The area of water ensonified was calculated using MapInfo Geographic Information System (GIS) software to create a "buffer" that extended on both sides of the vessel's trackline to the predicted 160-dB radius. Areas ensonified by the activities of the *Discover* are shown in Table E.2. The buffer included areas that were exposed to airgun sounds ≥160 dB one or more times (as a result of crossing tracklines or tracklines that were close enough for their 160 dB zones to overlap). Areas of water ensonified on more than one occasion, due to overlapping tracklines, were repeatedly counted in the area calculation as many times as they were ensonified. "Corrected" densities of marine mammals were estimated as described in the above section.

Table E.2. The areas (km2) potentially ensonified to various levels by the *Discoverer's* four different airgun array volumes (in3), operating within the study area during seismic periods of the Chukchi Sea cruise, 7 Oct.−12 Nov. 2006. (A) Maximum area ensonified, with overlapping areas counted multiple times. (B) Total area ensonified, with overlapping areas counted only once.

	Level of ensonification (dB re1µPa (rms))				
Area (km^2)	**160**	**170**	**180**	**190**	***Total***
1 airgun (40 in^3)[a]					
A. Including Overlap Area	3,800	1,800	984	549	***7,133***
B. Excluding Overlap Area	3,731	1,784	979	547	***7,041***
36 airguns (3320 in^3)					
A. Including Overlap Area	85,710	37,802	12,584	3,359	***139,455***
B. Excluding Overlap Area	58,188	30,208	11,151	3,096	***102,643***

[a] Estimates for radii for this airgun volume was obtained from a similarly sized array used in other studies.

Estimates of the numbers of potential *exposures* of marine mammals to sound levels ≥160 dB re 1 µPa (rms) were calculated by multiplying the following three values:

- number of kilometers of seismic survey,
- width around trackline ensonified to ≥160 dB re 1 µPa (rms) including *repeated counts* of areas ensonified on more than on occasion, and
- observed densities of marine mammals – "corrected" as summarized above

This value provides a maximum estimate of the number of exposures to sound levels ≥160 dB re 1 µPa (rms) if marine mammals did not show avoidance reactions.

Number of Individuals Exposed.—The method described above likely overestimates the number of different individual marine mammals exposed to airgun sounds at received levels ≥160 dB. To provide an estimate of individuals exposed, the same calculation described above was performed, except that areas ensonified to ≥160 dB on more than one occasion, due to overlapping tracklines, were counted only once. In this project involving several tracklines, approximately 100 m apart, the amount of overlap was high.

Estimates of the potential number of *individual* marine mammals exposed to sound levels ≥160 dB re 1 µPa (rms) were calculated by multiplying the following three values:

- number of kilometers of seismic survey,
- width around trackline ensonified to ≥160 dB re 1 µPa (rms) including *only one count* of areas ensonified on more than on occasion, and
- observed densities of marine mammals – "corrected" as summarized above

The area of water considered ensonified in this calculation is therefore smaller than in the first calculation. During this cruise, the estimated number of individuals exposed is much less than the estimated number of exposure incidents because seismic lines were closely spaced and overlap of ensonified areas occurred often. 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.

APPENDIX F:
Background on Marine Mammals in the Chukchi Sea

TABLE F-1. The habitat, abundance (in the Chukchi Sea), and conservation status of marine mammals inhabiting the project area.

Species	Habitat	Abundance	ESA[1]	IUCN[2]	CITES[3]
Odontocetes					
Beluga whale (*Delphinapterus leucas*)	Offshore, Coastal, Ice edges	50,000[4] 39,257[5]	Not listed	VU	I
Narwhal (*Monodon monoceros*)	Offshore, Ice edge	Rare[6]	Not listed	DD	II
Killer whale (*Orcinus orca*)	Widely distributed		Not listed	LR-cd	II
Harbor Porpoise (*Phocoena phocoena*)	Coastal, inland waters	Extralimital	Not listed	VU	II
Mysticetes					
Bowhead whale (*Balaena mysticetus*)	Pack ice & coastal	10,545[7]	Endangered	LR-cd	I
Gray whale (*Eschrichtius robustus*) (eastern Pacific population)	Coastal, lagoons	488[8] 17,500[9]	Not listed	LR-cd	I
Minke whale (*Balaenoptera acutorostrata*)	Shelf, coastal	0	Not listed	LR-cd	I
Humpback whale (*Megaptera novaeangliae*)	Mainly near-shore and banks	2036[10] 4005[11] 2866[12] >6000[13]	Endangered*	VU	I
Fin whale (*Balaenoptera physalus*)	Slope, mostly pelagic	0	Endangered	EN	I
Pinnipeds					
Walrus (*Odobenus rosmarus*)		188,316[14]	Not listed	–	II
Bearded seal (*Erignathus barbatus*)	Pack ice	300,000-450,000[15] 4863[16]	Not listed	–	–
Spotted seal (*Phoca largha*)	Pack ice	1000[17]	Not listed	–	–
Ringed seal (*Pusa hispida*)	Landfast & pack ice	Up to 3.6 million[18] 245,048[19] 326,500[20]	Not listed	–	–
Ribbon seal (*Histriophoca fasciata*)	Ice	100,000[21]	Not listed	N.A.	–
Carnivora					
Polar bear (*Ursus maritimus*)	Coastal, ice	>2500[22] 15,000[23]	Not listed	LR-cd	–

[1] U.S. Endangered Species Act.
[2] IUCN Red List of Threatened Species (2003). Codes for IUCN classifications: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; LR = Lower Risk (-cd = Conservation Dependent; -nt = Near Threatened; -lc = Least Concern); DD = Data Deficient.
[3] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2004).
[4] Total Western Alaska population, including Beaufort Sea animals that occur there during migration and in winter (Small and DeMaster 1995).
[5] Beaufort Sea population (IWC 2000).
[6] Population in Baffin Bay and the Canadian arctic archipelago is ~60,000 (DFO 2004); very few enter the Beaufort Sea.
[7] Abundance of bowheads surveyed near Barrow, as of 2001 (George et al. 2004); revised to 10,545 by Zeh and Punt (2005).
[8] Southern Chukchi Sea and northern Bering Sea (Clark and Moore 2002).
[9] North Pacific gray whale population (Rugh 2003 *in* Keller and Gerber 2004) ; see also Rugh et al. (2005).

[10] All feeding aggregations (Angliss and Lodge 2004).
[11] Abundance estimate for the central North Pacific stock (Calambokidis et al. 1997).
[12] Northern GOA and Aleutian Islands (Zerbini et al. 2004).
[13] North Pacific (Calambokidis and Barlow 2004).
[14] Pacific walrus population (USFWS 2000).
[15] Alaska population (USDI/MMS 1996).
[16] Eastern Chukchi Sea population (NMML, unpublished data).
[17] Alaska Beaufort Sea population (USDI/MMS 1996).
[18] Alaska estimate (Frost et al. 1988 *in* Angliss and Lodge 2004).
[19] Bering/Chukchi Sea population (Bengston et al. 2000).
[20] Alaskan Beaufort Sea population estimate (Amstrup 1995).
[21] Estimate for Bering Sea (Burns 1981); current estimate is unavailable.
[22] Amstrup et al. (2001).
[23] NWT Wildlife and Fisheries, http://www.nwtwildlife.rwed.gov.nt.ca/Publications/speciesatriskweb/polarbear.htm
* Listed as a strategic stock under the U.S. Marine Mammal Protection Act

APPENDIX G:
Visual Effort and Detections

TABLE G.1. All and useable[a] visual observation effort from the *Discoverer* (7 Oct.−12 Nov. 2006) and the *Octopus* (28 Sept.−11 Nov. 2006), within the Chukchi Sea, in (A) hours, and (B) kilometers, subdivided by Beaufort Wind Force and airgun status. Ramp-up effort is included in the "seismic" category.

	All Effort											Useable[a] Effort						
Beaufort Wind Force	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	***Total***	**0**	**1**	**2**	**3**	**4**	**5**	***Total***
Discoverer																		
A. Effort in h																		
Non-seismic	0	0	1	6	8	32	24	12	10	0[c]	***93***	0	0	0	0[c]	1	6	***7***
Post seismic[b]	0	0	0	2	4	2	2	2	0	0	***12***	N/A	N/A	N/A	N/A	N/A	N/A	***N/A***
Seismic	3	1	13	49	60	57	47	9	0	0	***239***	0[c]	1	2	11	18	10	***42***
Total	***3***	***1***	***14***	***57***	***72***	***91***	***73***	***23***	***10***	***0***	**344**	***0***	***1***	***2***	***11***	***19***	***16***	**49**
B. Effort in km																		
Non-seismic	0	0	9	32	47	171	137	118	129	2	***645***	0	0	0	1	9	40	***50***
Post seismic[b]	0	0	0	14	31	14	12	8	0	0	***79***	N/A	N/A	N/A	N/A	N/A	N/A	***N/A***
Seismic	23	12	117	428	492	455	361	51	0	0	***1939***	4	12	14	100	148	82	***360***
Total	***23***	***12***	***126***	***474***	***570***	***640***	***510***	***177***	***129***	***2***	**2663**	***4***	***12***	***14***	***101***	***157***	***122***	**410**
Octopus																		
A. Effort in h																		
Non-seismic	0	18	53	51	32	25	12	3	0	0	***194***	0	16	44	47	28	21	***156***
B. Effort in km																		
Non-seismic	0	145	494	586	333	346	128	23	0	0	***2055***	0	124	420	547	333	310	***1734***
Total Effort in h	***3***	***19***	***67***	***108***	***104***	***116***	***85***	***26***	***10***	***0***	**538**	***0***	***17***	***46***	***58***	***47***	***37***	**205**
Total Effort in km	***23***	***157***	***620***	***1060***	***903***	***986***	***638***	***200***	***129***	***2***	**4718**	***4***	***136***	***434***	***648***	***490***	***432***	**2144**

Note: N/A means not applicable.

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

[b] Period encompassing 3 min to 2 h after all airguns are shut down.

[c] Since effort has been rounded to the nearest hour, these values are greater than zero, but less than 0.5 h.

TABLE G.2. Total number of groups (individuals in parentheses) of marine mammals observed from the *Discoverer* (7 Aug.−22 Nov. 2006) and *Octopus* (28 Sept.−15 Nov. 2006) by species, seismic activity, and transit periods during the Chukchi Sea cruise. See Table 7.3 for the total number of useable[a] sightings within the project area (a subtotal of the numbers shown here)..

	Periods within Chukchi Sea Study Area			Transit Periods within Bering Sea			Transit Periods within Chukchi Sea	Total	
Species	**Non-Seismic[b]**	**Post-Seismic[c]**	**Seismic**	***Discoverer* Aug.[d]**	***Octopus* Sept./Nov.[e]**	***Discoverer* Nov.[f]**	***Discoverer* Aug.**	**Sight-ings**	**Indiv.**
Cetaceans									
Dall's Porpoise	N/A	N/A	N/A	N/A	2(8)	2(7)	N/A	4	15
Pacific White Sided Dolphin	N/A	N/A	N/A	3(18)	N/A	N/A	N/A	3	18
Killer Whale	N/A	N/A	N/A	N/A	N/A	1(4)	N/A	1	4
Bowhead Whale	N/A	N/A	N/A	1(3)	N/A	N/A	N/A	1	3
Gray Whale	N/A	N/A	N/A	N/A	8(17)	13(28)	N/A	21	45
Fin Whale	N/A	N/A	N/A	1(1)	N/A	N/A	N/A	1	1
Humpback Whale	N/A	N/A	N/A	2(3)	N/A	N/A	N/A	2	3
Unidentified Mysticete Whale	N/A	N/A	1(1)	6(8)	2(3)	1(2)	N/A	10	14
Unidentified Whale	N/A	N/A	N/A	3(5)	N/A	2(5)	2(5)	7	15
Unidentified Dolphin	N/A	N/A	N/A	3(7)	N/A	1(1)	N/A	4	8
Pinnipeds									
Pacific Walrus	1(2)	N/A	1(3)	N/A	N/A	N/A	N/A	2	5
Bearded Seal	17(42)	N/A	2(2)	N/A	N/A	N/A	N/A	19	44
Ringed Seal	2(2)	N/A	N/A	N/A	N/A	N/A	3(3)	5	5
Spotted Seal	6(6)	N/A	N/A	1(1)	N/A	N/A	N/A	7	7
Unidentified Seal	41(51)	N/A	3(3)	1(1)	N/A	N/A	2(2)	47	57
Unidentified Pinniped	1(1)	N/A	N/A	1(1)	N/A	2(2)	N/A	4	4
Total	***68(104)***	***N/A***	***7(9)***	***22(48)***	***12(28)***	***22(49)***	***7(10)***	***138***	***248***

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

[b] Includes both *Discoverer* and *Octopus* sightings.

[c] From 3 min to 1 hr after a seismic period for pinnipeds, or 3 min to 2 hrs after a seismic period for cetaceans.

[d] Includes transit periods when *Discoverer* travelled through Bering to the Chukchi Sea while in transit to survey Canadian Beaufort Sea.

[e] Includes transit periods when *Octopus* travelled from Nome AK to the Chukchi Sea study area and out of the study area to Dutch Harbor, AK.

[f] Includes transit periods when *Octopus* travelled from Nome AK to the Chukchi Sea study area and out of the study area to Dutch Harbor, AK.

Table G.3. Visual sightings of marine mammals made from the *Discoverer* (7 Aug.−22 Nov. 2006) and the *Octopus* (28 Sept.−15 Nov. 2006) within the Chukchi Sea survey area and during transits. A map of the sighting areas is shown in Figure G.1.

Vessel	Sighting ID	Species	Useable (Y) or Non-useable (N)[a]	Group Size	Day in 2006	Time (GMT)	Location[a]	Initial Sighting Distance (m) from observer	CPA[b] (m)	Initial Move-ment[c]	Initial Behav.[d]	Bf[e]	Water Depth (m)[f]	Vessel Activ.[g]	Airguns Vol. (in^3)[h]	Mitig. (SZ, PZ, None)[i]
Discoverer	1	Unidentified Mysticete Whale	Y	2	7-Aug	16:36:10	NP	416	408	SA	UN	2	121	TRANSIT	0	None
Discoverer	2	Unidentified Whale	N	3	7-Aug	22:42:51	NP	6562	4261	SA	BL	2	2122	TRANSIT	0	None
Discoverer	3	Pacific White Sided Dolphin	Y	10	7-Aug	23:47:56	NP	0	144	ST	PO	3	2433	TRANSIT	0	None
Discoverer	4	Unidentified Dolphin	Y	3	8-Aug	0:04:20	NP	0	144	ST	PO	3	2593	TRANSIT	0	None
Discoverer	5	Pacific White Sided Dolphin	Y	5	10-Aug	0:10:02	NP	50	161	SP	SA	2.5	3877	TRANSIT	0	None
Discoverer	6	Pacific White Sided Dolphin	Y	3	10-Aug	0:25:05	NP	30	145	SA	MI	2.5	3723	TRANSIT	0	None
Discoverer	7	Unidentified Dolphin	Y	3	10-Aug	2:30:33	NP	920	1047	SA	PO	2.5	3115	TRANSIT	0	None
Discoverer	8	Unidentified Mysticete Whale	Y	1	10-Aug	19:41:02	NP	1932	2036	SA	BL	4	3887	TRANSIT	0	None
Discoverer	9	Unidentified Mysticete Whale	Y	1	10-Aug	22:44:46	NP	215	332	SA	DI	3	3948	TRANSIT	0	None
Discoverer	10	Unidentified Mysticete Whale	Y	1	11-Aug	0:09:18	NP	1631	1707	AP	DI	4	3849	TRANSIT	0	None
Discoverer	11	Unidentified Whale	Y	1	12-Aug	18:41:41	NP	1412	1489	SP	BL	3	3701	TRANSIT	0	None
Discoverer	12	Unidentified Mysticete Whale	Y	2	14-Aug	1:43:33	NP	1631	1735	ST	BR	4	4656	TRANSIT	0	None
Discoverer	13	Unidentified Dolphin	Y	1	14-Aug	3:17:44	NP	1932	2057	PE	SW	3	4657	TRANSIT	0	None
Discoverer	14	Humpback Whale	Y	2	15-Aug	18:48:47	A	1932	415	MI	FS	4	78.5	TRANSIT	0	None
Discoverer	15	Unidentified Whale	Y	1	15-Aug	20:39:44	A	100	175	SP	DI	5	79.1	TRANSIT	0	None
Discoverer	16	Humpback Whale	Y	1	15-Aug	21:33:10	A	784	500	PE	FD	4	114	TRANSIT	0	None
Discoverer	17	Fin Whale	Y	1	16-Aug	15:52:14	A	493	603	SA	BL	5	115.2	TRANSIT	0	None
Discoverer	18	Unidentified Mysticete Whale	N	1	16-Aug	17:09:41	A	317	408	SA	BL	4.5	104.4	TRANSIT	0	None
Discoverer	19	Spotted Seal	Y	1	16-Aug	20:31:58	A	10	149	SP	SW	3	89.5	TRANSIT	0	None
Discoverer	20	Unidentified Seal	Y	1	16-Aug	22:13:30	A	10	144	NO	LG	2	80.4	TRANSIT	0	None
Discoverer	21	Unidentified Pinniped	Y	1	16-Aug	23:24:28	A	25	166	FL	TH	2	77.2	TRANSIT	0	None
Discoverer	22	Unidentified Whale	N	1	20-Aug	14:46:44	B	3096	1974	UN	BL	5	55.2	TRANSIT	0	None
Discoverer	23	Unidentified Whale	Y	4	20-Aug	15:08:40	B	3096	2450	UN	BL	5	59.6	TRANSIT	0	None
Discoverer	24	Ringed Seal	N	1	22-Aug	0:33:33	B	20	154	PE	FD	4	45	TRANSIT	0	None
Discoverer	25	Unidentified Seal	Y	1	23-Aug	2:40:08	C	416	420	MI	LO	1	96.4	TRANSIT	0	None
Discoverer	26	Ringed Seal	Y	1	23-Aug	2:49:01	C	100	244	NO	DI	1	95.2	TRANSIT	0	None
Discoverer	27	Unidentified Seal	Y	1	23-Aug	2:55:49	C	1932	244	NO	RE	1	92.7	TRANSIT	0	None
Discoverer	28	Ringed Seal	N	1	23-Aug	3:04:27	C	100	175	SP	LO	1	89.7	TRANSIT	0	None
Discoverer	29	Ringed Seal	Y	1	23-Aug	5:53:04	C	100	161	NO	LO	1.5	16.4	TRANSIT	0	None
Discoverer	30	Ringed Seal	Y	1	23-Aug	18:53:36	C	215	312	ST	SW	1	18	TRANSIT	0	None
Discoverer	31	Ringed Seal	Y	1	23-Aug	19:03:19	C	100	212	ST	SW	1	17.7	TRANSIT	0	None
Discoverer	32	Unidentified Seal	Y	1	23-Aug	19:33:37	C	416	527	MI	LO	1	18	TRANSIT	0	None
Discoverer	33	Unidientified Seal	Y	1	23-Aug	19:53:00	C	493	621	PE	LO	1	17.4	TRANSIT	0	None
Discoverer	34	Ringed Seal	Y	1	23-Aug	20:49:21	C	317	431	ST	LO	1	16.2	TRANSIT	0	None
Discoverer	35	Ringed Seal	Y	1	23-Aug	21:07:59	C	317	431	SA	LO	1	16.2	TRANSIT	0	None
Discoverer	36	Unidentified Seal	Y	1	24-Aug	0:53:08	C	185	285	SP	FD	1	10.7	TRANSIT	0	None
Discoverer	37	Unidentified Seal	Y	1	24-Aug	2:11:33	C	50	174	UN	DI	1	11.1	TRANSIT	0	None
Discoverer	38	Ringed Seal	Y	1	24-Aug	2:33:44	C	10	146	SP	SW	1	11.5	TRANSIT	0	None
Discoverer	39	Unidientified Seal	Y	1	24-Aug	2:37:11	C	185	185	SA	LO	1	11.6	TRANSIT	0	None
Discoverer	40	Ringed Seal	Y	1	24-Aug	3:20:21	C	50	164	PE	LO	1	11.2	TRANSIT	0	None
Discoverer	41	Unidentified Seal	Y	1	24-Aug	3:24:05	C	284	377	SP	FD	1	11.1	TRANSIT	0	None
Discoverer	42	Ringed Seal	Y	1	24-Aug	3:34:15	C	215	329	SA	FD	1	11	TRANSIT	0	None
Discoverer	43	Unidentified Seal	Y	1	24-Aug	3:39:41	C	493	603	SA	FD	1	11.2	TRANSIT	0	None
Discoverer	44	Unidentified Seal	Y	1	24-Aug	5:00:48	C	451	562	SA	LO	1	11.4	TRANSIT	0	None
Discoverer	45	Unidentified Seal	Y	1	24-Aug	5:17:06	C	606	715	SA	FD	1	11.2	TRANSIT	0	None
Discoverer	46	Unidentified Seal	Y	1	24-Aug	5:28:46	C	451	262	SA	FD	1	11.2	TRANSIT	0	None
Discoverer	47	Unidentified Seal	Y	1	24-Aug	5:42:39	C	299	429	SA	FD	1	10.8	TRANSIT	0	None

TABLE G.3. Continued.

Vessel	Sighting ID	Species	Useable (Y) or Non-useable (N)[a]	Group Size	Day in 2006	Time (GMT)	Location[a]	Initial Sighting Distance (m) from observer	CPA[b] (m)	Initial Move-ment[c]	Initial Behav.[d]	Bf[e]	Water Depth (m)[f]	Vessel Activ.[g]	Airguns Vol. (in^3)[h]	Mitig. (SZ, PZ, None)[i]
Discoverer	48	Ringed Seal	Y	1	24-Aug	15:30:39	C	493	578	SP	SW	0	13.4	TRANSIT	0	None
Discoverer	49	Ringed Seal	Y	1	24-Aug	15:54:54	C	10	149	MI	FD	0	13.1	TRANSIT	0	None
Discoverer	50	Ringed Seal	N	1	24-Aug	17:30:42	C	10	149	ST	SW	0	15.4	TRANSIT	0	None
Discoverer	51	Unidentified Seal	N	1	24-Aug	19:38:55	C	199	298	SP	FD	0	14.2	TRANSIT	0	None
Discoverer	52	Unidentified Seal	Y	1	24-Aug	20:33:39	C	544	653	ST	FD	0	16	TRANSIT	0	None
Discoverer	53	Ringed Seal	N	1	24-Aug	20:39:09	C	215	332	SA	SI	0	16	TRANSIT	0	None
Discoverer	54	Ringed Seal	Y	1	24-Aug	21:29:15	C	300	430	SA	FD	1	16	TRANSIT	0	None
Discoverer	55	Unidentified Seal	Y	1	24-Aug	21:35:14	C	299	331	MI	TH	1	16.2	TRANSIT	0	None
Discoverer	56	Ringed Seal	Y	1	24-Aug	21:39:19	C	284	408	SA	FD	1	16.4	TRANSIT	0	None
Discoverer	57	Ringed Seal	N	1	24-Aug	21:54:32	C	269	363	MI	FD	0	16.2	TRANSIT	0	None
Discoverer	58	Unidentified Seal	N	1	24-Aug	21:59:20	C	683	791	MI	FD	0	16.2	TRANSIT	0	None
Discoverer	59	Ringed Seal	Y	1	24-Aug	22:09:46	C	100	163	MI	TH	0	16.2	TRANSIT	0	None
Discoverer	60	Ringed Seal	N	1	24-Aug	22:28:15	C	386	411	SA	SW	0	16.1	TRANSIT	0	None
Discoverer	61	Ringed Seal	N	1	24-Aug	22:50:20	C	544	653	SP	SW	1	16	TRANSIT	0	None
Discoverer	62	Ringed Seal	Y	1	24-Aug	22:56:33	C	683	810	PE	SW	1	16	TRANSIT	0	None
Discoverer	63	Ringed Seal	Y	1	24-Aug	23:19:14	C	256	400	PE	SW	1	16	TRANSIT	0	None
Discoverer	64	Ringed Seal	Y	1	24-Aug	23:24:45	C	606	750	PE	SW	1	16	TRANSIT	0	None
Discoverer	65	Ringed Seal	Y	1	24-Aug	23:48:12	C	400	344	MI	SW	1	16.3	TRANSIT	0	None
Discoverer	66	Unidentified Seal	N	1	25-Aug	0:04:32	C	256	372	SA	FD	0	16.6	TRANSIT	0	None
Discoverer	67	Ringed Seal	Y	2	25-Aug	0:09:56	C	284	428	SA	FD	0	16.4	TRANSIT	0	None
Discoverer	68	Unidentified Seal	N	1	25-Aug	2:25:09	C	573	537	SA	FD	0	16.2	TRANSIT	0	None
Discoverer	69	Ringed Seal	N	1	25-Aug	18:45:14	C	185	234	SA	FD	1	15.1	TRANSIT	0	None
Discoverer	70	Ringed Seal	N	1	25-Aug	18:48:24	C	451	595	PE	TH	1	15.1	TRANSIT	0	None
Discoverer	71	Unidentified Seal	N	1	25-Aug	18:58:02	C	337	450	SA	SI	1	15	TRANSIT	0	None
Discoverer	72	Ringed Seal	N	1	25-Aug	19:48:16	C	199	298	SA	FD	1	14.4	TRANSIT	0	None
Discoverer	73	Ringed Seal	Y	1	25-Aug	20:07:06	C	234	347	PE	FD	1	15	TRANSIT	0	None
Discoverer	74	Unidentified Seal	Y	1	25-Aug	20:42:38	C	386	411	SP	FD	1	15	TRANSIT	0	None
Discoverer	75	Ringed Seal	Y	1	25-Aug	20:47:09	C	493	296	PE	FD	0	15	TRANSIT	0	None
Discoverer	76	Ringed Seal	N	2	25-Aug	21:43:55	C	199	245	SP	FD	1	15.2	TRANSIT	0	None
Discoverer	77	Ringed Seal	Y	1	25-Aug	22:31:51	C	173	317	PE	SW	1	15	TRANSIT	0	None
Discoverer	78	Ringed Seal	Y	1	25-Aug	23:01:38	C	493	637	PE	SW	1	15	TRANSIT	0	None
Discoverer	79	Ringed Seal	Y	1	25-Aug	23:41:37	C	317	431	SA	SW	1	14.8	TRANSIT	0	None
Discoverer	80	Ringed Seal	Y	1	25-Aug	23:56:28	C	100	193	PE	OT	1	15	TRANSIT	0	None
Discoverer	81	Ringed Seal	Y	1	26-Aug	0:16:32	C	153	188	ST	SW	1	14.5	TRANSIT	0	None
Discoverer	82	Unidentified Seal	Y	1	26-Aug	0:20:31	C	173	212	SA	TH	1	14.4	TRANSIT	0	None
Discoverer	83	Ringed Seal	Y	1	26-Aug	0:38:36	C	215	288	SA	FD	1	13.8	TRANSIT	0	None
Discoverer	84	Ringed Seal	N	1	26-Aug	1:06:32	C	244	388	SA	FD	1	14	TRANSIT	0	None
Discoverer	85	Unidentified Seal	Y	1	26-Aug	2:40:59	C	493	578	SA	FD	2	14.4	TRANSIT	0	None
Discoverer	86	Ringed Seal	N	1	26-Aug	15:19:42	C	250	319	SA	SW	0	14.1	TRANSIT	0	None
Discoverer	87	Ringed Seal	N	1	26-Aug	16:54:23	C	100	175	MI	DI	0	12.8	TRANSIT	0	None
Discoverer	88	Ringed Seal	N	1	26-Aug	17:25:15	C	400	430	PE	SW	0	12.7	TRANSIT	0	None
Discoverer	89	Ringed Seal	N	1	26-Aug	17:42:42	C	300	345	SP	FD	0	12.4	TRANSIT	0	None
Discoverer	90	Ringed Seal	N	1	26-Aug	18:45:13	C	317	408	SA	FD	0	12.6	TRANSIT	0	None
Discoverer	91	Ringed Seal	Y	1	26-Aug	23:19:26	C	493	578	PE	SW	0	9.4	TRANSIT	0	None
Discoverer	92	Unidentified Seal	Y	1	27-Aug	0:51:39	C	784	911	SA	SI	0.5	11.6	TRANSIT	0	None
Discoverer	93	Ringed Seal	Y	1	27-Aug	1:00:23	C	234	332	SA	SW	1	13	TRANSIT	0	None
Discoverer	94	Ringed Seal	N	1	27-Aug	1:18:06	C	300	430	PE	FD	0.5	14	TRANSIT	0	None
Discoverer	95	Ringed Seal	Y	1	27-Aug	1:26:09	C	400	543	PE	SW	0.5	14.1	TRANSIT	0	None
Discoverer	96	Ringed Seal	Y	1	27-Aug	1:56:42	C	299	413	SA	TH	0.5	13.6	TRANSIT	0	None
Discoverer	97	Unidentified Seal	Y	1	27-Aug	4:00:52	C	337	450	ST	FD	0.5	13.8	TRANSIT	0	None
Discoverer	98	Ringed Seal	Y	1	27-Aug	4:13:25	C	451	472	SA	FD	0.5	14.6	TRANSIT	0	None
Discoverer	99	Unidentified Seal	N	1	27-Aug	4:42:51	C	317	447	UN	UN	1	13	TRANSIT	0	None

TABLE G.3. Continued.

Vessel	Sighting ID	Species	Useable (Y) or Non-useable (N)[a]	Group Size	Day in 2006	Time (GMT)	Location[a]	Initial Sighting Distance (m) from observer	CPA[b] (m)	Initial Move-ment[c]	Initial Behav.[d]	Bf[e]	Water Depth (m)[f]	Vessel Activ.[g]	Airguns Vol. (in^3)[h]	Mitig. (SZ, PZ, None)[i]
Discoverer	100	Ringed Seal	Y	1	27-Aug	16:21:52	D	150	244	SA	SW	0	15.3	TRANSIT	0	None
Discoverer	101	Ringed Seal	N	1	27-Aug	21:16:47	D	75	192	SA	FD	1	11.8	TRANSIT	0	None
Discoverer	102	Ringed Seal	N	1	27-Aug	21:20:34	D	386	530	PE	FD	1	11.2	TRANSIT	0	None
Discoverer	103	Ringed Seal	N	1	27-Aug	22:39:52	D	400	488	SP	SW	1	13	TRANSIT	0	None
Discoverer	104	Ringed Seal	N	1	28-Aug	0:07:09	D	500	610	SP	SW	1	17.2	TRANSIT	0	None
Discoverer	105	Ringed Seal	N	1	28-Aug	0:22:15	D	100	175	SA	FD	0	17.4	TRANSIT	0	None
Discoverer	106	Ringed Seal	N	1	28-Aug	0:56:04	D	50	194	SA	FD	0	18.5	TRANSIT	0	None
Discoverer	107	Ringed Seal	N	1	28-Aug	1:08:00	D	100	235	ST	SW	1	18.6	TRANSIT	0	None
Discoverer	108	Ringed Seal	N	1	28-Aug	3:00:00	D	100	226	SA	FD	1	16.2	TRANSIT	0	None
Discoverer	109	Ringed Seal	N	1	28-Aug	3:13:22	D	50	192	SA	FD	1	14.2	TRANSIT	0	None
Discoverer	110	Ringed Seal	N	1	28-Aug	3:21:19	D	25	166	SA	TH	1	14.8	TRANSIT	0	None
Discoverer	111	Ringed Seal	N	1	28-Aug	15:53:11	D	50	152	SP	SW	1	17.6	TRANSIT	0	None
Discoverer	112	Unidentified Seal	Y	1	28-Aug	20:33:59	D	493	603	SA	LO	1	29.1	TRANSIT	0	None
Discoverer	113	Ringed Seal	Y	1	28-Aug	20:43:56	D	416	545	SA	FD	1	33.6	TRANSIT	0	None
Discoverer	114	Unidentified Seal	Y	1	29-Aug	4:26:53	D	30	166	SA	FD	0	55.7	TRANSIT	0	None
Discoverer	115	Bowhead Whale	N	3	30-Aug	23:31:02	D	6000	6073	UN	BR	1	40	TRANSIT	0	None
Discoverer	116	Unidentified Seal	Y	1	31-Aug	1:08:24	D	416	272	ST	SI	0	47	TRANSIT	0	None
Discoverer	117	Ringed Seal	Y	1	31-Aug	1:27:56	D	284	415	ST	FD	0	49.7	TRANSIT	0	None
Discoverer	118	Ringed Seal	Y	1	31-Aug	2:30:37	D	234	374	SA	FD	0	61.4	TRANSIT	0	None
Discoverer	1	Bowhead Whale	N	1	9-Oct	1:48:00	C	250	345	SP	SW	7	55.6	TRANSIT	0	None
Discoverer	2	Unidentified Seal	N	1	10-Oct	2:41:10	C	100	212	SP	SW	7.5	38	OT	0	None
Discoverer	3	Pacific Walrus	Y	3	14-Oct	23:31:26	B	493	235	SA	SW	6	41.2	OT	0	SZ
Discoverer	4	Unidentified Mysticete Whale	Y	1	16-Oct	1:21:30	C	4136	4275	UN	BL	4	46.4	LS	3320	None
Discoverer	5	Unidentified Seal	Y	1	27-Oct	0:17:11	B	606	622	MI	LO	3	46	LS	3320	None
Discoverer	6	Bearded Seal	N	1	27-Oct	19:47:57	B	150	259	SA	TH	7	43.4	SH	40	None
Discoverer	7	Unidentified Seal	Y	1	2-Nov	0:21:20	B	606	750	SP	FD	1	43.6	LS	3370	None
Discoverer	8	Bearded Seal	N	1	2-Nov	23:59:00	C	606	746	SA	FD	3	38	LS	3040	None
Discoverer	9	Unidentified Seal	N	1	5-Nov	1:00:39	B	150	283	MI	FD	6	45.2	SH	40	None
Discoverer	10	Unidentified Seal	N	1	10-Nov	21:52:50	B	100	212	SA	NO	3	41.2	OT	0	None
Discoverer	11	Unidentified Seal	N	1	12-Nov	1:10:37	B	215	312	MI	FD	6	49.6	OT	0	None
Discoverer	12	Unidentified Seal	N	1	12-Nov	2:06:25	B	30	173	PE	TH	5	48.4	OT	0	None
Discoverer	13	Gray Whale	N	2	12-Nov	23:17:51	A	1932	2036	SA	SW	4	42.6	TRANSIT	0	None
Discoverer	14	Gray Whale	Y	5	12-Nov	23:26:06	A	1932	1937	SP	SW	4	41.6	TRANSIT	0	None
Discoverer	15	Gray Whale	Y	2	12-Nov	23:30:00	A	4532	3170	UN	BL	4	41.6	TRANSIT	0	None
Discoverer	16	Gray Whale	Y	1	12-Nov	23:45:00	A	1932	852	SA	FD	4	42	TRANSIT	0	None
Discoverer	17	Gray Whale	N	7	13-Nov	0:13:41	A	416	440	SP	SW	4	42.2	TRANSIT	0	None
Discoverer	18	Gray Whale	N	1	13-Nov	0:26:12	A	1412	1489	SA	FD	4	41.8	TRANSIT	0	None
Discoverer	19	Gray Whale	N	1	13-Nov	0:38:59	A	1631	1757	SA	FD	4	41.2	TRANSIT	0	None
Discoverer	20	Gray Whale	N	1	13-Nov	0:42:48	A	3096	3221	UN	BL	4	41	TRANSIT	0	None
Discoverer	21	Gray Whale	N	1	13-Nov	0:45:50	A	4532	4605	UN	FD	4	40.8	TRANSIT	0	None
Discoverer	22	Gray Whale	N	1	13-Nov	0:49:17	A	3096	3199	UN	BL	4	40.7	TRANSIT	0	None
Discoverer	23	Gray Whale	N	2	13-Nov	1:21:36	A	150	271	ST	SW	4	39.8	TRANSIT	0	None
Discoverer	25	Unidentified Pinniped	N	1	15-Nov	0:22:43	A	150	194	ST	FD	6	42	TRANSIT	0	None
Discoverer	26	Dall's Porpoise	N	4	15-Nov	22:03:00	A	5	148	SP	BO	7	95.8	TRANSIT	0	None
Discoverer	27	Dall's Porpoise	N	3	16-Nov	2:37:00	A	5	149	SP	BO	7	117	TRANSIT	0	None
Discoverer	28	Unidentified Dolphin	N	1	18-Nov	2:32:40	A	20	154	ST	SW	6	70.9	TRANSIT	0	None
Discoverer	29	Unidentified Whale	Y	1	21-Nov	1:37:14	A	150	271	UN	UN	4	104	TRANSIT	0	None
Discoverer	30	Unidentified Pinniped	Y	1	21-Nov	19:20:16	A	185	262	SP	FD	2	69.5	TRANSIT	0	None
Discoverer	31	Killer Whale	Y	4	21-Nov	21:46:49	A	920	1059	SA	SW	4	109	TRANSIT	0	None
Discoverer	32	Unidentified Mysticete Whale	N	2	21-Nov	22:28:36	A	17000	17124	UN	BL	4	91.4	TRANSIT	0	None
Discoverer	33	Gray Whale	N	2	21-Nov	22:54:00	A	1932	1506	NO	SW	1	98.8	TRANSIT	0	None
Discoverer	34	Gray Whale	N	2	21-Nov	23:22:18	A	7500	7602	UN	DI	4	103	TRANSIT	0	None

TABLE G.3. Continued.

Vessel	Sighting ID	Species	Useable (Y) or Non-useable (N)[a]	Group Size	Day in 2006	Time (GMT)	Location[a]	Initial Sighting Distance (m) from observer	CPA[b] (m)	Initial Move-ment[c]	Initial Behav.[d]	Bf[e]	Water Depth (m)[f]	Vessel Activ.[g]	Airguns Vol. (in^3)[h]	Mitig. (SZ, PZ, None)[i]
Discoverer	35	Unidentified Whale	M	4	22-Nov	0:27:02	A	4532	4657	UN	SW	4	107	TRANSIT	0	None
Octopus	1	Gray Whale	Y	1	29-Sep	23:12:30	B	500	200	PE	SW	3	47	OT	0	None
Octopus	2	Bowhead Whale	Y	1	29-Sep	23:29:30	B	800	800	SP	SW	3	47	OT	0	None
Octopus	3	Gray Whale	Y	1	29-Sep	23:37:30	B	800	800	SP	SW	3	47	OT	0	None
Octopus	4	Gray Whale	Y	1	29-Sep	23:47:30	B	241	241	SP	SW	3	47	OT	0	None
Octopus	5	Gray Whale	Y	7	29-Sep	23:57:30	B	1397	825	MI	SW	3	47	OT	0	None
Octopus	6	Unidentified Whale	Y	1	30-Sep	0:38:30	B	500	200	NO	BL	3	48	OT	0	None
Octopus	7	Gray Whale	Y	1	30-Sep	1:06:46	B	900	200	SP	SW	2	49	OT	0	None
Octopus	8	Bowhead Whale	Y	3	30-Sep	2:24:30	B	2174	456	ST	SW	2	49	OT	0	None
Octopus	9	Bowhead Whale	Y	1	30-Sep	2:50:30	B	50	50	NO	FL	2	50	OT	0	None
Octopus	10	Unidentified Seal	N	1	30-Sep	18:21:30	B	100	100	PE	LO	1	51	OT	0	None
Octopus	11	Unidentified Seal	N	1	30-Sep	18:57:30	B	20	20	ST	FD	1	51	OT	0	None
Octopus	12	Unidentified Seal	N	2	30-Sep	19:04:30	B	100	100	SP	LO	1	50	OT	0	None
Octopus	13	Unidentified Seal	N	1	30-Sep	19:13:30	B	100	100	SP	LO	1	50	OT	0	None
Octopus	14	Bearded Seal	N	1	30-Sep	19:19:30	B	164	164	SP	LO	1	50	OT	0	None
Octopus	15	Unidentified Seal	Y	1	30-Sep	19:19:30	B	178	178	SA	FD	1	50	OT	0	None
Octopus	16	Bearded Seal	Y	1	30-Sep	19:47:30	B	164	164	NO	LO	1	49	OT	0	None
Octopus	17	Bearded Seal	Y	1	30-Sep	19:47:30	B	241	241	NO	LO	1	49	OT	0	None
Octopus	18	Bearded Seal	Y	1	30-Sep	19:48:30	B	164	120	SP	LO	1	49	OT	0	None
Octopus	19	Unidentified Seal	Y	2	30-Sep	20:48:56	B	50	50	NO	LO	1	48	OT	0	None
Octopus	20	Bearded Seal	Y	12	30-Sep	20:48:56	B	241	195	MI	DI	1	48	OT	0	None
Octopus	21	Bearded Seal	Y	3	30-Sep	21:03:30	B	316	316	SP	LO	1	48	OT	0	None
Octopus	22	Unidentified Seal	Y	1	30-Sep	21:04:30	B	30	30	SP	LO	1	48	OT	0	None
Octopus	23	Unidentified Seal	N	1	30-Sep	21:04:30	B	20	10	NO	LO	1	48	OT	0	None
Octopus	24	Unidentified Seal	N	1	30-Sep	21:26:30	B	241	241	SP	LO	1	46	OT	0	None
Octopus	25	Unidentified Seal	Y	2	30-Sep	21:34:30	B	241	241	SP	LO	1	46	OT	0	None
Octopus	26	Bearded Seal	Y	1	30-Sep	21:44:30	B	50	50	SA	LO	1	46	OT	0	None
Octopus	27	Unidentified Seal	Y	1	30-Sep	22:04:30	B	195	195	NO	LO	1	46	OT	0	None
Octopus	28	Bearded Seal	Y	2	30-Sep	22:08:30	B	50	50	ST	LO	1	46	OT	0	None
Octopus	29	Unidentified Seal	Y	1	30-Sep	22:08:30	B	100	100	SP	LO	1	46	OT	0	None
Octopus	30	Bearded Seal	Y	12	30-Sep	22:17:14	B	456	456	SP	LO	1	45	OT	0	None
Octopus	31	Bearded Seal	Y	1	30-Sep	22:17:14	B	124	124	NO	LO	1	45	OT	0	None
Octopus	32	Bearded Seal	Y	1	30-Sep	22:24:31	B	195	120	SP	LO	1	45	OT	0	None
Octopus	33	Bearded Seal	Y	1	30-Sep	22:36:00	B	164	140	SP	LO	1	45	OT	0	None
Octopus	34	Unidentified Seal	Y	1	30-Sep	22:47:00	B	316	300	NO	FD	1	44	OT	0	None
Octopus	35	Unidentified Seal	Y	1	30-Sep	22:47:00	B	142	142	SP	SW	1	44	OT	0	None
Octopus	36	Unidentified Seal	Y	3	30-Sep	23:03:00	B	164	164	NO	LO	1	44	OT	0	None
Octopus	37	Unidentified Seal	Y	1	30-Sep	23:03:00	B	200	200	NO	LO	1	44	OT	0	None
Octopus	38	Unidentified Seal	Y	1	30-Sep	23:20:30	B	124	124	NO	LO	1	44	OT	0	None
Octopus	39	Unidentified Seal	Y	2	30-Sep	23:30:00	B	825	800	NO	DI	1	44	OT	0	None
Octopus	40	Unidentified Seal	Y	2	30-Sep	23:43:30	B	456	456	NO	LO	1	43	OT	0	None
Octopus	41	Unidentified Seal	Y	1	1-Oct	0:55:20	B	124	124	NO	LO	1	45	OT	0	None
Octopus	42	Unidentified Seal	Y	2	1-Oct	1:17:45	B	316	316	NO	FD	1	46	OT	0	None
Octopus	43	Unidentified Seal	Y	1	1-Oct	1:23:10	B	180	180	NO	LO	1	46	OT	0	None
Octopus	44	Unidentified Seal	Y	1	1-Oct	1:50:00	B	20	20	NO	LO	1	45	OT	0	None
Octopus	45	Harbor Porpoise	Y	2	1-Oct	1:55:00	B	241	241	MI	DI	1	47	OT	0	None
Octopus	46	Spotted Seal	Y	1	1-Oct	2:31:30	B	80	50	ST	LO	1	47	OT	0	None
Octopus	47	Harbor Porpoise	Y	2	1-Oct	2:53:30	B	80	80	SA	FD	1	47	OT	0	None
Octopus	48	Unidentified Seal	Y	1	3-Oct	0:09:30	C	241	200	NO	LO	2	48	OT	0	None
Octopus	49	Unidentified Seal	Y	1	3-Oct	0:26:59	C	316	316	SA	DI	2	47	OT	0	None
Octopus	50	Bearded Seal	Y	1	3-Oct	0:52:11	C	195	195	SA	SW	2	47	OT	0	None
Octopus	51	Bearded Seal	Y	1	3-Oct	1:00:16	C	124	120	SA	LO	2	47	OT	0	None

TABLE G.3. Continued.

Vessel	Sighting ID	Species	Useable (Y) or Non-useable (N)[a]	Group Size	Day in 2006	Time (GMT)	Location[a]	Initial Sighting Distance (m) from observer	CPA[b] (m)	Initial Move-ment[c]	Initial Behav.[d]	Bf[e]	Water Depth (m)[f]	Vessel Activ.[g]	Airguns Vol. (in^3)[h]	Mitig. (SZ, PZ, None)[i]
Octopus	52	Unidentified Seal	Y	2	3-Oct	1:14:37	C	587	587	SP	SW	2	45	OT	0	None
Octopus	53	Gray Whale	N	2	6-Oct	1:40:30	C	50	50	MI	BL	4	13	OT	0	None
Octopus	54	Unidentified Mysticete Whale	N	1	6-Oct	3:37:30	C	50	50	SA	BL	4	13	OT	0	None
Octopus	55	Gray Whale	N	1	7-Oct	1:18:30	C	40	20	MI	BL	4	13	OT	0	None
Octopus	93	Pacific Walrus	Y	2	14-Oct	19:40:00	B	60	40	SA	OT	3	41	OT	0	None
Octopus	56	Unidentified Pinniped	Y	1	15-Oct	19:39:00	C	20	20	PE	SW	3	45	OT	0	None
Octopus	57	Ringed Seal	Y	1	15-Oct	23:19:56	C	15	15	SP	LO	3	45	OT	0	None
Octopus	58	Spotted Seal	Y	1	15-Oct	23:53:00	C	100	100	NO	LO	3	45	OT	0	None
Octopus	59	Unidentified Mysticete Whale	N	1	16-Oct	22:27:00	C	30	30	PE	SW	4	11	OT	0	None
Octopus	60	Unidentified Seal	Y	1	16-Oct	23:58:28	C	124	124	NO	LO	4	57	OT	0	None
Octopus	61	Unidentified Seal	Y	1	17-Oct	1:21:10	C	130	130	SA	PO	7	119	OT	0	None
Octopus	62	Ringed Seal	Y	1	17-Oct	18:34:27	C	15	10	SP	LO	3	57	OT	0	None
Octopus	92	Unidentified Seal	Y	1	17-Oct	23:11:30	C	316	316	NO	LO	4	51	OT	0	None
Octopus	63	Spotted Seal	Y	1	18-Oct	23:21:00	B	164	140	NO	LO	2	43	OT	0	None
Octopus	64	Unidentified Seal	Y	1	22-Oct	20:58:30	C	50	50	NO	LO	4	43	OT	0	None
Octopus	65	Unidentified Seal	Y	1	22-Oct	21:02:00	C	15	15	NO	LO	4	43	OT	0	None
Octopus	66	Bearded Seal	Y	1	22-Oct	21:39:28	C	5	5	NO	LO	5	42	OT	0	None
Octopus	67	Unidentified Seal	Y	1	22-Oct	22:16:38	C	72	72	SA	LO	5	43	OT	0	None
Octopus	68	Spotted Seal	Y	1	23-Oct	21:00:30	B	124	124	NO	LO	1	39	OT	0	None
Octopus	69	Spotted Seal	Y	1	23-Oct	21:51:25	B	241	241	NO	LO	1	37	OT	0	None
Octopus	70	Unidentified Seal	Y	2	23-Oct	21:54:00	B	241	241	SA	SW	1	37	OT	0	None
Octopus	71	Unidentified Seal	Y	1	29-Oct	0:00:30	C	80	80	NO	LO	3	46	OT	0	None
Octopus	72	Unidentified Seal	Y	1	29-Oct	0:12:39	C	10	10	SP	LO	3	46	OT	0	None
Octopus	73	Unidentified Seal	Y	1	29-Oct	20:36:57	C	100	100	SP	LO	3	46	OT	0	None
Octopus	74	Spotted Seal	Y	1	1-Nov	23:00:00	B	164	140	MI	LO	1	46	OT	0	None
Octopus	75	Bearded Seal	Y	1	4-Nov	23:35:17	B	142	140	SP	LO	5	49	OT	0	None
Octopus	76	Gray Whale	Y	2	5-Nov	0:00:00	B	1000	140	MI	BL	5	45	OT	0	None
Octopus	77	Bearded Seal	Y	1	11-Nov	22:25:00	B	15	15	FL	FD	5	49	OT	0	None
Octopus	78	Unidentified Seal	Y	1	11-Nov	22:49:00	B	50	50	NO	UN	4	49	OT	0	None
Octopus	79	Unidentified Mysticete Whale	Y	1	11-Nov	23:13:00	B	100	100	UN	BL	5	48	OT	0	None
Octopus	80	Unidentified Mysticete Whale	Y	2	12-Nov	11:10:30	A	2174	2170	SA	BL	2	38	TRANSIT	0	None
Octopus	81	Gray Whale	Y	2	12-Nov	13:15:00	A	825	825	SP	BL	2	37	TRANSIT	0	None
Octopus	82	Gray Whale	Y	3	12-Nov	13:28:00	A	1397	100	SP	BL	2	38	TRANSIT	0	None
Octopus	83	Gray Whale	Y	1	12-Nov	13:41:30	A	825	825	SA	BL	2	38	TRANSIT	0	None
Octopus	84	Gray Whale	Y	3	12-Nov	13:48:30	A	10	10	FL	SW	2	38	TRANSIT	0	None
Octopus	85	Gray Whale	Y	2	12-Nov	14:00:00	A	500	370	UN	BL	2	38	TRANSIT	0	None
Octopus	86	Gray Whale	Y	2	12-Nov	14:13:51	A	825	100	NO	BL	2	38	TRANSIT	0	None
Octopus	87	Gray Whale	Y	3	12-Nov	14:21:27	A	825	825	SA	BL	3	38	TRANSIT	0	None
Octopus	88	Gray Whale	Y	1	12-Nov	14:31:00	A	200	200	UN	BL	3	40	TRANSIT	0	None
Octopus	89	Unidentified Mysticete Whale	Y	1	12-Nov	14:48:00	A	2000	2000	UN	BL	3	39	TRANSIT	0	None
Octopus	90	Dall's Porpoise	N	4	14-Nov	11:53:30	A	1	1	SP	WR	5	134	TRANSIT	0	None
Octopus	91	Dall's Porpoise	N	4	15-Nov	18:16:19	A	1	1	SP	BR	5	174	TRANSIT	0	None

[a] Useable or non-useable sightings: Y= useable sightings made during useable daylight periods of visual observation, as defined in *List of Acronyms and Abbreviations,* N= non-useable sightings.
[b] Refers to generalized locations shown in Figure G.1.
[c] Closest point of approach: chase vessel sightings have closest point of approach to airguns.
[d] Initial movement of the animal(s) relative to the vessel: MI=milling, FL=Flee, PE=swimming perpendicular to ship or across bow, SA=swimming away, SP=swimming parallel, ST=swimming toward, NO=no movement, UN=unknown.

[e] Initial behavior observed: BR=breach, FL=fluke, DI=dive, FD=forward dive, SW=swim, TR=travel, ST=surface-active travel, LG=log, RE=rest, LO=look, SI=sink, TH=thrash, FE/FG=feed, MI=mill, SA=surface-active, UN=unknown.
[f] Beaufort Wind Force Scale.
[g] Activity of the vessel at the time of the sighting: TR=travelling within the study area, OT=other, DP=deploying equipment.
[h] Combined volume of operating airguns at the time of the sighting.
[i] Mitigation measure taken: SZ=safety zone shut-down, PZ=safety zone power-down, None=no measure taken.

Appendix H:

MARINE MAMMAL DENSITY ESTIMATES

TABLE I.1. Expected densities of marine mammals in offshore areas of the Alaskan Chukchi Sea (see Chapter 4 for more details). Densities are corrected for *f*(0) and *g*(0) biases (see Appendix E).

Species	**Density - Seismic** (No. individuals /1000 km^2)	**Density - Non-seismic** (No. individuals /1000 km^2)
Cetaceans		
Unidentified Whale	0	0.382
Odontocetes		
Harbor Porpoise	0	2.481
Mysticetes		
Unidentified Mysticete Whale	1.717	0.363
Bowhead Whale	0	3.273
Gray Whale	0	4.718
Pinnipeds		
Unidentified Pinniped	0	1.882
Odobenids		
Pacific Walrus	12.836	1.809
Phocids		
Unidentified Seal	17.805	69.618
Bearded Seal	0	105.242
Ringed Seal	0	6.617
Spotted Seal	0	17.131