MARINE MAMMAL MONITORING AND MITIGATION DURING A MARINE GEOPHYSICAL SURVEY IN THE ARCTIC OCEAN, AUGUST–SEPTEMBER 2010: 90-DAY REPORT

Prepared by

Alaska Research Associates, Inc.
1101 East 76th Avenue, Suite B, Anchorage, AK 99518

for

U.S. Geological Survey
345 Middlefield Rd.
Menlo Park, CA 94025

National Marine Fisheries Service
Office of Protected Resources
1315 East-West Hwy, Silver Spring, MD 20910-3282

U.S. Fish and Wildlife Service, Marine Mammals Management Office
1101 E. Tudor Rd., Anchorage, AK 99503-6199

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Joseph Beland and Darren Ireland

LGL Alaska Research Associates, Inc.
1101 East 76th Ave., Suite B, Anchorage, AK 99518, U.S.A.

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TABLE OF CONTENTS

APPENDICES:

LIST OF ACRONYMS AND ABBREVIATIONS

~	approximately
ADCP™	Acoustic Doppler Current Profiler
Bf	Beaufort Wind Force
CCGS	Canadian Coast Guard Ship
CITES	Convention on International Trade in Endangered Species
CLOS	Convention on the Law of the Sea
CPA	Closest (Observed) Point of Approach
dB	decibel
EA	Environmental Assessment
EEZ	Exclusive Economic Zone
ESA	(U.S.) Endangered Species Act
f(0)	sighting probability density at zero perpendicular distance from survey track; equivalently, 1/(effective strip width)
ft	feet
G. gun	GI gun without the use of the injector
GSC	Geological Survey of Canada
g(0)	probability of seeing a group located directly on a survey line
h	hours
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
µPa	micro Pascal
m	meters
mi	miles
min	minutes
MMPA	(U.S.) Marine Mammal Protection Act
MST	Mountain Standard Time
n	sample size
n.mi.	nautical miles
NMFS	(U.S.) National Marine Fisheries Service
No.	number
pk-pk	peak-to-peak
PSO	Protected Species Observer
re	in reference to
rms	root-mean-square
s	seconds

s.d.	standard deviation
SPL	Sound pressure level
UNEP	United Nations Environmental Programme
U.S.	United States
USCG	United States Coast Guard
USCGC	United States Coast Guard cutter
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

EXECUTIVE SUMMARY

Introduction

The United States Geological Survey (USGS) conducted a marine geophysical survey in the Arctic Ocean north of Alaska in cooperation with the Geological Survey of Canada (GSC) from August to early September 2010. The purpose of this study was to survey potential areas of the extended continental shelf to which the United States may legitimately have sovereign rights under Article 76 of the Convention on the Law of the Sea (CLOS). Two vessels operated during the geophysical survey, the *Louis S. St-Laurent*, a Canadian Coast Guard Ship (CCGS) that towed a relatively small airgun array as well as a hydrophone streamer to record reflected seismic data, and the *Healy,* a United States Coast Guard (USCG) icebreaker, which was used to collect bathymetric data and sediment and rock samples, as well as to break and clear ice for the *Louis S. St-Laurent* during seismic operations in ice-covered areas. In situations where the airgun array (and hydrophone steamer) could not be towed safely due to ice cover, the *Louis S. St-Laurent* broke ice for the *Healy* to collect higher-quality multibeam data.

Marine geophysical surveys emit sounds into the water at levels 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 United States (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.

Sounds generated by icebreaking activity are considered by NMFS to be a continuous sound. NMFS (2005) indicates the disturbance threshold for marine mammals by continuous sounds is a received sound pressure level (SPL) of 120 dB re 1 μPa (rms). While breaking ice, the noise from the ship, including impact with ice, engine noise, and propeller cavitation, would exceed 120 dB (rms). Therefore, potential "takes" of marine mammals could occur during icebreaking activities.

The USGS's geophysical survey activities conducted from the *Louis S. St-Laurent* in U.S. waters and icebreaking activities by the *Healy* in the Arctic Ocean were performed under the provisions of an Incidental Harassment Authorization (IHA) issued by NMFS. Survey operations from the *Louis S. St-Laurent* in Canadian or international waters were conducted under provisions of a Canadian authorization based on Canada's environmental assessment of the survey activities. The IHA included provisions to minimize the possibility that marine mammals might occur close to the seismic source and be exposed to levels of sound high enough to cause hearing damage or other injuries, and to reduce behavioral disturbances that might be considered as "take by harassment" under the MMPA.

A mitigation program was conducted to avoid or minimize potential effects of USGS's geophysical survey on marine mammals, and to ensure that USGS was in compliance with the provisions of the IHA. This required that protected species observers (PSOs) onboard the seismic vessel, *Louis S. St-Laurent*, detect marine mammals within or about to enter the designated safety radii around the active airgun array, and in such cases initiate an immediate power down (or shut down if necessary) of the airguns.

The primary objectives of the monitoring and mitigation program were to:

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 icebreaking sounds; and

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

This 90-day report describes the methods and results for the monitoring work specifically required to meet the above primary objectives. In this report, only survey operations by the *Louis S. St-Laurent* that occurred in U.S. waters were included. In contrast, all *Healy* operations in U.S., Canadian and international waters were included.

Seismic Program Described

The USGS, in cooperation with the GSC, conducted a marine geophysical survey in the Arctic Ocean north of Alaska from early August to early September 2010. They *Healy* was used to collect bathymetric and shallow sub-surface data, as well as five piston cores of sea floor sediments. The *Louis S. St-Laurent* collected seismic reflection and refraction data using a three-airgun array. The vessels worked in concert when ice conditions were heavy, with the one vessel breaking ice for the ship collecting data.

The United States (U.S.), through the U.S. Interagency Task Force on the Extended Continental Shelf, collaborated with Canada in 2008 and 2009 on similar extended continental shelf studies with the same vessels in international and Canadian waters of the Arctic Ocean. The two icebreaking vessels contributed different capabilities in order to collect data needed by both nations more efficiently, save money, avoid redundancy, and foster cooperation. Generally, the *Healy* collects bathymetric (sea-floor topography) data and the *Louis S. St-Laurent* collects seismic reflection profile data.

The purpose of the project was to survey the potential areas of "extended continental shelf" to which either Canada or the United States may legitimately lay claim. The Convention on the Law of the Sea (CLOS) established criteria within Article 76 to determine the area beyond the 200 n.mi. limit where nations can exert sovereign rights to natural resources on and beneath the sea floor, including energy, minerals, and sedentary animal species. The United States has an inherent interest in knowing, and declaring to others, the extent of its sovereign rights with regard to the U.S. extended continental shelf.

Article 76 of CLOS provides two formulae for finding the outer limits of the extended continental shelf, one based on bathymetry measurements and a second based on sediment thickness measurements. The coastal nation can use whichever formula is more advantageous up to a maximum distance determined from either of two constraint lines, one based on a distance of 100 n.mi. seaward of the 2500 m (8202 ft) isobath, or 350 n.mi. measured from the coastal baselines. In all but the very northernmost part of the Canada Basin of the Arctic Ocean, the more favorable formula for both the U.S. and Canada uses sediment thickness measurements.

The principal objectives of the 2010 USGS and GSC program were to, ***(1)*** acquire multichannel seismic reflection and refraction data along positions that serve to establish sediment thicknesses along Canadian and US western Arctic continental margins, and, ***(2)*** to acquire bathymetric sounding data at specific locations along this same margin in order to validate bathymetric data acquired by other means (e.g. satellite altimetry) to establish baseline information such as the 2500 m (8202 ft) contour and foot of slope positions. Strategic ship tracklines were established that permit meeting these criteria and that complement data acquired in earlier phases of this program or exist from legacy programs from national and international sources. Line orientations were also established to permit conducting scientific investigations regarding the origin of the Amerasian Basin and associated submarine land masses.

The *Healy* departed from Dutch Harbor on 2 Aug, and the *Louis S. St-Laurent* departed from Kugluktuk, Nunavut, Canada on 6 Aug. The two vessels rendezvoused on 10 Aug and began seismic operations in the U.S. EEZ (Exclusive Economic Zone) on 12 Aug. The seismic study in the U.S. EEZ was concluded on 17 Aug (MST). The two vessels then moved to international waters where survey activities occurred until 4 Sep. After completing the survey the *Healy* sailed south to Barrow where the PSOs disembarked on 6 Sep. The *Louis S. St-Laurent* returned to Kugluktuk, Nunavut, Canada on 15 Sep.

The *Healy* used a 12 kHz multibeam echo sounder, (Kongsberg EM122), a 3.5 kHz chirp sub-bottom profiler (Knudsen 3260) and a "piloting" echo sounder (ODEC 1500) continuously when underway and during the seismic profiling. Acoustic Doppler current profilers (75-kHz and 150-kHz) were also used on the *Healy*.

Acoustic sources on board the *Louis S. St-Laurent* included an airgun array comprised of three Sercel G-guns and a Knudsen 320BR echo sounder operating at 12 kHz. The *Louis S. St-Laurent* also towed a 3.5 kHz sub-bottom profiler while in open water and when not working with the *Healy*. The airgun array consisted of two 500 in^3 and one 150 in^3 airguns for an overall discharge of 1150 in^3. Table 3.1 presents the sound pressure level radii of the airgun array. The *Louis S. St-Laurent* towed a multichannel hydrophone streamer ~300 m (984 ft) in length and also deployed marine sonobuoys to acquire seismic reflection and refraction data. The sonobuoys were deployed off the stern of the *Louis S. St-Laurent* at irregular but frequent periods during seismic operations with as many as three deployments per day.

Monitoring Results

The *Louis S. St-Laurent* conducted seismic surveys in the U.S. EEZ from 12 Aug to 17 Aug 2010. Airgun operations occurred along 854 km (531 mi) in the U.S. EEZ. The full airgun array was ramping up or active along 839 km (521 mi) of trackline, and the single mitigation gun operated along 15 km (9 mi) of trackline due to mechanical issues with the full array. PSOs were on watch for a total of 1118 km (695 mi; 129 hr) in the U.S. EEZ. In the U.S. EEZ, PSOs on the *Louis S. St-Laurent* monitored for marine mammals during all periods of airgun operations. All observation effort was during daylight. Survey effort from the *Healy* was included in analyses of seismic activity within the U.S. EEZ when the *Healy* was within 75 km (47 mi) of the *Louis S. St-Laurent.* The *Healy* conducted operations within 75 km (47 mi) of the *Louis S. St-Laurent* in the U.S. EEZ along a total of 969 km (602 mi) of trackline, 448 km (278 mi) of which PSOs aboard the *Healy* were on watch. While the *Healy* did not conduct any seismic operations in the U.S. EEZ, approximately 145 km (90 mi) of PSO effort from the *Healy* was considered exposed to seismic sounds due to the proximity of the *Healy* to the active seismic source towed by the *Louis S. St-Laurent*.

During seismic survey operations in the U.S. EEZ, eleven individual marine mammals in nine groups were observed by *Louis S. St-Laurent* and *Healy* PSOs. Eight of the sightings (nine individuals) were of ringed seals, and one sighting (two individuals) was of a polar bear. No power downs or shut-downs of the airguns were necessary or requested by the *Louis S. St-Laurent* PSOs due to the detection of a marine mammal within the ≥180 and ≥190 dB safety radii.

Based on direct observations from the *Louis S. St-Laurent* and *Healy*, no marine mammals occurred within the ≥180 or ≥190 dB rms safety radii while the airguns were firing. However, the number of marine mammals visually detected by PSOs likely underestimated the actual numbers that were present. Alternative estimates of the number of marine mammals potentially exposed to various sound levels were made based on densities calculated from earlier marine mammal surveys in and near the Arctic Ocean and the actual amount of seismic activity that occurred during the 2010 survey. Based on average (best) density estimates calculated from previous surveys and the actual amount of seismic activity conducted in the U.S. EEZ, we estimated that ~189 individual cetaceans and ~901 individual seals may have been exposed to seismic sounds ≥160 dB re 1 μPa (rms) during the survey if all animals showed no avoidance of the vessel. Less than one polar bear is likely to have been exposed to sound levels ≥160 rms.

The *Healy* traveled an additional 7111 km (4819 mi) when it was outside U.S. waters or not within close proximity (75 km; 47 mi) of the *Louis S. St-Laurent* in the U.S. EEZ during the 2010 USGS survey. PSO survey effort during this period was broken down into icebreaking and non-icebreaking periods defined by when the vessel was operating in ≥80 percent ice cover and <80% ice cover, respectively. Using that criterion, the *Healy* conducted icebreaking activities along 2833 km (1760 mi) of trackline, with the remaining 4278 km (2658 mi) of travel having occurred in <80% ice cover. PSO monitoring effort from the *Healy* totaled 2736 km (1700 mi) during icebreaking periods and 3129 km (1944 mi) during non-icebreaking periods.

PSOs aboard the *Healy* recorded an additional 81 marine mammal sightings of 89 individuals when it was outside U.S. waters or not within close proximity (75 km; 47 mi) of the *Louis S. St-Laurent* in the U.S. EEZ. The majority (~72%; n = 58) of these sightings occurred during icebreaking periods. Ringed Seal (n = 29) was the most frequently identified species during icebreaking periods, followed by polar bear (n = 7) and bearded seal (n = 6). The remaining 16 sightings during icebreaking periods were of unidentified seals. Ringed seal (n = 11) was also the most frequently identified species during non-icebreaking periods, followed by polar bear (n = 5), bearded seal (n = 2), and gray whale (n = 1). The remaining four sightings during non-icebreaking periods were of unidentified seals. The seal sighting rate from the *Healy* during icebreaking periods was greater than during non-icebreaking periods.

Based on available data on marine mammal densities in the Arctic Ocean and the area ensonified, we estimated that between ~303 and ~1137 individual marine mammals may have been exposed to icebreaking sounds ≥120 dB re 1 μPa (rms) during the survey if all marine mammals showed no avoidance of the vessel. The only density estimate that could be calculated from observations made during icebreaking periods of the 2010 survey was for seals in water. Using the density estimate calculated from the 2010 observations of seals in water during icebreaking periods and the area ensonified, we estimated that ~260 individual seals would have been exposed to sound levels ≥120 dB if all animals exhibited no avoidance of the ≥120 dB zone.

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We thank the captains and crews of the *Louis S. St-Laurent* and *Healy* for their support during this project. We also thank representatives of the National Marine Fisheries Service, U.S. Fish & Wildlife Service, North Slope Borough Department of Wildlife Management, Alaska Eskimo Whaling Commission and Minerals Management Service for their advice and comments. Jonathan Childs, Deborah Hutchinson, Carolyn Degnan, Bryan Belay, and Beth Haley provided valuable support prior to and during the field season. We also thank all of the protected species observers (PSOs) who participated in the project. They were essential to the completion and success of this endeavor: Kwasi Addae, Sarah Ashworth, Ralph Kaleak, Jonah Nakimayak, Justin Pudenz, Dale Ruben, and John Ruben.

1. BACKGROUND AND INTRODUCTION

The United States Geological Survey (USGS) conducted a marine geophysical survey in the Arctic Ocean north of Alaska in cooperation with the Geological Service of Canada (GSC) from 11 Aug. to 6 Sept. 2010. Seismic operations were conducted from the Canadian Coast Guard Ship (CCGS) *Louis S. St-Laurent*, a polar class icebreaker. The United States Coast Guard Cutter (USCGC) *Healy*, also a polar class icebreaker, was used to collect multibeam bathymetry and chirp sub-bottom data, as well as sediment and rock samples. The two vessels operated both within and outside of the U.S. Exclusive Economic Zone (EEZ; 200-n.mi from shore). During seismic surveys in ice covered waters the *Healy* traveled in front of the *Louis S. St-Laurent* to break ice and clear ice for the *Louis S. St-Laurent*. In the heaviest ice conditions when seismic operations were precluded, the *Louis S. St-Laurent* escorted the *Healy* for optimal multibeam and chirp data acquisition. In open water areas the vessels coordinated efforts but operated more independently.

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 known 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. Potential effects, however, may be reduced by marine mammals moving away from approaching sound sources (Reiser et al. 2009; Richardson et al. 1995, 1999; Stone 2003; Gordon et al. 2004; Smultea et al. 2004). Continuous sounds from icebreaking activities also have the potential to effect marine mammals by causing a disruption of behavioral patterns. Either behavioral/distributional effects or (if they occur) auditory effects would 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”.

Only a few species of cetaceans and pinnipeds inhabit parts of the Arctic Ocean in or near the survey area. The National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) share jurisdiction over the marine mammal species that could be encountered during the project. Two species under NMFS jurisdiction that are listed as “Endangered” under the ESA, including bowhead whale (*Balaena mysticetus*), and fin whale (*Balaenoptera physalus*), do or may occur in portions of the survey area. Additionally, NMFS initiated a status review to determine if listing as endangered or threatened under the ESA was warranted for four other species that occur in the project area including ringed seal (*Phoca fasciata*), spotted seal (*P. largha*), bearded seal (*Erignathus barbatus*), and ribbon seal (*Histriophoca fasciata*; NMFS 2008a,b). Subsequently NMFS (2008c) announced that listing of the ribbon seal as threatened or endangered was not warranted at this time. More recently NMFS (2009) determined that no listing action was warranted for the Bering Sea and Okhotsk populations of spotted seal. The USFWS manages two marine mammal species that occur in the Arctic Ocean, the Pacific walrus (*Odobenus rosmarus*) and polar bear (*Ursus maritimus*). The polar bear was recently listed as threatened under the ESA (USFWS 2008) and a petition to list Pacific walrus as threatened or endangered (CBD 2008) is under consideration by USFWS.

On 27 May 2010, USGS requested an Incidental Harassment Authorization (IHA) from NMFS for the incidental “take” of marine mammals by USGS’s proposed geophysical survey in the Arctic Ocean in 2010. An addendum to supplement the Incidental Harassment Authorization Application (IHAA) was also submitted to address the potential marine mammal “takes” from icebreaking activity intrinsic to the project. NMFS issued an IHA to USGS on 11 Aug 2010 (Appendix A). The IHA authorized “potential take by harassment" of various cetacean and seal species during the geophysical survey described in this report

This document serves to meet reporting requirements specified in the IHA The purposes of this report is to describe this geophysical research project in the Arctic Ocean (emphasizing the seismic survey), to describe the associated marine mammal monitoring and mitigation programs and their results, and to estimate the numbers of marine mammals potentially affected by the project. In this report, only survey operations by the *Louis S. St-Laurent* that occurred in U.S. waters were included. In contrast, all *Healy* operations in U.S., Canadian and international waters were included.

Incidental Harassment Authorization

IHAs issued to seismic operators include provisions to minimize the possibility that marine mammals close to the seismic source might be exposed to levels of sound high enough to cause hearing damage or other injuries. During this project, sounds were generated by the airguns (3 Sercel G-guns) used during the seismic study, a 12 kHz multibeam bathymetric sonar, a 12 kHz echo sounder, a 3.5 kHz chirp sub-bottom profiler, a 3.5 kHz hydrographic sub-bottom profiler, a piloting echo sounder, two acoustic Doppler current profilers, icebreaking activities and general vessel and helicopter operations. Given the nature of the operations and mitigation measures, no serious injuries or deaths of marine mammals were anticipated from the geophysical survey. No such injuries or deaths were attributed to these activities. Nonetheless, the seismic survey operations and icebreaking activities 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.

Under current NMFS guidelines (e.g., NMFS 2010b), "safety radii" for marine mammals around airgun arrays are customarily defined as the distances within which the received pulse levels are expected to be ≥180 dB re 1 μPa (rms)[1] for cetaceans and ≥190 dB re 1 μPa (rms) for pinnipeds. Those safety radii are based on an assumption that seismic pulses received at lower received levels will not injure marine mammals or impair their hearing abilities, but that higher received levels *might* have some such effects. The mitigation measures required by NMFS 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.

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

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[1] "rms" means "root mean square", and represents a form of average across the duration of the sound pulse as received by the animal. Received levels of airgun pulses measured on an "rms" basis (sometimes described as Sound Pressure Level, SPL) 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 3 of this report). SEL (energy) measures may be more relevant to marine mammals than are rms values (Southall et al. 2008), but the current regulatory requirements are based on rms values.

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. 2006a,b,c).

In general, disturbance effects are expected to depend on the species of marine mammal, the activity of the animal at the time of exposure, 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 have shown avoidance at received levels substantially lower than 160 dB re 1 µPa rms (Miller et al. 1999; Richardson et al. 1999). However, recently acquired acoustic evidence suggests that some whales may not react as much or in the same manner as suggested by those earlier studies (Blackwell et al. 2008). Beluga whales may, at times, also show avoidance at received levels below 160 dB (Miller et al. 2005). In contrast, bowhead whales on the summer feeding grounds tolerate received levels of 160 dB or sometimes more without showing significant avoidance behavior (Richardson et al. 1986; Miller et al. 2005; Lyons et al. 2008).

A notice regarding the proposed issuance of an IHA for the USGS geophysical survey in the Arctic Ocean was published by NMFS in the *Federal Register* on 8 Jul 2010 and public comments were invited. On 11 Aug 2010, USGS received the IHA from NMFS that had been requested for the geophysical survey. On 29 Sep 2010, NMFS published a second notice in the *Federal Register* to announce the issuance of the IHA (NMFS 2010b). A copy of the NMFS IHA is included in this report as Appendix A.

NMFS granted the IHA to USGS on the assumptions that

- the numbers of marine mammals potentially harassed (as defined by NMFS criteria) during seismic and icebreaking 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.

Mitigation and Monitoring Objectives

The objectives and methods of the mitigation and monitoring program were described in detail in USGS's IHA application (USGS 2010a) and in the IHA issued by NMFS to USGS (Appendix A). An explanation of the monitoring and mitigation requirements was published by NMFS in the *Federal Register* (NMFS 2010a,b).

The main purpose of the mitigation program was to avoid or minimize potential effects of USGS's seismic survey on marine mammals. This required that shipboard PSOs detect marine mammals within or about to enter the designated safety radii, 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 number of airguns firing. 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 activation of the 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 (see Appendix A and Chapter 3).

The primary objectives of the monitoring and mitigation program were as follows:

1. provide real-time sighting data needed to implement the mitigation requirements;
2. estimate the numbers of marine mammals potentially exposed to strong seismic pulses;
3. determine the reactions (if any) of potentially exposed marine mammals.

Specific mitigation and monitoring objectives identified in the IHA are described in Appendix A. Mitigation and monitoring measures that were implemented during the survey in the Arctic Ocean are described in detail in Chapter 3.

Report Organization

The primary purpose of this report is to describe USGS's 2010 Arctic Ocean seismic survey including the associated monitoring and mitigation programs, and to present results as required by the IHA (Appendix A) This report includes four chapters:

1. background and introduction (this chapter);
2. description of the seismic study;
3. description of the marine mammal monitoring and mitigation requirements and methods, including safety radii;
4. results of the marine mammal monitoring program, including estimated numbers of marine mammals potentially "taken by harassment".

In addition, there are 12 Appendices. Details of procedures that are more-or-less consistent across seismic surveys where marine mammal monitoring and mitigation measures were in place are provided in the Appendices and are only summarized in the main body of this report. The Appendices include:

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

B. a copy of the response letter from USFWS for determination of the need for an ESA consultation;

C. a copy of the letter of concurrence from NMFS regarding ESA section 7 consultation;

D. a copy of the Polar Bear Interaction Plan followed during this project;

E. background on development and implementation of safety radii;

F. characteristics of the *Louis S. St-Laurent* and its airguns and its sonars;

G. characteristics of the *Healy* and its sonars;

H. details on monitoring, mitigation, and data analysis methods;

I. Beaufort wind force definitions;

J. background on marine mammals in the project region;

K. monitoring effort and marine mammal monitoring results;

L. list of all marine mammal detections.

2. ARCTIC OCEAN SEISMIC SURVEY DESCRIBED

Procedures used to obtain seismic data during the USGS survey were similar to those used during previous GSC surveys in 2008 and 2009 (Jackson and DesRoches 2010, Mosher et al. 2009), and to a lesser degree the previous surveys aboard the *Healy* in 2005 and 2006 (Haley and Ireland 2006, Haley 2006). The USGS survey used seismic refraction and reflection techniques to characterize the earth's crust, including a three-airgun array as the energy source, and marine sonobuoys plus a towed multichannel hydrophone streamer ~300 m (984 ft) in length as the receiver systems. Sonobuoys were deployed off the stern of the *Louis S. St-Laurent* at irregular but frequent periods during seismic operations with as many as three deployments per day. (Sonobuoys are passive seismic receivers that transmit the seismic signal to the seismic vessel by radio. The sonobuoys are programmed to scuttle after 8 hours in the water). Additional sources from both survey vessels included: a 12-kHz multibeam bathymetric sonar, a 12-kHz echo sounder, a 3.5-kHz chirp sub-bottom profiler, a 3.5 kHz hydrographic sub-bottom profiler, a piloting echo sounder, and two acoustic Doppler current profilers. These sources were used to map the bathymetry and sub-bottom conditions to obtain other data needed for the geophysical studies.

The following section provides a brief description of the operations and instrumentation used during USGS's 2010 geophysical program in the Arctic Ocean insofar as necessary to satisfy the reporting requirements of the IHA issued by NMFS (Appendix A). More detailed information on the *Louis S. St-Laurent* and *Healy,* as well as the equipment aboard each vessel is provided in Appendices F and G.

Operating Areas, Dates, and Navigation

The USGS and the GSC used the *Louis S. St-Laurent* and *Healy* in a coordinated manner to conduct geophysical research in the Arctic Ocean in 2010. The *Louis S. St-Laurent,* the seismic source vessel, departed from Kugluktuk, Nunavut, Canada on 06 Aug and entered the study area on 11 Aug. The *Louis S. St-Laurent* collected seismic data in an area within the U.S. EEZ (200 n.mi. limit) bounded by approximately 71º to 75ºN latitude and 145º to 152ºW longitude in water depths ranging from ~1,800 to 4,000 m (5907 to 13,125 ft; Fig 2.1). Seismic operations within the U.S. EEZ were conducted from 12 Aug to 17 Aug. The *Louis S. St-Laurent* departed the U.S. EEZ on 17 Aug and moved to international and Canadian waters where it continued operations until 4 Sep[2].

The *Louis S. St-Laurent's* airguns were operated along 854 km (531 mi) of trackline within the U.S. EEZ in 2010. Periods of full array firing plus periods of lead in, lead out, and ramp up occurred along 839 km (521 mi) of trackline. Ramp ups of the airguns occurred on two occasions during the seismic survey in the U.S. EEZ, each involved a start up from no airguns operating. Ramp ups were required by the NMFS IHA (see Chapter 3 and Appendix A). Ramp ups involved an increase in the number of active airguns such that the source level increases by no more than 6 dB per 5 min period. For this array, ramp up began with the smallest of the G-guns (150 in^3), the second G-gun (500 in^3) was added after a period of 5 min, and the remaining G-gun (500 in^3) was added after another 5 min. The single mitigation gun operated along the remaining 15 km (9 mi) of trackline due to mechanical issues.

[2] Only survey operations by the *Louis S. St-Laurent* conducted in U.S. waters were included in this report. In contrast, all *Healy* operations in U.S., Canadian and international waters were included.

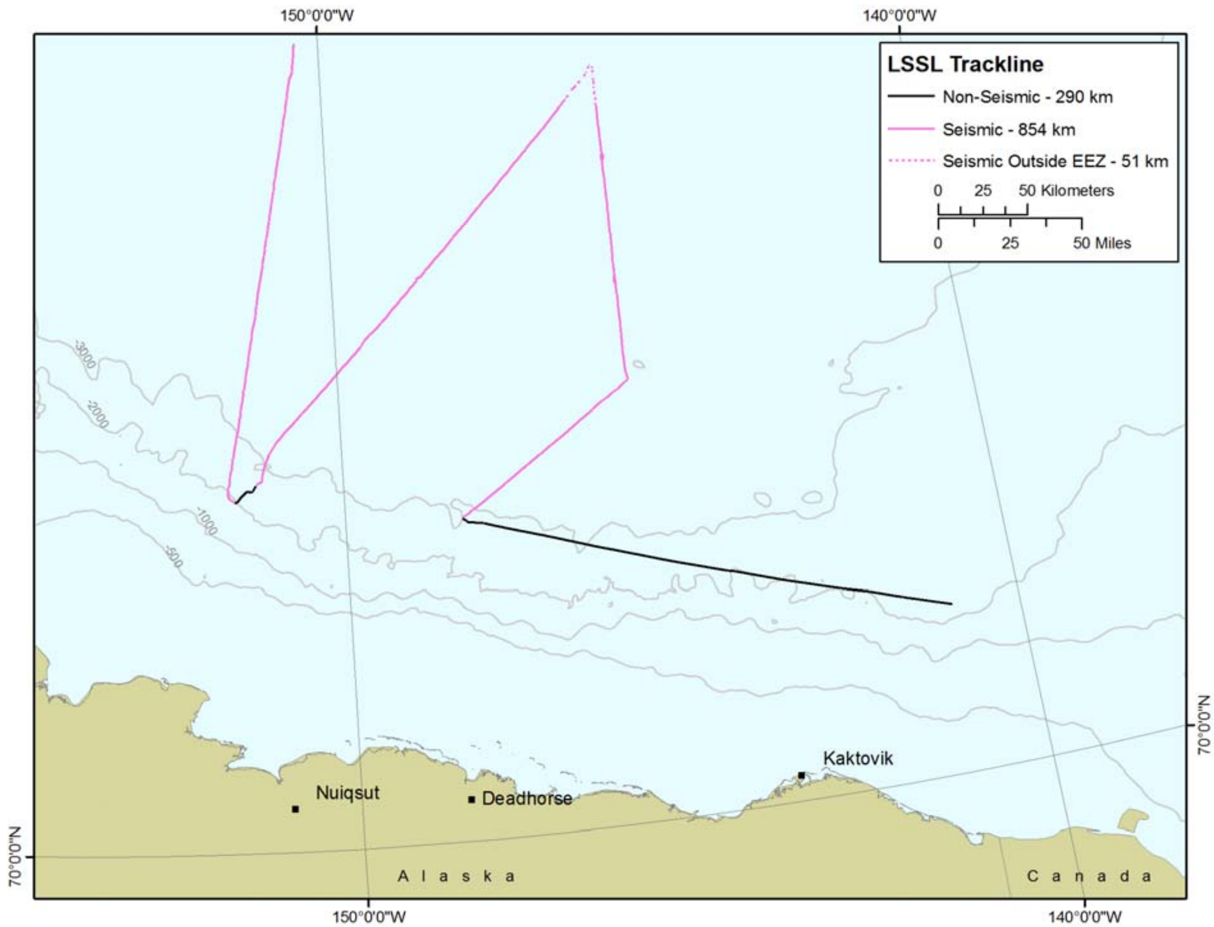

FIGURE 2.1. The *Louis S. St-Laurent's* trackline in the U.S. EEZ showing (in magenta) the parts of the track where seismic operations occurred.

The *Healy* departed Dutch Harbor on 2 Aug and arrived in the study area on 6 Aug. The *Healy* did not deploy an airgun array during the 2010 USGS geophysical program. Instead, it was used to collect bathymetric data and sediment and rock samples, as well as to break and clear ice for the *Louis S. St-Laurent* during seismic operations in ice-covered areas. The track of the *Healy* extended from northeast of Point Barrow, Alaska, to northwest of Prince Patrick Island, Northwest Territories, Canada (Fig 2.2). More specifically, operations occurred from approximately 70ºN to 83ºN, between 119º and 157ºW[2] (Fig. 2.2). The *Healy* conducted operations from ~06 Aug to 04 Sep at which time the *Healy* traveled to Barrow where the PSOs and science crew disembarked on 06 Sep. A chronology of the research cruise is presented in Table 2.1.

Throughout the survey, position, speed, and water depth were logged digitally every ~60 s from the *Louis S. St-Laurent* and *Healy*. In addition, the position of the *Louis S. St-Laurent*, water depth, and information on the airgun array were logged for every airgun shot while the *Louis S. St-Laurent* was on a seismic line and collecting geophysical data. The geophysics crew kept an electronic log of events, as did the protected species observers (PSOs) while on duty.

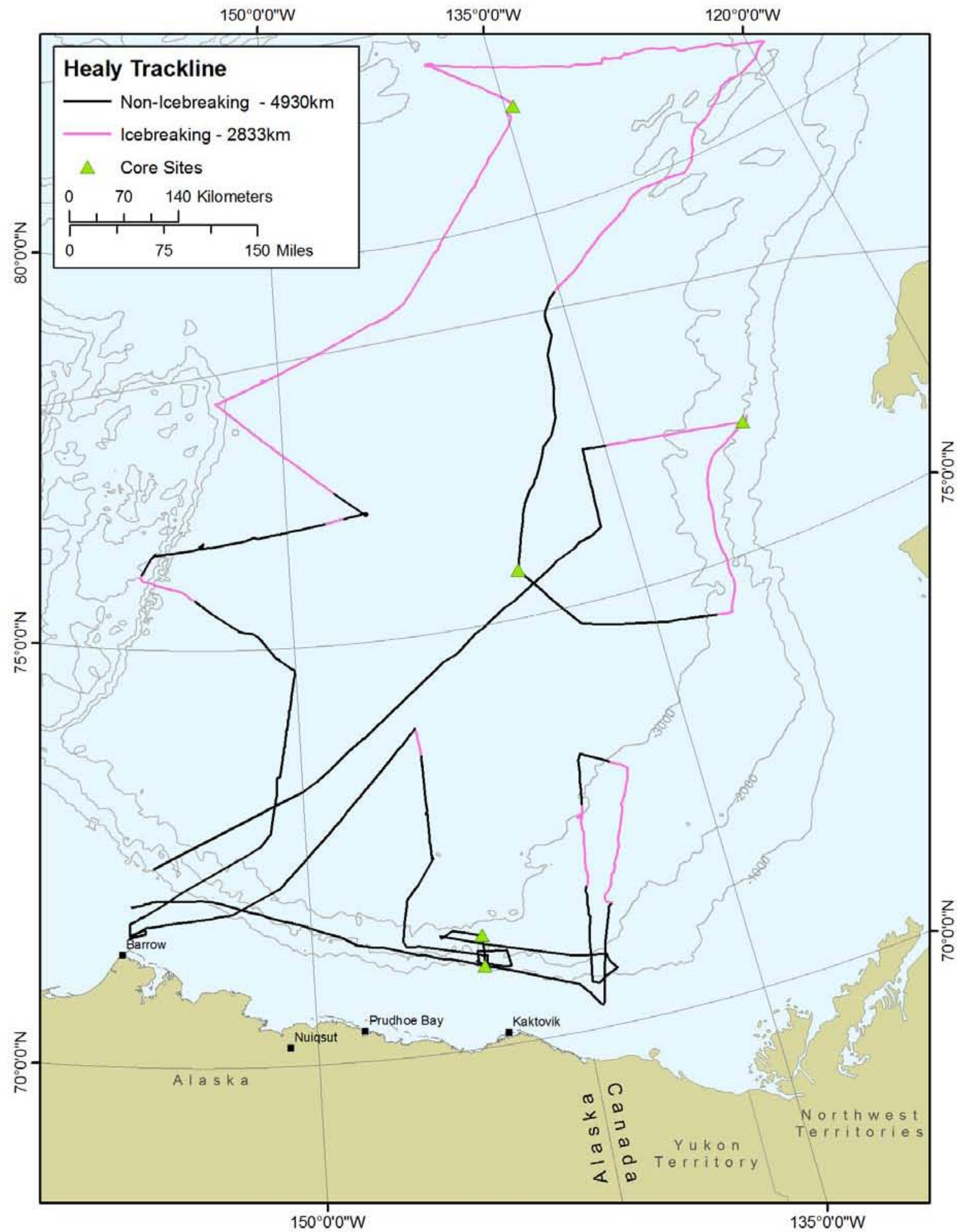

FIGURE 2.2. The *Healy's* trackline in the Arctic Ocean north of Point Barrow, Alaska, showing (in magenta) the parts of the track where icebreaking activity occurred. Coring locations are indicated by green triangles.

TABLE 2.1. Chronology of events during the Aug–Sep 2010 USGS geophysical survey. Times shown are in Mountain Standard Time (MST; UTC -07:00).

Date	Time	Vessel	Event Description
2-Aug	16:00	Healy	Healy departed Dutch Harbor
6-Aug	10:00	LSSL	LSSL underway Kugluktuk, Nunavut, Canada
7-Aug	17:23	Healy	Cross -141W; commence hydrographic survey of US-Canada disputed zone
10-Aug	17:30	Both	Rendezvous; transfer personnel; proceed in convoy toward US EEZ
10-Aug	22:54	Healy	Cross -141W; finish hydrographic survey of US-Canada disputed zone
11-Aug	6:30	Healy	Proceeds alone within US EEZ for sampling program
11-Aug	13:30	Healy	US Incidental Harassment Authorization received by email
11-Aug	15:00	LSSL	MSR received to conduct science ops in US EEZ
11-Aug	20:15	Healy	Coring station HLY1002-1P[a]
12-Aug	4:19	Healy	Coring station HLY1002-2P
12-Aug	16:07	LSSL	SOL 6 seismic in US EEZ
13-Aug	7:20	Healy	Healy joins LSSL for SOL 7
15-Aug	10:30	Healy	Healy departs LSSL in light ice to run to Barrow for crew and parts
17-Aug	11:30	Healy	Healy rejoins LSSL
17-Aug	22:50	LSSL	LSSL exits US EEZ
20-Aug	11:45	Both	Transiting to international waters to continue seismic operations
23-Aug	22:00	Healy	Conducting seamount survey
25-Aug	3:46	Healy	Coring station HLY1002-3P
27-Aug	20:30	Healy	Underway for bathymetric program
28-Aug	6:11	Healy	Healy enters CA EEZ for MB bathymetry
30-Aug	0:47	Healy	Healy leaves CA EEZ
31-Aug	5:54	Healy	Coring station HLY1002-4P
31-Aug	22:23	Healy	Healy enters CA EEZ for MB and sampling
2-Sep	11:36	Healy	Coring station HLY1002-5P
4-Sep	12:00	Healy	Healy breaks off joint program to head to Barrow
4-Sep	13:19	Healy	Healy departs CA EEZ
6-Sep	7:00	Healy	Arrive Barrow for disembarkation

[a]P = Piston core (2400 lb weightstand)

Airgun Description

The seismic source used for the 2010 USGS geophysical survey consisted of three Sercel G-guns with a total volume of 1150 in^3. The three-gun array was comprised of two 500 in^3 and one 150 in^3 G-guns in a triangular configuration (Appendix Fig. E.2). The 150-in^3 G-gun was used as a mitigation source during power downs when marine mammals were observed within or about to enter the applicable full array safety radius and during mechanical issues. The G-gun array was towed just behind the stern of the *Louis S. St-Laurent* at a depth of ~11.2 m (36.6 ft; Appendix Fig. E.3). One hydrophone streamer ~300 m (984 ft) in length was towed behind the airgun array. Air compressors aboard the *Louis S. St-Laurent* were the source of high pressure air used to operate the airgun array. Seismic pulses were emitted at various intervals depending on vessel speed (typically ~19.5 s) and recorded at a 2 ms sampling rate. The 19.5 s spacing corresponds to a shot interval of ~44 m (144 ft) at the typical survey speed of 4.0–4.5 kts. In general, the *Louis S. St-Laurent* towed this system along a predetermined survey track, although adjustments were occasionally made during repairs to the equipment. Characteristics of the airgun array are detailed in Appendix E.

Multibeam Bathymetric Sonar and Echosounders

Along with the airgun operations, additional acoustic systems operated during the cruise included a 12-kHz echo sounder from the *Louis S. St-Laurent* and a 12-kHz Kongsberg multibeam bathymetric echo sounder and a 3.5-kHz hydrographic sub-bottom profiler from the *Healy*. These sources operated throughout most of the cruise to map the bathymetry and sub-bottom conditions in order to meet the geophysical science objectives. During seismic operations, these sources typically operated simultaneously with the airguns. Depth-sounders are employed routinely by sea-going vessels to monitor water depths. The various sonars are described in further detail in Appendices F and G.

3. MONITORING, MITIGATION, AND DATA ANALYSIS METHODS

This chapter describes the marine mammal monitoring and mitigation measures implemented during the geophysical survey in the Arctic Ocean to address the requirements specified in the IHA (Appendix A). The section begins with a brief summary of the monitoring tasks relevant to mitigation for marine mammals. 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 2010 cruise from the *Louis S. St-Laurent* and *Healy*, and a description of data analysis methods.

Monitoring Tasks

The main purposes of the vessel-based monitoring program were to ensure that the provisions of the IHA issued to USGS by NMFS were satisfied, effects on marine mammals were minimized, and any observable effects on animals were documented. Tasks specific to monitoring are listed below (also see Appendix A):

- use of dedicated Protected Species Observers (PSOs) aboard the *Louis S. St-Laurent* (source vessel) and *Healy* throughout the geophysical survey;
- visually monitor the occurrence and behavior of marine mammals near the airgun array when the airguns were operating and during a sample of the times when they were not;
- use the visual sightings of marine mammals as the basis for implementing the required mitigation measures;
- record (insofar as possible) the effects of the airgun operations and the resulting sounds on marine mammals;
- estimate the number of marine mammals potentially exposed to airgun sounds at specified levels.

Safety and Potential Disturbance Radii

Under current NMFS guidelines (e.g., NMFS 2000), "safety radii" for marine mammals around airgun arrays are customarily defined as the distances within which received pulse levels are ≥180 dB re 1 µPa (rms) for cetaceans and ≥190 dB re 1 µPa (rms) for pinnipeds. These safety criteria are based on a cautionary assumption that seismic pulses at lower received levels will not harm these animals or impair their hearing abilities, but that 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.

Sound propagation from the three-airgun array was measured in 2009 during a seismic calibration experiment (Mosher et al. 2009, Roth and Schmidt 2010). A transmission loss model was then constructed assuming spherical (20LogR) spreading and using the source level estimate (235 dB re 1µPa 0-peak; 225 dB re 1 µPa rms) from the measurements. The use of 20LogR spreading fit the data well out to ~1 km (0.6 mi) where variability in measured values increased (see Appendix E for more details and a figure of the transmission loss model compared to the measurement data). Source level estimates from the array were also estimated by using the Gundalf® modeling package which produced an estimated source level output of 236.7 dB 0-peak (226.7 dB rms). Using this slightly stronger source level estimate and 20LogR spreading the 180 and 190 dB rms radii were estimated to be 216 m (708 ft) and 68 m (222 ft), respectively. As a conservative measure for the safety radii, the sound-level radii indicated by the empirical data and source models were more than doubled to 500 m (1641 ft) for the 180-dB isopleth and increased by ~1.5 times to 100 m (327 ft) for the 190-dB isopleth (Table 3.1). These larger, more cautionary distances were used by PSOs for implementing mitigation measures during the survey.

The rms (root mean square) received levels that are used as impact criteria for marine mammals are not directly comparable to the peak or peak-to-peak values normally used to characterize source levels of airguns. The measurement units used above to describe the airgun source, peak or peak-to-peak dB, are always higher than the rms dB referred to in much of the biological literature. A measured received level of 160 dB rms in the far field would typically correspond to a peak measurement of about 170 to 172 dB, and to a peak-to-peak measurement of about 176 to 178 decibels, *as measured for the same pulse received at the same location* (Greene 1997; McCauley et al. 1998, 2000a). The precise difference between rms and peak or peak-to-peak values for a given pulse depends on the frequency content and duration of the pulse, among other factors. However, the rms level is always lower than the peak or peak-to-peak level for an airgun-type source.

TABLE 3.1. Sound level radii for the three-airgun array and mitigation airgun for the 2010 USGS geophysical survey.

	Estimated Distances to Received Levels (m)		
Seismic Source Volume	**190 dB rms**	**180 dB rms**	**160 dB rms**
150 in^3 mitigation gun	30	75	750
1150 in^3 (three G-gun array)	100	500	2500

Mitigation Measures as Implemented

The primary mitigation measures that were implemented during the USGS geophysical survey 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 H. 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 USGS survey were modeled and measured, with precautionary estimates adopted, based on Gundolf® source modeling and measurements from a 2009 seismic calibration experiment (Mosher et al. 2009, Roth and Schmidt 2010), as noted above and described in Appendix E.
2. Power-down or shut-down procedures would have been implemented if 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.
4. A ramp-up procedure was implemented whenever operation of the airguns was initiated if >10 min had elapsed since a complete shut down of the full airgun array.
5. In order for seismic operations to start up, the entirety of the largest applicable safety radius to be monitored by PSOs on the vessel must have been visible for at least 30 min.

The specific procedures applied during power downs, shut downs and ramp ups are described in Appendix H. Briefly, a ***power down*** involves reducing the number of operating airguns from the full array to a single "mitigation" airgun, when a marine mammal is observed approaching or is first detected already within the full array safety radius. A ***shut down*** involves suspending operation of all airguns in the event of a marine mammal being sighted within or approaching the mitigation gun safety radius either after the full array had been powered down or upon initial observation. A ***ramp up*** involves a gradual increase in the number of airguns operating (from no airguns firing) usually accomplished by doubling the number of operating airguns in the array every 5 minutes. Ramp ups were used, but no power downs or shut downs were required.

Additional Mitigation Measures for the USGS Cruise as required by USFWS

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

1. The *Louis S. St-Laurent* and *Healy* observe a 0.5-mi. (800 m) exclusion zone around walruses and polar bears sighted in the water or on land or ice. Vessels must also reduce speed and steer around walruses and polar bears when able to do so.
2. All polar bear or walrus sightings be reported to USFWS within 24 h.
3. USGS develop a polar bear interaction plan specific to the project area that met USFWS' approval.

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 PSOs aboard the *Louis S. St-Laurent* and *Healy* 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 pinnipeds to >190 dB re µPa (rms). ***(2)*** Document numbers of marine mammals present, any reactions of marine mammals to seismic and icebreaking 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 4.

The visual monitoring methods that were implemented during this cruise were similar to those used during various previous seismic cruises conducted under IHAs since 2003. The standard visual observation methods are described in detail in Appendix H.

During the entire USGS geophysical survey, PSOs were stationed on both the *Louis S. St-Laurent* and the *Healy*. Three trained PSOs, knowledgeable about marine mammals of the Arctic, were recruited through a Canadian Hunters and Trappers committee to work on the *Louis S. St-Laurent*. These observers boarded the *Louis S. St-Laurent* in Kugluktuk, Nunavut, Canada. Three experienced PSOs and an Alaska Native observer were also aboard the *Healy* at the outset of the project. Before survey operations began in U.S. waters, two of the PSOs on the *Healy* transferred to the *Louis S. St-Laurent*. Thus, during operations in the U.S.

EEZ, a complement of five observes were on the source vessel, the *Louis S. St-Laurent*, and two were stationed on the *Healy*. When not surveying in U.S. waters, the distribution of PSOs returned to three on the *Louis S. St-Laurent* and four on the *Healy*. At least one PSO onboard the seismic source vessel (*Louis S. St-Laurent*) maintained a visual watch for marine mammals during all daylight hours while airguns were in use in U.S. waters. Visual observations on both the *Louis S. St-Laurent* and *Healy* were conducted exclusively from the bridge. Nighttime watches were never necessary because there was no darkness during the seismic survey in the U.S. EEZ. 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, and with 7 x 50 handheld binoculars. Appendix H provides further details regarding visual monitoring methods.

Data Analysis Methods

Categorization of Data

Observer effort and marine mammal sightings were divided into several analysis categories related to environmental conditions and vessel activity. The categories were similar to those used during various other recent seismic studies conducted under IHAs in this region (e.g., Funk et al. 2008, Ireland et al. 2007 a,b, Haley and Ireland 2006). Data were error checked using Visual Basic programming code and MapInfo GIS were used to perform calculations and append data categories described below.

Species Groups

Results are presented separately by species groups including cetaceans, pinnipeds (excluding walrus), walrus, and polar bear. Cetaceans and pinnipeds are treated separately due to expected differences in potential reactions to industry activities. Polar bear sightings are presented separately due to their management by the U.S. Fish and Wildlife Service. No Pacific walruses were observed during this project

Geographic Boundaries and Vessel Role

Data were categorized by the geographic region in which they were collected and by the vessel on which the observers were stationed. Sightings and effort data from the *Louis S. St-Laurent* were only included in this report when they were collected within the U.S. EEZ. In contrast, all sightings and effort data from the *Healy* when it was operating east or north of Pt. Barrow (71.4 °N, 156.5° W) were included in this report (Fig. 2.1 and Fig. 2.2).

Seismic Periods

Data were categorized as “seismic”, “non-seismic”, or “post-seismic” to allow comparison of sightings during these different operational states. Seismic data included those collected from the *Louis S. St-Laurent* while the full airgun array or single mitigation gun were operating within the U.S. EEZ. Data from the *Healy* were also considered “seismic” if it was within 2.5 km (1.5 mi) of the *Louis S. St-Laurent* while the full airgun array was firing or within 0.75 km (0.5 mi) while the mitigation gun was firing within the U.S. EEZ. “Post-seismic” periods were from 3 min to 1 h (pinnipeds and polar bears) or 3 min to 2 h (cetaceans) after cessation of seismic activity and were not used in comparisons or density calculations as noted above. The post seismic period for the *Healy* data was defined using the same time periods but only if the *Healy* was within 2.5 km (1.5 mi) of the active seismic array. The period from 0 to 3 minutes after airguns stopped was included in the seismic category because any marine mammals sighted within that time would have likely been present in very nearly the same location when seismic survey activity had been occurring given the relatively slow vessel speed during operations (~7.4 km/h, or 4 kt, average). The 1 and 2 h long post-seismic periods correspond to the time required for a source vessel to transit to an area in which the received sound level would not have been likely to have much (if any) effect on the distributions of marine mammals, or for animals to return to the area where operations had been occurring. "Non-seismic" data from the *Louis S. St-Laurent* included all data before the airguns were activated and after the respective post-seismic periods were complete. From the *Healy*, non-seismic data included the same periods described for the *Louis S. St-Laurent*, but only when it was within 75 km (47 mi) of the *Louis S. St-Laurent*. The distance of 75 km (47 mi) was chosen as the cutoff for this category because it was similar to the various ≥120 dB distances measured from large airgun arrays in the Chukchi and Beaufort seas (Jankowski et al. 2008, Reiser et al. 2008).

Icebreaking Periods

During periods when the *Healy* was outside U.S. waters or not within 75 km (47 mi) of the *Louis S. St-Laurent* in the U.S. EEZ, the data were categorized as "icebreaking" or "non-icebreaking" to allow comparison of sightings during these different operational states. Icebreaking data included those collected from the *Healy* while it was in ≥80% ice cover. Non-icebreaking data from the *Healy* included all data recorded while it was in <80% ice cover.

Sighting Rate Calculation and Comparisons

Sighting rates (sightings/1000 km of observer effort) are presented by vessel within the analysis categories of seismic activity (both vessels) and icebreaking activity (*Healy* only). Sightings rates during seismic and non-seismic periods for this cruise should be interpreted with caution due to the limited amount of observer effort within each category (<500 km; 311 mi). Sighting rates calculated within the analysis category of icebreaking activity had >1000 km (621 mi) of effort and are generally considered more reliable. Sighting rates of seals and polar bears during icebreaking and non-icebreaking periods included animals in the water and animals hauled out on ice. Where appropriate and sample sizes permitted, comparisons of sightings rates between categories were made using the G-test. The G-test is a likelihood ratio test, akin to the chi-square test commonly used in similar cases.

Sighting rates have the potential to be biased by a number of different factors. In order to present meaningful and comparable sighting rates, especially for purposes of considering the potential effects of seismic activity on the distribution and behavior of marine mammals, effort and sightings data were categorized by sighting conditions (e.g. environmental conditions), operational conditions, and other vessel proximity. The criteria were intended to exclude data from periods of observation effort when conditions would have made it unlikely to detect marine mammals that were at the surface. If those data were to be included in analyses, important metrics like sightings rates and densities would be biased downward.

Criteria for Sighting Rate Data

Different definitions were used for pinnipeds and cetaceans in order to account for assumed differences in their reactions to seismic survey and vessel activities. Therefore, effort and sightings occurring under the following conditions were excluded when calculating sighting rates and densities.

- periods 3 min to 1 h for pinnipeds and polar bears, or 2 h for cetaceans, after the airguns were turned off (post-seismic period);
- periods when ship speed was <3.7 km/h (2 kt);

- periods aboard a vessel when one or more vessels were operating within 5 km (3.1 mi) for cetaceans and 1 km (0.6 mi) for pinnipeds in the forward 180° of that vessel;
- periods with seriously impaired visibility including:
    - all nighttime observations;
    - visibility distance <3.5 km (2.2 mi);
    - Beaufort wind force (Bf) >5 (Bf >2 for Minke whales, belugas, and porpoises; See Appendix I for Beaufort wind force definitions).

This categorization system was designed primarily to distinguish potential differences in behavior and distribution of marine mammals during periods with airgun activity versus periods without airgun activity. 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).

Distribution and Behavior

Marine mammal behavior is difficult to observe because individuals and/or groups are often at the surface only briefly, and may avoid the vessel. 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). Limited behavioral data were collected during this project because marine mammals were often observed at distances too far from the vessel to determine behavior, and they were typically not tracked for long distances or durations while the vessel was underway.

Data collected during visual observations provided some information about behavioral responses of marine mammals to the seismic survey and icebreaking activity. However, due to the relatively few number of sightings during this project there was often insufficient data within the seismic and icebreaking categories to warrant statistical comparison between the different operational states of the following types data:

- bearings and distances of initial sightings to marine mammals from the PSO observation station and/or the nearest seismic sound source;
- estimated closest observed points of approach (CPA) of animals relative to either the airgun array (*Louis S. St-Laurent*) or the observer (*Healy*);
- observed behavior of animals at the time of the initial sighting;
- animal movements relative to vessel movements; and
- reaction of animals in response to the vessel or seismic sounds.

Closest Point of Approach

The closest point of approach (CPA) of each sighting to the observer position on the vessel was recorded. In addition, the CPA of each sighting to the airgun array was calculated in GIS for sightings from the *Louis S. St-Laurent*. The mean CPA to the observer or airgun array was calculated separately for sightings from each vessel and within vessel activity periods (i.e. seismic vs. non-seismic periods; icebreaking vs. non-icebreaking periods). Standard deviation and range of distances (m) to the observer were also calculated for seal sightings in water and hauled out on ice during icebreaking and non-icebreaking periods for the *Healy*. Meaningful comparisons of mean CPAs of animals during seismic and non-seismic periods were not able to be made due to the low sample sizes from both the *Louis S. St-Laurent* and *Healy* within the U.S. EEZ. Mean CPAs of seals in water during icebreaking periods were compared to those during non-icebreaking periods from the *Healy* using a Wilcoxon rank-sum test. Mean CPAs of seals in the water were also compared to the mean CPA distance for seals on ice from the *Healy* using a Wilcoxon rank-sum test.

Similar to sighting rate calculations, the calculation of mean CPA distances and subsequent comparisons during different seismic and icebreaking states could be biased by including data from observation periods of poor visibility or when animals may have been affected by something other than seismic sounds or sounds associated with icebreaking activity. Therefore, only sightings that met the criteria for inclusion in the sighting rate calculations were used in the calculation of mean CPA distances.

Initial Behavior

For each sighting an initial behavior was recorded. Animal behavior codes included: dive, thrash dive, look, rest, swim, flee, none, and unknown. The initial behaviors of animals (including animals in the water and hauled out on ice) during seismic periods were compared between the *Louis S. St-Laurent* and the *Healy*. There were no animals observed during non-seismic periods within the U.S. EEZ. The initial behaviors of animals in water and hauled out on ice were compared during icebreaking and non-icebreaking periods for the *Healy*.

Movement

Animal movements relative to the vessel were grouped into five categories: swim (move) away, swim (move) towards, neutral (e.g. parallel), none, or unknown. The observed movements of animals that fell into these categories (including animals in the water and hauled out on ice) were compared between the *Louis S. St-Laurent* and the *Healy* during seismic periods. There were no animals observed during non-seismic periods within the U.S. EEZ. The relative proportion of observed movement patterns of seals in the water that fell into these categories were compared during icebreaking and non-icebreaking periods for the *Healy*. The relative proportion of observed movement patterns of animals hauled out on ice was also presented for the *Healy*.

Reaction Behavior

Animal reactions in response to the vessel or the seismic source were recorded by PSOs aboard the *Louis S. St-Laurent* and the *Healy*. Reaction behavior codes recorded by PSOs included: flee, look, dive, “sink” dive, “swim towards”, and no reaction. The observed reaction behaviors of animals were presented for all sightings, however, due to the minimal amount of displayed reaction behavior by animals between vessel activity periods only limited comparisons were possible.

Estimation of Densities during Seismic Operations

There were too few sightings and too little observation effort during the limited survey operations within the U.S. EEZ to allow reliable calculations of densities from this survey alone. Therefore, we used densities reported or calculated from earlier marine mammal surveys in and near the Arctic Ocean to estimate “take by harassment”. These calculations are an estimate of the numbers of marine mammals that might have been present during the 2010 USGS seismic study in the Arctic Ocean. The densities used in this report are the same as those presented in the IHA application for this study (NMFS 2010b).

Both "maximum estimates" as well as "best estimates" of marine mammal densities were calculated. The best (or average) estimate is based on available distribution and abundance data and represents the number of animals that may have been encountered during the survey, assuming no avoidance of the airguns or vessel. The maximum estimate is either the highest estimate from applicable distribution and abundance data or the average estimate increase by a multiplier intended to produce a very conservative (over) estimate of the number of animals that may have been present in the survey area.

Because the very low sample sizes did not allow us to use the sighting data collected during the cruise to estimate densities of marine mammals near the seismic activity, the density estimates calculated from previous projects resulted in much higher estimates of "take" than would be expected from the low numbers of sightings recorded by the observers during this portion of the survey.

Estimating Numbers Potentially Affected by the Seismic Survey

NMFS practice in situations with intermittent impulsive sounds like seismic pulses has been to assume that "take by harassment" (Level B) may occur if marine mammals are exposed to received levels of sounds exceeding 160 dB re 1 μPa rms (NMFS 2005, 2006). The reaction threshold for most toothed whales is unknown but presumably higher because of their poorer hearing sensitivity at low frequencies (NMFS 2005; NMFS 2006; Richardson et al. 1995; Richardson and Würsig 1997). However, the limited empirical data for beluga whales indicate that they may be relatively responsive to airgun sounds as compared with other toothed whales (Miller et al. 2005). When calculating the number of mammals potentially affected, we used the ≥160 dB rms radius shown in Table 3.1.

Two methods were used to estimate the number of pinnipeds and cetaceans exposed to airgun sound levels that might have caused disturbance or other effects. The methods were:

(A) minimum estimates based on direct observations during seismic activities; and

(B) maximum estimates based on pinniped and cetacean densities reported or calculated from earlier marine mammal surveys in and near the Arctic Ocean multiplied by the area of water exposed to seismic sounds ≥160 dB by the seismic survey.

The actual number of individuals exposed to, and potentially affected by, seismic survey sounds was likely between these minimum and maximum estimates resulting from methods ***(A)*** and ***(B)***.

Method ***(B)*** above provided an estimate of the number of animals that would have been exposed to airgun sounds at various levels if the seismic activities did not influence the distribution of animals near the activities. However, it is known that some animals are likely to 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 160 dB rms radii around the seismic source (i.e., 2.5 km [1.6 mi]), the distribution and behavior of cetaceans may have been altered as a result of the seismic survey. The distribution and behavior of pinnipeds may have been altered within some lesser distance. These effects could occur because of reactions to the active airgun array, or to other sound sources or other vessels working in the area.

The aforementioned densities were used to estimate the number of animals potentially affected by seismic operations (method ***(B)***). This involved using two approaches to estimate the extent to which marine mammals may have been exposed to given sound levels ≥160, ≥180, and ≥190 dB rms:

1. Estimates of the number of different *individual* marine mammals exposed; and
2. Estimates of the average number of *exposures* each individual may have received.

For the *Louis S. St-Laurent*, we used the 160, 180, and 190 dB rms distances summarized in Table 3.1. The following description of the two different methods refers only to the ≥160 dB rms sound level, but the same method of calculation was used for ≥180 and ≥190 dB rms sound levels.

The first method ("individuals") involved multiplying the following three values:

- km of seismic survey;
- width of area assumed to be ensonified to ≥160 dB (2 × 160 dB radius), with areas ensonified on more than one occasion counted *only once*; and
- densities of marine mammals estimated from earlier marine mammal surveys in and near the Arctic Ocean.

The second approach ("exposures") represented the average number of times a given area of water within the seismic survey area was ensonified to the specified level. If an animal remained in approximately the same location through the duration of the survey activities it could have been exposed an equivalent number of times. The value was calculated as the ratio of the area of water ensonified *including* multiple counts of areas exposed more than once to the area of water ensonified *excluding* multiple counts of areas exposed more than once. The 2010 USGS seismic survey had a very limited amount of overlap of ensonified areas due to the relatively small sound source and long survey lines, which led to a relatively low estimate of the number of exposures per individual (i.e. close to 1).

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., Funk et al. 2008; Ireland et al. 2007a,b; Patterson et al. 2007).

Estimation of Densities during Icebreaking Operations

Sightings of seals in the water (i.e. not hauled out on ice) recorded from the *Healy* during this project were used to estimate densities in areas with ≥80 % ice cover and <80 % ice cover. However, these density estimates must be interpreted with caution because of the limited number of sightings from which they have been calculated and a potentially significant bias in the data. The bias was caused by the variable amount of open water along the icebreaker's track, and the fact that the ship tended to move through leads and polynyas of open water, often with ice at varying distances to either side. The heterogeneity of habitat (and its effect on the detectability of seals in the water) as a function of lateral distance from the trackline limits the application of standard line-transect methodology to the data. The variable presence of ice to either side of the trackline effectively truncated the in-water (and on-ice sightings) at variable and often unknown distances. The sighting distribution of swimming seals was effectively right-truncated by solid ice at variable lateral distances. The sighting distribution of hauled-out seals was effectively left-truncated by at variable distances by open water near the ship. Despite this potential bias in the data, we calculated detection functions and densities for seals in water during icebreaking (defined as periods of ≥80 % ice cover) and non-icebreaking periods (<80 % ice cover) using the software program DISTANCE. The distances recorded to sightings of seals on ice were non-standard and detection functions estimated in DISTANCE from those data showed very poor fit, so densities of seals on ice were not calculated.

Because the sightings data collected during the 2010 cruise were limited and could only be used with caution in estimating densities of marine mammals in the survey area, we also used the densities from earlier studies that were summarized in the IHA application for this study. Further details on the estimation of densities used during the survey are provided in Appendix H.

Estimating Numbers Potentially Affected by Icebreaking Activities

For purposes of the IHA, NMFS assumes that any marine mammal that might have been exposed to continuous icebreaking noise with received sound levels ≥120 dB re 1 μPa (rms) may have been appreciably disturbed and therefore "taken". We estimated the area potentially exposed to received levels ≥120 dB due to icebreaking operations by multiplying the distance traveled while breaking ice (conditions of 8/10 ice or greater) by the estimated cross-track distance to received levels of 120 dB caused by icebreaking. The 120 dB received sound level radius around the *Healy* while icebreaking was estimated using a spherical spreading model and a source level of 185 dB re 1 μPa-m. The model estimated that icebreaking sounds would diminish below 120 dB beyond 1750 m, resulting in a cross-track distance of 3500 m. To calculcate the number of marine mammals potentially exposed to received levels ≥120 dB re 1 μPa (rms) by icebreaking, we multiplied the estimated area ensonified to ≥120 dB, by the expected species density.

4. MARINE MAMMAL MONITORING RESULTS

Monitoring Effort and Marine Mammal Encounter Results

This chapter summarizes the visual monitoring effort and marine mammal sightings from the *Louis S. St-Laurent* and *Healy* during USGS's 2010 geophysical survey. The *Louis S. St-Laurent* entered U.S. waters on ~11 Aug and conducted seismic operations within the U.S. EEZ until it moved into international waters on 17 Aug. The *Healy* entered the Beaufort Sea on 6 Aug and conducted surveys, without the use of airguns, in the Arctic Ocean until it returned to Barrow on 6 Sep. In this report, only survey operations by the *Louis S. St-Laurent* in U.S. waters were included. In contrast, all *Healy* operations in U.S., Canadian and international waters were included. Additional information regarding the activities of the *Louis S. St-Laurent* and *Healy* can be found in Chapter 2. Descriptions of the vessels and survey equipment can be found in Appendices F and G.

Observation Effort

In 2010, the *Louis S. St-Laurent* traveled along a total of 1144 km (711 mi) of trackline in the U.S. EEZ. Airgun operations occurred along 854 km (531 mi) of that trackline. The full airgun array was ramping up or active along 839 km (521 mi) of trackline, and the single mitigation gun operated along 15 km (9 mi) of trackline due to mechanical issues with the full array. The airguns did not operate along the remaining 290 km (180 mi) of trackline in the U.S. EEZ. PSOs were on watch for a total of 1118 km (695 mi; 129 hr) in the U.S. EEZ. In the U.S. EEZ, PSOs on the *Louis S. St-Laurent* monitored for marine mammals during all periods of airgun operations (all in daylight). Darkness was not encountered during the seismic survey in the U.S. EEZ

Survey effort from the *Healy* was included in analyses of seismic activity within the U.S. EEZ when the *Healy* was within 75 km (47 mi) of the *Louis S. St-Laurent.* The *Healy* conducted operations within 75 km (47 mi) of the *Louis S. St-Laurent* in the U.S. EEZ along a total of 969 km (602 mi) of trackline, ~448 km (278 mi) of which PSOs aboard the *Healy* were on watch. While the *Healy* did not conduct any seismic operations in the U.S. EEZ, approximately 145 km (90 mi) of PSO effort from the *Healy* was considered exposed to seismic sounds due to the proximity of the *Healy* to the active seismic source towed by the *Louis S. St-Laurent*.

The *Healy* traveled an additional 7111 km (4819 mi) when it was outside U.S. waters or not within close proximity (75 km; 47 mi) of the *Louis S. St-Laurent* in the U.S. EEZ. During this period, survey effort from the *Healy* was broken down into icebreaking vs. non-ice breaking periods (≥80 percent ice cover vs. <80% ice cover). The *Healy* conducted icebreaking activities along 2833 km (1760 mi) of trackline, with the remaining 4278 km (2658 mi) of trackline considered non-icebreaking. PSO monitoring effort from the *Healy* totaled 2736 km (1700 mi) during icebreaking periods and 3129 km (1944 mi) during non-icebreaking periods.

Observer Effort by Beaufort Wind Force

Beaufort wind force (Bf) during observations from the *Louis S. St-Laurent* ranged from zero to seven within the U.S. EEZ. Approximately 67% of *Louis S. St-Laurent* effort within the U.S. EEZ occurred during conditions with Bf ≥ 4. Beaufort wind force during observations from the *Louis S. St-Laurent* within the U.S. EEZ were similar during seismic and non-seismic periods (Fig. 4.1). Observations from the *Healy* while it was inside the U.S. EEZ and within 75 km (47 mi) of the *Louis S. St-Laurent* occurred during Beaufort wind force ranging from zero to four. Approximately 92% of this effort occurred during conditions of Bf ≤3.

Observations from the *Healy* while it was outside U.S. waters or not within close proximity (75 km; 47 mi) of the *Louis S. St-Laurent* in the U.S. EEZ occurred during Beaufort wind force ranging from zero to five. Beaufort wind force during observations from the *Healy* tended to be much lower during icebreaking periods than non-icebreaking periods (Fig. 4.2). Approximately 94% of observations during icebreaking periods occurred in Beaufort wind force categories 0–1 compared to only 43% of observations during non-icebreaking periods.

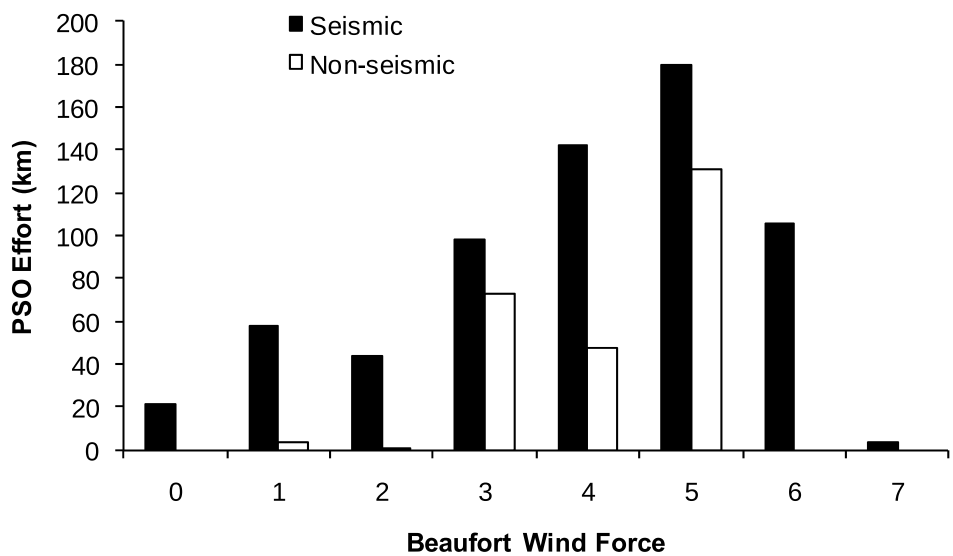

FIGURE 4.1. PSO effort (km) from the *Louis S. St-Laurent* by Beaufort wind force and seismic activity during the 2010 geophysical survey. Beaufort wind force was not recorded during ~211 km (131 mi) of observer effort.

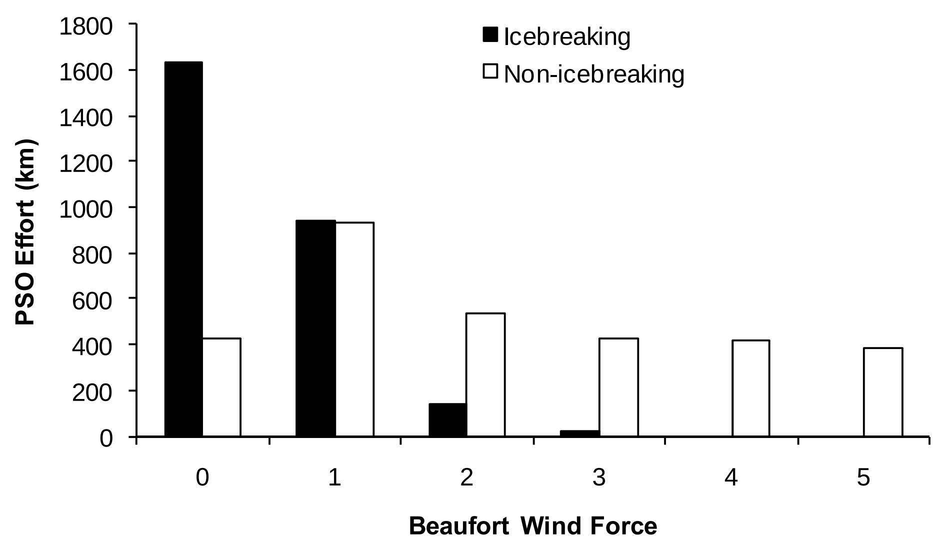

FIGURE 4.2. PSO effort (km) from the *Healy* by Beaufort wind force and icebreaking activity during the 2010 geophysical survey.

<u>*Observer Effort by Vessel Activity*</u>

During the geophysical survey in the U.S. EEZ observer effort from the *Louis S. St-Laurent* totaled 1118 km (695 mi; 129 hr). The majority of that effort occurred during seismic periods: 75% while the full array was active and 1% while the mitigation airgun was active (Fig. 4.3). Observer effort during non-seismic periods accounted for the remaining 24% of total effort: Inside the U.S. EEZ, observer effort from the *Healy* totaled ~448 km (278 mi) when it was within 75 km (47 mi) of the *Louis S. St-Laurent* (Fig. 4.3). The *Healy* did not conduct any seismic activity in the study area. However, ~145 km (90 mi) of observer effort were considered exposed to seismic survey activity due the proximity of the *Healy* to the active seismic source towed by the *Louis S. St-Laurent* (Fig. 4.3). The remaining 303 km (188 mi) of observer effort within the U.S. EEZ from the *Healy* were considered non-seismic.

When the *Healy* was outside U.S. waters or not within close proximity (75 km; 47 mi) of the *Louis S. St-Laurent* in the U.S. EEZ*,* observer effort occurred over an additional 5865 km (3644 mi). PSO monitoring effort from the *Healy* totaled 2736 km (1700 mi) during icebreaking periods (≥80% ice cover) and 3129 km (1944 mi) during non-icebreaking periods (<80% ice cover).

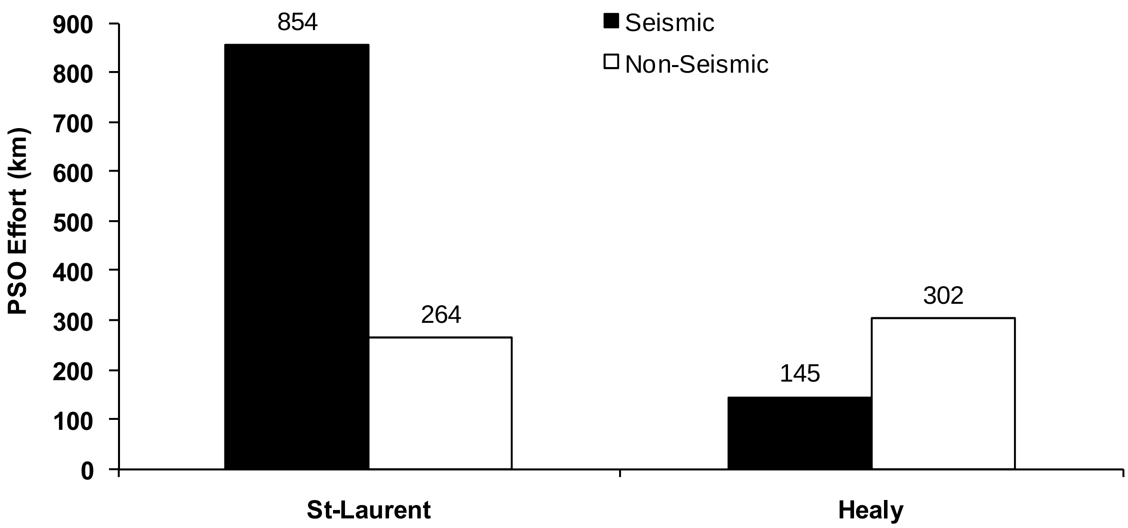

FIGURE 4.3. PSO effort (km) from the *Louis S. St-Laurent* and *Healy* by seismic activity during the 2010 geophysical survey inside the U.S. EEZ.

Marine Mammal Sightings

During seismic survey operations in the U.S. EEZ, eleven individual marine mammals in nine groups were observed by *Louis S. St-Laurent* and *Healy* PSOs. Eight of the sightings (nine individuals) were of ringed seals, and one sighting (two individuals) was of a polar bear.

PSOs aboard the *Healy* recorded an additional 81 marine mammal sightings of 89 individuals when it was outside U.S. waters or not within close proximity (75 km; 47 mi) of the *Louis S. St-Laurent* in the U.S. EEZ. Details of each marine mammal sighting observed from the *Louis S. St-Laurent* during survey operations in the U.S. EEZ, as well as details of each marine mammal sighted from the *Healy* during operations in U.S., Canadian and international waters are available in Appendix L. The sightings data below are presented separately for three species groups: cetaceans, seals, and polar bears. There were no sightings of Pacific walrus recorded during the survey activities.

Cetacean Sightings

Only one cetacean sighting of an individual gray whale was recorded from the *Healy* during survey activities in 2010. The gray whale was observed approximately 50 km (31 mi) from Pt. Barrow on 16 Aug while the *Healy* was transiting through open-water en route to Barrow to pick up equipment and personnel. The *Healy* was not in close proximity (>75 km; 47 mi) to the *Louis S. St-Laurent* at the time of the sighting.

No cetaceans were recorded by the *Louis S. St-Laurent* during the 2010 geophysical survey inside the U.S. EEZ.

Cetacean Sightings by Vessel Activity

No cetacean sightings were recorded from either the *Louis S. St-Laurent* or *Healy* during periods of seismic survey activity. The single cetacean sighting recorded from the *Healy* was made during a non-icebreaking period when the *Healy* was operating close to the coast picking up supplies and personnel from Barrow (Appendix Table K.5).

Cetacean Sighting Rates

Cetacean sighting rates were calculated using only the periods of effort that met the criteria for being able to reliably detect cetaceans (See Chapter 3 and Appendix K) and the sightings that occurred during those periods.

Meaningful comparisons of cetacean sighting rates during seismic and non-seismic periods could not be made because of the absence of cetacean sightings during periods of seismic survey activity. The limited number of cetacean sightings during icebreaking and non-icebreaking periods also precluded any meaningful comparisons of cetacean sightings rates during those periods.

Seal Sightings

PSOs observed six individual seals in six groups from the *Louis S. St-Laurent* during survey activities in the U.S. EEZ (Table 4.1). All seal sightings were of ringed seals.

There were 76 seals sighted in 70 groups from the *Healy* during the entire 2010 geophysical survey (Table 4.1). Of the 50 seal sightings that were identified to species, 42 were of ringed seals. The remaining eight were bearded seals. Most of the unidentified seals were likely ringed seals based on the visual monitoring results and the known abundance and distribution of ringed seals in the study area. The majority of seal sightings (56%) recorded from the *Healy* were on ice.

The reason for the large difference in number of seals sighted between vessels is because only data from the *Louis S. St-Laurent* are included when it was in the U.S. EEZ, whereas the data presented for the *Healy* included all observations in U.S., Canadian, and international waters.

Seal Sightings by Vessel Activity

All six seal sightings recorded from the *Louis S. St-Laurent* occurred while airguns were active. None of these seals, however, were observed within or approaching the ≥190 dB (rms) safety zone around the operating airguns so no power downs or shut downs of the airgun array were necessary. Of the 70 seal sightings recorded from the *Healy*, two seal sightings of three individual ringed seals were recorded when the *Healy* was in close proximity to the *Louis S. St-Laurent*. The three ringed seals were observed on ice while the airguns of the *Louis S. St-Laurent* were firing, but they were well outside of the applicable safety radius of the *Louis S. St-Laurent*, and thus no mitigation was required. Approximately 73% of the seal sightings (n = 51) recorded from the *Healy* occurred during icebreaking periods; the majority of which (61%) were on ice.

TABLE 4.1. Number of sightings (number of individuals) of seals from the *Louis S. St-Laurent* and *Healy* during the 2010 geophysical survey. Only sightings from the *Louis S. St-Laurent* that occurred within the U.S. EEZ are reported.

Species	*St-Laurent*	*Healy*	*Total*
Seals in Water			
Bearded Seal	0	1 (1)	***1 (1)***
Ringed Seal	6 (6)	21 (22)	***27 (28)***
Unidentified Seal	0	9 (9)	***9 (9)***
Seals on Ice			
Bearded Seal	0	7 (7)	***7 (7)***
Ringed Seal	0	21 (23)	***21 (23)***
Unidentified Seal	0	11 (14)	***11 (14)***
Total Seals	***6 (6)***	***70 (76)***	***76 (82)***

Seal Sighting Rates

Seal sighting rates were calculated using only the periods of effort that met the criteria for being able to reliably detect seals (See Chapter 3 and Appendix K) and the sightings that occurred during those periods.

The seal sighting rate from the *Louis S. St-Laurent* during seismic periods (3.9 sightings/1000 km; 6.3 sightings/1000 mi) was higher than the rate during non-seismic periods (0.0 sightings/1000 km; 0.0 sightings/1000 mi). The limited amount of effort that met the analysis criteria during both seismic and non seismic periods from the *Louis S. St-Laurent* makes the comparison of questionable value.

The seal sighting rate (including seals in the water and hauled out on ice) from the *Healy* during icebreaking periods (≥80% ice cover) was significantly higher than during non-icebreaking periods (G = 16.167, *df* = 1, *p* = <0.001; Fig. 4.4).

Polar Bear Sightings

Two polar bears (one sighting) were recorded from the *Louis S. St-Laurent* during the geophysical survey inside the U.S. EEZ. Both polar bears were sighted on ice during seismic operations. Neither of these polar bears, however, were observed within or approaching the *Louis S. St-Laurent's* ≥190 dB (rms) safety zone. Twelve polar bear sightings comprised of 14 individuals were recorded by PSOs on the *Healy* (Table 4.2). All of the polar bear sightings were seen on ice during periods when the *Healy* was outside the U.S. EEZ or not in close proximity to the *Louis S. St-Laurent* within the U.S. EEZ.

The polar bear sighting rates from the *Healy* were calculated using the same effort periods and associated sightings as those defined for pinnipeds. During icebreaking periods the polar bear sighting rate was 4.3 on ice sightings/1000 km (7.0 on ice sightings/1000 mi; *n* = 6) which was higher than the rate during non-icebreaking periods (2.9 on ice sightings/1000 km; 4.7 on ice sightings/1000 mi; *n* = 4). However, the difference between the sighting rates during icebreaking and non-icebreaking periods was not statistically significant (G = 0.394, *df* = 1, *p* = 0.540).

No Pacific walrus sightings were recorded by the *Louis S. St-Laurent* or *Healy* PSOs during the 2010 geophysical survey.

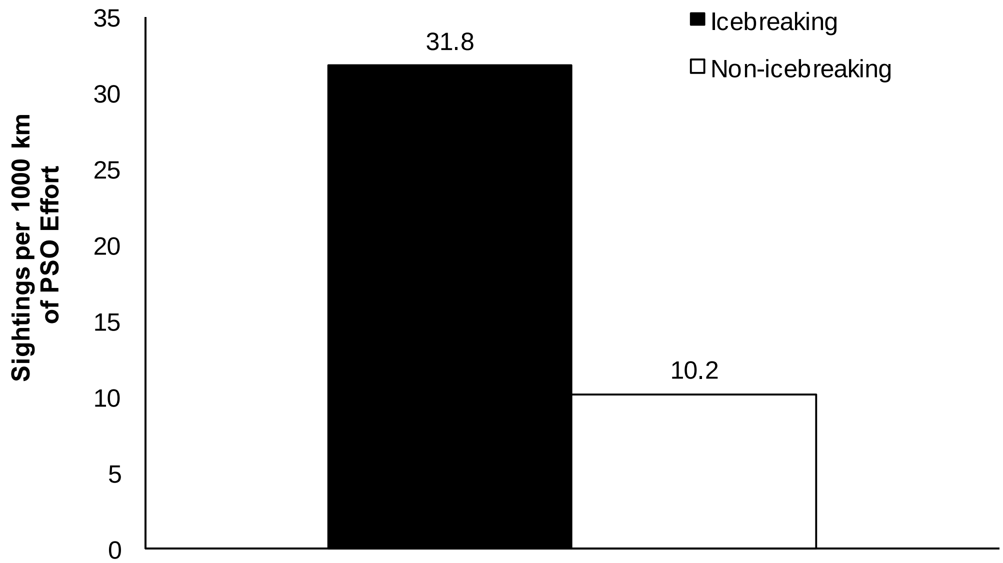

FIGURE 4.4. Seal sighting rates (animals in water and on ice) by icebreaking state from the *Healy* during the 2010 geophysical survey.

TABLE 4.2. Number of sightings (number of individuals) of polar bears from the *Louis S. St-Laurent* and *Healy* during the 2010 geophysical survey.

Species	***St-Laurent***	***Healy***	***Total***
Polar Bears			
In Water	0	0	***0***
On Ice/land	1 (2)	12 (14)	***13 (16)***
Total Polar Bears	***1 (2)***	***12 (14)***	***13 (16)***

Distribution and Behavior of Marine Mammals

Data collected during visual observations provided information about behavioral responses of marine mammals to the survey activities. The relevant data collected from the *Louis S. St-Laurent* and *Healy* included estimated closest observed points of approach (CPA) to the vessel, movement relative to the vessel, and behavior and reaction of animals at the time of the initial detections. CPA of marine mammals was calculated from the location of the position of the airguns (or, during non-seismic periods, where the airguns would have been positioned behind the vessel, if deployed).

Only limited behavioral data were collected during this project because individuals and/or groups of marine mammals were often at the surface only briefly. In addition, the *Louis S. St-Laurent* and *Healy* followed specific tracklines during the survey activities and were not able to follow animals for further observation. This resulted in difficulties resighting animals, and in determining whether two sightings some minutes apart were repeat sightings of the same individual(s).

Cetaceans

The single gray whale sighted during the 2010 USGS geophysical survey had a CPA to the *Healy* of 2500 m (8202 ft) and its initial behavior was "blow." The gray whale had an unknown movement and did not show a reaction to the *Healy*.

Seals

Seal Distribution and Closest Observed Point of Approach

The mean closest points of approach of seals were calculated using only the sightings that occurred during periods of effort that met the criteria for being able to reliably detect seals (See Chapter 3 and Appendix K). The single seal sighting inside the U.S. EEZ observed from the *Louis S. St-Laurent* that met the analysis criteria occurred during seismic activity and had a CPA to the airguns of 237 m (777 ft). Only one of the 59 seal sightings recorded from the *Healy* that met the analysis criteria occurred in close enough proximity to the *Louis S. St-Laurent* during seismic activity to be classified as a seismic sighting. That sighting was of two individual ringed seals on ice and had a CPA of 700 m (2298 ft). No seal sightings occurred during non-seismic periods within the U.S. EEZ from either the *Louis S. St-Laurent* or *Healy*. The low sample size from both the *Louis S. St-Laurent* and *Healy* during seismic and non-seismic periods within the U.S. EEZ precluded any meaningful analyses of seal CPA as a function of seismic state.

The mean CPA for seals in water was greater during icebreaking than non-icebreaking periods, but the difference was not significant (Wilcoxon test: W = 79.0, $p = 0.914$; Table 4.3). This result, however, should be interpreted with caution due to low sample size, particularly during non-icebreaking periods. The mean CPA for seals hauled out on ice was also greater during icebreaking than non-icebreaking periods; however, the low sample size during non-icebreaking periods precluded a statistical analysis (Table 4.3).

If the sightings during icebreaking and non-icebreaking are pooled, the mean CPA for seals in the water from the *Healy* was 656 m (2151 ft; $n = 26$), and the mean CPA distance for seals on ice was 1828 m (5997 ft; $n = 32$; Table 4.4). The mean CPA for seals on ice was significantly greater than the mean CPA for seals in water from the *Healy* (Wilcoxon test: W = 704.5, $p = <0.001$). This is likely due to the fact that seals are much easier to detect when hauled out on the ice, and can therefore be sighted at greater distances. However, due to the low sample sizes during non-icebreaking periods the difference between pooled samples should also be viewed with caution.

Seal Movement

The majority (67%; $n = 4$) of the seal sightings recorded during seismic activity in the U.S. EEZ from the *Louis S. St-Laurent* were observed swimming away from the vessel. The only other seal sighting that exhibited a movement relative to the *Louis S. St-Laurent* was observed swimming towards the vessel ($n = 1$).

The three individual seals on ice (two sightings) observed from the *Healy* during seismic activity in the U.S. EEZ did not move relative to the vessels. There were no seal sightings from either the *Louis S. St-Laurent* or *Healy* during non-seismic periods in the U.S. EEZ.

TABLE 4.3. Mean closest observed point of approach (CPA) to the observers on the *Healy* of seals in the water and on ice during icebreaking and non-icebreaking periods of the 2010 geophysical survey.

Vessel Activity and Seal Location	Mean CPA (m)[a]	s.d.	Range (m)	*n* Sightings
***Healy* Icebreaking**				
Seals in Water	744	1029	50-3000	17
Seals on Ice	2044	722	400-3000	27
***Healy* Non-icebreaking**				
Seals in Water	489	596	100-2000	9
Seals on Ice	660	270	300-1000	5

[a] CPA = *Closest Point of Approach*. For *Healy*: this value is the marine mammal's closest point of approach to PSO/vessel.

TABLE 4.4. Mean closest observed point of approach (CPA) to the observers on the *Healy* of seals in the water and on ice when sightings during icebreaking and non-icebreaking periods are pooled.

Species	Mean CPA (m)[a]	s.d.	Range (m)	*n* Sightings
Seals in Water	656	898	50-3000	26
Seals on Ice	1828	841	300-3000	32

[a] CPA = *Closest Point of Approach*. For *Healy*: this value is the marine mammal's closest point of approach to PSO/vessel.

Seals in the water were most often recorded swimming away from the *Healy* (32%, or $n = 10$). The second most frequently observed type of movement relative to the vessel was swimming towards (23%, or $n = 7$). Approximately 13% ($n = 4$) of seals demonstrated "neutral" movement relative to the vessel, i.e., they swam neither towards nor away from the vessel. "No" or unknown movement was recorded for the remaining 32% of seal sightings. Seal movement patterns relative to the *Healy* were similar during icebreaking and non-icebreaking periods with the exception of "unknown," which was recorded during icebreaking periods but not during non-icebreaking periods (Fig. 4.5).

Approximately 73% of the seals ($n = 27$) first observed on ice from the *Healy* displayed either no movement or their movement was neutral relative to the vessel. One seal sighting on ice was observed moving away from the *Healy*. Movement patterns could not be determined for the remaining 24% ($n = 9$) seals sighted on ice.

Seal Initial Behavior

The most frequently recorded seal behavior from the *Louis S. St-Laurent* during seismic periods in the U.S. EEZ was swimming ($n = 3$). Other seal initial behaviors observed from the *Louis S. St-Laurent* included, "dive," and "thrash" dive. One seal sighting recorded during seismic activity from the *Healy* was observed on ice "resting". The remaining seal sighting from the *Healy* during seismic activity was observed crawling off a snowy ledge onto the ice. Meaningful comparisons of seal behavior during seismic and non-seismic periods within the U.S. EEZ could not be made due to the low number of seal sightings during seismic and non-seismic periods.

The two most frequently observed initial behaviors by seals in water were "look" and "swim," which collectively accounted for ~77% of those recorded from the *Healy*. "Dive" was the next most common seal behavior. Other initial behaviors of seals observed less frequently included, "resting," "fleeing" and "thrash" dive. The most frequently recorded seal behaviors on ice were "resting" and "look". Seals first observed on the ice usually remained hauled out while the vessel passed. Seal behaviors were similar between icebreaking and non-icebreaking periods (Table 4.5).

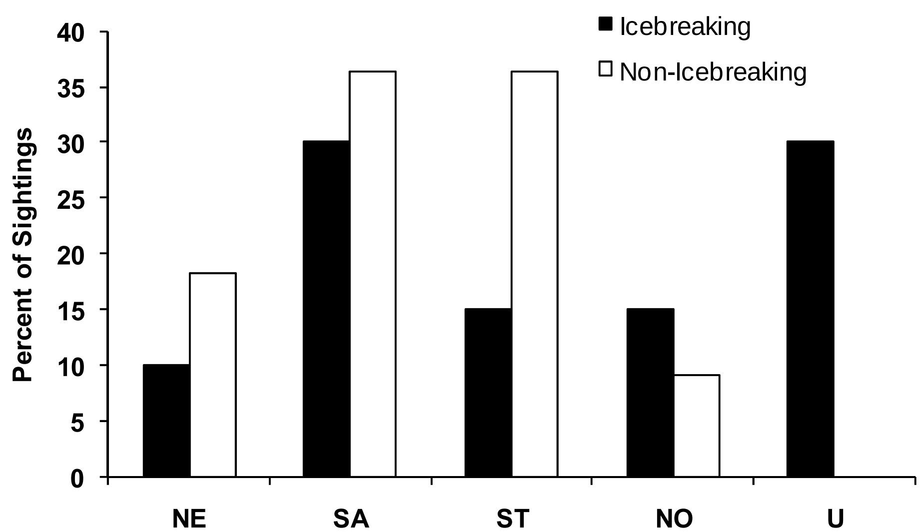

FIGURE 4.5. Movement relative to the vessel of seals observed in water during icebreaking and non-icebreaking periods from the *Healy*. Movement codes: NE = Neutral, SA = Swim Away, ST = Swim Towards, NO = No Movement, U = Unknown.

TABLE 4.5. Comparison of seal behaviors by icebreaking state from the *Healy* during the 2010 geophysical survey.

	Initial Behavior								
Vessel Activity and Seal Location	**Dive**	**Thrash**	**Look**	**Rest**	**Swim**	**Flee**	**None**	**Unknown**	**Totals**
***Healy* Icebreaking**									
Seals in Water	2	1	11	1	5	0	0	0	***20***
Seals on Ice	0	0	9	19	0	0	2	1	***31***
***Healy* Non-icebreaking**									
Seals in Water	2	0	3	0	5	1	0	0	***11***
Seals on Ice	1	0	4	1	0	0	0	0	***6***

<u>*Seal Reaction Behavior*</u>

Approximately 71% of seals in water observed from the *Healy* demonstrated no detectable reaction to the vessel. Looking at the vessel was the most commonly displayed reaction behavior to the *Healy* by seals in water ($n = 5$). Other observed reactions by seals in water to the *Healy* included "dive," "sink" dive, and "swim towards." All six seal sightings recorded during seismic activity in the U.S. EEZ from the *Louis S. St-Laurent* exhibited no reaction. The only observed reactions for seals on ice were "look" and "dive." Data regarding seal reaction behavior to the *Healy* suggested no obvious difference during icebreaking and non-icebreaking periods.

Polar Bears

<u>*Distribution and Closest Observed Point of Approach*</u>

The mean closest points of approach of polar bears were calculated using only the sightings that occurred during periods of effort that met the criteria for being able to reliably detect polar bears (See Chapter 3 and Appendix K).

All 10 polar bear sightings recorded from the *Healy* that met the data analysis criteria were on ice and occurred during periods when the *Healy* was not in close proximity of the *Louis S. St-Laurent*. Polar bear CPA to the *Healy* was greater during non-icebreaking periods (2750 m or 9021 ft; $n = 4$) than icebreaking periods (1937 m or 6357 ft; $n = 6$). No Pacific walruses were observed from either the *Louis S. St-Laurent* or *Healy* during the 2010 USGS geophysical survey.

<u>*Movement and Initial Behavior*</u>

Of the 12 sightings of polar bears on ice observed from the *Healy*, eight displayed either no movement or their movement was neutral relative to the vessel. Movement patterns could not be determined for three polar bear sightings, and two polar bears were walking away. The most frequently recorded polar bear behavior from the *Healy* was walking ($n = 8$). Other polar bear initial behaviors observed included, "fleeing," "look," and "unknown." There was no obvious difference in polar bear movement or initial behavior observed from the *Healy* between icebreaking and non-icebreaking periods. The two polar bears (one sighting) recorded during seismic activity in the U.S. EEZ from the *Louis S. St-Laurent* were observed running parallel to the vessel. The initial behavior of both polar bears was looking at the vessel.

<u>*Reaction Behavior*</u>

Nine polar bear sightings observed from the *Healy* demonstrated no detectable reaction to the vessel. The only observed reactions by a polar bear to the *Healy* were "flee" and "look." The only polar bear sighting recorded from the *Louis S. St-Laurent* demonstrated no detectable reaction to the vessel.

Mitigation Measures Implemented

No power downs or shut-downs of the airguns were necessary or requested from the *Louis S. St-Laurent* or *Healy* due to the detection of a marine mammal within the ≥180 and ≥190 dB safety radii. The eight seal sightings and single polar bear sighting during seismic activity within the U.S. EEZ were outside the ≥190 dB safety radius. All other sightings within the U.S. EEZ occurred either during periods when the airguns were not active, or when the *Healy* was not in close proximity (75 km; 47 mi) to the active seismic source towed by the *Louis S. St-Laurent*.

Estimated Number of Marine Mammals Present and Potentially Affected by Airguns

Meaningful estimates of "take by harassment" were difficult to obtain 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 presumed to vary among different species, individuals within species, and situations. ***(3)*** The distance to which a received sound level reaches a specific criterion such as 190 dB, 180 dB, 170 dB, or 160 dB re 1 μPa (rms) is variable. The received sound level depends on water depth, sound-source depth, water-mass and bottom conditions, and—for directional sources—aspect (Chapter 3; 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 near the surface (Greene and Richardson 1988; Tolstoy et al. 2004a,b) and even further reduced for animals that are on ice.

Two methods were used to estimate the number of marine mammals exposed to seismic sound levels strong enough that they might have caused a disturbance or other potential impacts. The procedures included ***(A)*** minimum estimates based on the direct observations of marine mammals by PSOs, and ***(B)*** maximum estimates based on seal and cetacean densities obtained during earlier marine mammal surveys in and near the Arctic Ocean. The actual number of individuals exposed to, and potentially impacted by, strong seismic survey sounds likely was between the minimum and maximum estimates provided in the following sections. Further details about the methods and limitations of these estimates are provided below in the respective sections.

Disturbance and Safety Criteria

Table 3.1 summarizes estimated received sound levels at various distances from the *Louis S. St-Laurent's* three-airgun array. The predicted 160-dB radii are assumed disturbance criteria, and were based on Gundolf® source modeling and measurements from a 2009 seismic calibration experiment (Mosher et al. 2009, Roth and Schmidt 2010). The 180 and 190 dB radii were considered when establishing safety radii, used in 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 re 1 μPa (rms), respectively. The safety and disturbance radii were used after the field season to estimate numbers of marine mammals exposed to various received sound levels.

Estimates from Direct Observations

All sightings data were included in the following exposure estimates based on direct observations regardless of whether they met the respective pinniped or cetacean data-analysis criteria described in Chapter 3. The number of marine mammals observed from the *Louis S. St-Laurent* and *Healy* during the geophysical survey in the U.S. EEZ provides a minimum estimate of the number potentially affected by seismic sounds. This was likely an underestimate of the actual number potentially present and potentially affected as described in detail in Chapter 3.

Cetaceans Potentially Exposed to Sounds ≥180 dB re 1 μPa (rms)

No cetaceans were observed from the *Louis S. St-Laurent* or *Healy* while the airguns were active during the geophysical survey in the U.S. EEZ. Therefore, based only on the direct observations of PSOs, zero cetaceans were exposed to received sound levels of ≥180 dB (rms). The fact that no bowhead whales or other cetacean species were observed during or near seismic operations is consistent with the findings of NMFS's ESA Section 7 consultation for listed species (Appendix C). It is unlikely, but possible, that PSOs failed to detect cetaceans within the *Louis S. St-Laurent's* ≥180 dB (rms) safety zone given the timing and location of the survey and relatively small size of the radii (500 m or 1641 ft).

Seals Potentially Exposed to Sounds ≥190 dB re 1 µPa (rms)

Six sightings of six individual seals were recorded from the *Louis S. St-Laurent* while its airguns were active. In addition, two sightings of three individual seals were recorded from the *Healy* when it was in close proximity (75 km; 47 mi) to the active seismic source towed by the *Louis S. St-Laurent*. All seals were sighted while the *Louis S. St-Laurent's* full airgun array was operating. None of these seals, however, were observed within or approaching the ≥190 dB (rms) safety zone around the operating airguns. Therefore, based only on direct observations by PSOs, zero seals were exposed to received sound levels ≥190 dB (rms).

Pacific Walruses Potentially Exposed to Sounds ≥180 dB re 1 µPa (rms)

There were no Pacific walrus sightings during the 2010 USGS geophysical survey.

Polar Bears Potentially Exposed to Sounds ≥190 dB re 1 µPa (rms)

Two polar bears (one sighting) were recorded from the *Louis S. St-Laurent* while airguns were active during the geophysical survey inside the U.S. EEZ. Both polar bears were sighted on ice while the full airgun array was operating. Neither of these polar bears, however, were observed within or approaching the *Louis S. St-Laurent's* ≥190 dB (rms) safety zone. Therefore, based only on direct observations by PSOs, zero polar bears were exposed to received sound levels ≥190 dB (rms).

Estimates Extrapolated from Density

The number of animals actually sighted by observers within the various sound threshold distances during seismic activity provided a minimum estimate of the number potentially affected by seismic sounds. Some animals probably moved away before coming within visual range of PSOs, and it was unlikely that PSOs were able to detect all of the marine mammals near the vessel. 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 (e.g. fog), glare, intervening ice, or other factors limiting sightability. Visibility and high sea conditions are often significant limiting factors.

Some animals may also have avoided the area near the *Louis S. St-Laurent* 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 dB (rms) radii around the source (i.e., 2.5 km; ~1.6 mi), 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. Changes in distribution and behavior could result from reactions to the airguns, or to the *Louis S. St-Laurent* and *Healy* themselves. The extent to which the distribution and behavior of pinnipeds might be affected by the airguns is uncertain, given variable previous results (Harris et al. 2001; Moulton and Lawson 2002; Miller et al. 2005, Reiser et al. 2009). It was not possible to determine if cetaceans or pinnipeds beyond the distance at which they were detectable by PSOs exhibited avoidance behavior.

The methodology used to estimate the areas exposed to received levels ≥160 dB, ≥170 dB, ≥180 dB and ≥190 dB was described briefly in Chapter 3, *Data Analyses,* and in greater depth in Appendix H. Densities were based on earlier marine mammal surveys in and near the Arctic Ocean by Stirling et al.

(1982), Kingsley (1986), Moore et al. (2000), Haley and Ireland (2006), Haley (2006), Jackson and DesRoches (2010) and Mosher et al. (2009), and the Bowhead Whale Aerial Survey Program (BWASP). The density data from past surveys are summarized in Table 4.6, and the ensonified areas from the 2010 USGS geophysical survey are presented in Table 4.7.

Both "maximum estimates" as well as "best estimates" of marine mammal densities were calculated. The best (or average) estimate is based on available distribution and abundance data and represents the most likely number of animals that may be encountered during the survey, assuming no avoidance of the airguns or vessel. The maximum estimate is either the highest estimate from applicable distribution and abundance data or the average estimate increased by a multiplier intended to produce a very conservative (over) estimate of the number of animals that may be present in the survey area.

The aforementioned densities of marine mammals multiplied by the area of water ensonified (exposed to seismic sounds) were used to estimate the number of *individual* marine mammals exposed to sound levels ≥160, 170, 180, and 190 dB (rms). The average number of *exposures* per individual marine mammal was calculated based on the overlap in ensonified areas around nearby seismic lines considering that an animal remaining in the area would have been exposed repeatedly to the passing seismic source.

The estimates provided here are based on the actual amount of seismic surveying during this project. In contrast, the estimates provided in the IHA application and EA for this project (USGS 2010a, Haley et al. 2010) were based on the then-anticipated amount of survey. The estimates in the IHA application and EA assumed that there would be slightly less seismic surveying within the U.S. EEZ than actually occurred (~806 km vs. 854 km; 501 mi vs. 531 mi). Thus, the present estimates derived from the published densities are higher than those in the EA and IHA applications, even though the take estimates are based on the same assumed density data. In addition, the following exposure estimates based on density assume that all mammals present were well below the surface where they were exposed to received sound levels at various distances summarized in Table 3.1. In fact, some pinnipeds were hauled out on the ice, and remained there as the ship passed, and some pinnipeds and cetaceans in the water might have remained close to the surface, where sound levels would be reduced by pressure-release effects (Greene and Richardson 1988). Finally, some pinnipeds and cetaceans may have moved away from the path of the *Louis S. St-Laurent* because of an avoidance response to the approaching vessel and its airguns. Therefore, the following estimates are likely to overstate actual numbers of marine mammals exposed to various received sound levels.

Cetaceans

Table 4.8 summarizes the estimated numbers of cetaceans that might have been exposed to received sounds at various levels based on the multiplication of the density data shown in Table 4.6, and the ensonified areas presented in Table 4.7.

(A) ≥160 dB (rms): Based on the density estimates from previous surveys and the area ensonified by this project we estimated that between 189 and 381 individual cetaceans may have been exposed to airgun pulses ≥160 dB re 1 µPa (rms) from the *Louis S. St-Laurent* during the survey if all cetaceans showed no avoidance of active airguns or vessels (Table 4.8). Based on the species likely to occur in the survey area and available densities, ~85% of these animals would have been belugas, and ~15% would have been bowhead whales. Estimates for other cetacean species would have been minimal.

TABLE 4.6. Estimated densities of marine mammals, in U.S. waters, offshore in the Beaufort Sea and Arctic Ocean. Only a minimal amount of area was near the ice margin, so open water densities were used exclusively. Densities are corrected for *f*(0) and *g*(0) biases.

Species	**Density - Open Water Average** (No. individuals /1000 km^2)	**Density - Open Water Maximum** (No. individuals /1000 km^2)
Cetaceans		
Beluga	35.4	70.9
Bowhead whale	6.1	12.2
Fin whale	0.0	0.1
Gray whale	0.0	0.1
Harbor porpoise	0.0	0.1
Humpback whale	0.0	0.1
Killer whale	0.0	0.1
Minke whale	0.0	0.1
Narwhal	0.0	0.1
Total Cetacean Density	***41.5***	***83.8***
Seals		
Bearded seal	9.6	38.4
Ringed seal	188.3	753.0
Spotted seal	0.1	0.4
Total Seal Density	***198.0***	***791.8***
Polar bears	***0.1***	***0.4***

TABLE 4.7. Estimated areas (km^2) ensonified to various sound levels during the 2010 USGS geophysical survey in U.S. waters in the Arctic Ocean, 11 - 17 August, 2010.

	Level of ensonification dB re 1 µPa (rms)			
Area (km^2)	**160**	**170**	**180**	**190**
Including Overlap Area	4632	1245	909	181
Excluding Overlap Area	4548	1236	907	181

(B) ≥180 dB (rms): If there were no avoidance of airgun noise by cetaceans, we estimated that there would have been between 38 and 76 individual cetaceans exposed approximately one time each to seismic sounds ≥180 dB (Table 4.8). However, cetaceans likely to occur in this region have shown significant avoidance of sound levels lower than 180 dB (rms) and therefore likely moved away before being exposed to received levels ≥180 dB. As noted earlier, no cetacean sightings were reported from the *Louis S. St-Laurent* during seismic operations in the U.S. EEZ.

Seals

Table 4.9 summarizes the estimated numbers of seals that might have been exposed to received sounds at various levels in the Arctic Ocean during 2010 seismic operations. As described above, the calculations of potential seal exposures to various received sound levels were based on density estimates from previous marine mammal surveys and the actual amount of seismic survey conducted in 2010 from the *Louis S. St-Laurent* (Table 4.6).

(A) ≥160 dB (rms): We estimated that between 901 and 3601 individual seals may have been exposed to airgun pulses at received levels ≥160 dB re 1 µPa (rms) during the geophysical survey if all animals exhibited no avoidance of the ≥160 dB zone (Table 4.9). Based on the species likely to occur in the survey area and available densities, ~95% of these animals would have been ringed seals, and ~5% would have been bearded seals. Estimates for spotted seals would have been minimal.

(B) ≥ 190 dB (rms): Based on the density estimates from previous surveys and the area ensonified, we estimated that between 36 and 143 individual seals may have been exposed to airgun pulses ≥190 dB re 1 µPa (rms) from the *Louis S. St-Laurent* during the survey if there was no avoidance of the airguns or vessels (Table 4.9). PSOs aboard the *Louis S. St-Laurent* did not record any seals within the ≥190 dB zone and it is likely that few if any were actually exposed to that received level of sound.

Pacific Walruses

There were no Pacific walrus sightings from either the *Louis S. St-Laurent* or *Healy* during the 2010 USGS geophysical survey, and based on sightings and density estimates from previous surveys in the region, Pacific walrus were unlikely to have been present in the vicinity of the 2010 survey activities.

TABLE 4.8. Estimated numbers of individual cetaceans potentially exposed to received sound levels ≥160, 170, 180, and 190 dB (rms) and average number of exposures per individual during the USGS geophysical survey in U.S. waters in the Arctic Ocean, 11- 17 August, 2010. Estimates are based on densities calculated from previous surveys in the region and the actual amount of seismic activity conducted in 2010.

	Based on Average Open-Water Density		**Based on Maximum Open-Water Density**	
Exposure level in dB re 1µPa (rms)	**Individuals**	**Exposures per Individual**	**Individuals**	**Exposures per Individual**
Cetaceans				
≥160	189	1	381	1
≥170	51	1	104	1
≥180	38	1	76	1
≥190	8	1	15	1

TABLE 4.9. Estimated numbers of individual seals exposed to received sound levels ≥160, 170, 180, and 190 dB (rms) and average number of exposures per individual during the USGS geophysical survey in U.S. waters in the Arctic Ocean, 11- 17 August, 2010. Estimates are based on densities calculated from previous surveys in the region and the actual amount of seismic activity conducted in 2010.

	Based on Average Open-Water Density		Based on Maximum Open-Water Density	
Exposure level in dB re 1µPa (rms)	**Individuals**	**Exposures per Individual**	**Individuals**	**Exposures per Individual**
Seals				
≥160	901	1	3601	1
≥170	245	1	979	1
≥180	180	1	718	1
≥190	36	1	143	1

Polar Bears

The estimated number of polar bears that might have been exposed to various levels of received sounds are summarized in Table 4.10. The density data used to calculate these numbers are presented in Table 4.6.

(A) ≥ 160 dB (rms): We estimated between one and two individual polar bears would have been exposed to airgun pulses ≥160 dB re 1 µPa (rms) from the *Louis S St. Laurent* during the survey if there was no avoidance of the ≥160 dB zone (Table 4.10). This estimate also assume that the polar bears would have been in the water and well below the surface where pressure release effects would not have diminished the seismic sounds below 160 dB (rms).

(*B) ≥ 170, ≥ 180, ≥ 190 dB (rms*): Based on the density estimates from previous surveys (Table 4.10), less than one polar bear would have been exposed to sound levels ≥170 dB re 1 µPa (rms), assuming no avoidance behavior.

TABLE 4.10. Estimated number of individual polar bears exposed to received sound levels ≥160, 170, 180, and 190 dB (rms) and average number of exposures per individual during the 2010 USGS geophysical survey in U.S. waters in the Arctic Ocean, 11- 17 August, 2010. Estimates are based on densities calculated from previous surveys in the region and the actual amount of seismic activity conducted in 2010.

	Based on Average Open-Water Density		Based on Maximum Open-Water Density	
Exposure level in dB re 1µPa (rms)	**Individuals**	**Exposures per Individual**	**Individuals**	**Exposures per Individual**
Polar Bears				
≥160	<1	1	2	1
≥170	<1	1	<1	1
≥180	<1	1	<1	1
≥190	<1	1	<1	1

Estimated Number of Marine Mammals Potentially Affected by Icebreaking

Sounds generated by icebreaking activity are considered by NMFS to be a continuous sound and NMFS (2005) indicates the existing threshold for Level B harassment by continuous sounds is a received sound level of 120 dB SPL. While breaking ice, the noise from the *Healy*, including impact with ice, engine noise, and propeller cavitation, was above the "baseline" levels generated by the vessel in open water and exceeded 120 dB. Therefore, potential takes of marine mammals could have resulted from the icebreaking activity the *Healy* conducted during the 2010 USGS geophysical survey. This section presents take estimates based exclusively on the icebreaking survey component of the project, and the number of takes provided below are in addition to the number of estimated takes due to seismic activity in the U.S. EEZ.

It is important to note that non-icebreaking vessels, as well as natural sounds such as those arising from sea ice motion and whale flukes hitting the ocean surface, also present similar sound impacts. Underwater noise from various vessels, including tug boats, oceanographic research vessels, and fisheries research vessels in open water, as well as icebreakers traversing sea ice, often exceed 120 dB, the existing threshold for Level B harassment set by NMFS (2005).

Estimates from Direct Observations

All sightings data were included in the following exposure estimate based on direct observations regardless of whether they met the respective pinniped or cetacean data-analysis criteria described in Chapter 3. The number of marine mammals observed from the *Healy* during icebreaking periods provides a minimum estimate of the number potentially affected by sounds generated by icebreaking activities. This was likely an underestimate of the actual number potentially present and potentially affected.

Marine Mammals Potentially Exposed to Sounds ≥120 dB re 1 μPa (rms)

There were 58 sightings of 63 individual marine mammals observed by *Healy* PSOs while the *Healy* was conducting icebreaking operations during the 2010 geophysical survey. Of the 58 marine mammal sightings that occurred during icebreaking activities, 33 sightings (34 individuals) were observed within the ≥120 dB zone of the *Healy*. Approximately 88% of these sightings were of seals (n = 29), and the remaining 12% were of polar bears (n = 4).

Estimates Extrapolated from Density

The numbers of marine mammals potentially disturbed by icebreaking operations are estimated below based on available data about marine mammal distribution and densities in the Arctic Ocean. These estimates were then compared to the densities estimated from the limited number of sightings observed from the *Healy* during icebreaking periods of the 2010 USGS geophysical survey.

The aforementioned densities of marine mammals multiplied by the area of water ensonified (exposed to icebreaking sounds) were used to estimate the number of *individual* marine mammals exposed to sound levels ≥120 dB (rms). The density data from past marine mammal surveys are summarized in Table 4.11, and the density data from the 2010 USGS geophysical survey, including corrections for sightability biases, are summarized in Table 4.12. The area ensonified to ≥120 dB from icebreaking activity totaled ~9916 km^2 (3829 mi^2). The methodology used to estimate the areas exposed to received levels ≥120dB (rms) was described in Chapter 3, *Data Analysis*, and in more detail in Appendix H..

The estimates provided here are based on the actual amount of icebreaking activity during this project. In contrast, the estimates provided in the IHA application and EA for this project (USGS 2010b, Haley et al. 2010) were based on the then-anticipated amount of icebreaking activity. The estimates in the IHA application and EA assumed that there would be more icebreaking activity than actually occurred. Thus, the present estimates derived from the published densities are lower than those in the EA and IHA applications, even though the take estimates are based on the same density estimates.

TABLE 4.11. Estimated summer densities of marine mammals, in polar pack ice habitat in the Arctic Ocean. Densities are corrected for *f*(0) and *g*(0) biases.

Species	**Density - Polar Pack Average** (No. individuals /1000 km^2)	**Density - Polar Pack Maximum** (No. individuals /1000 km^2)
Cetaceans		
Beluga	3.5	7.1
Bowhead whale	0.6	1.2
Fin whale	0.0	0.1
Gray whale	0.0	0.1
Harbor porpoise	0.0	0.1
Humpback whale	0.0	0.1
Killer whale	0.0	0.1
Minke whale	0.0	0.1
Narwhal	0.0	0.1
Total Cetacean Density	***4.1***	***9.0***
Seals		
Bearded seal	1.3	5.1
Ringed seal	25.1	100.4
Spotted seal	0.0	0.0
Total Seal Density	***26.4***	***105.5***
Polar bears	***0.0***	***0.2***

TABLE 4.12. Estimated densities of seals in water by icebreaking state from the *Healy* during the 2010 USGS geophysical survey in the Arctic Ocean. Densities are corrected for *f*(0) and *g*(0) biases.

Species	**Icebreaking Density (No. individuals /1000 km2)**	**Non-Icebreaking Density (No. individuals /1000 km2)**
Seals in water	26.2	9.7

Marine Mammals Potentially Exposed to Sounds ≥120 dB re 1 µPa (rms)

Based on available data on marine mammal densities in the Arctic Ocean and the area ensonified, we estimated that between ~303 and ~1137 individual marine mammals may have been exposed to icebreaking sounds ≥120 dB re 1 µPa (rms) during the survey if all marine mammals showed no avoidance of the vessel (Table 4.13). Based on the species likely to occur in the survey area and average (best) available densities, ~82% of these animals would have been ringed seals, ~12% would have been belugas, ~4% would have been bearded seals, ~2% would have been bowhead whales, and less than 1% would have been polar bears. Estimates for other marine mammal species would have been negligible.

The only density estimate that could be calculated from observations made during icebreaking periods of the 2010 survey was for seals in water. The density estimate for seals in water was extremely close to the average (best) estimate based on available distribution and abundance data (26.2 vs. 26.4 individuals/1000 km^2). Using the density estimate calculated from the 2010 observations of seals in water during icebreaking periods and the area ensonified, we estimated that ~260 individual seals may have been exposed to sound levels ≥120 dB if all animals exhibited no avoidance of the ≥120 dB zone. Estimated density for seals in water during icebreaking activity was nearly three times higher than during non-icebreaking activity (26.2 vs. 9.7 individuals/1000 km^2), however, this result should be interpreted with caution due to low sample sizes, particularly during non-icebreaking periods (n = 8; Table 4.12)

TABLE 4.13. Estimated number of individual marine mammals exposed to received sound levels ≥120 dB (rms) while breaking ice outside U.S. waters during the 2010 USGS geophysical survey in the Arctic Ocean. Estimates are based on densities calculated from previous surveys in the region and the actual amount of icebreaking activity conducted in 2010.

	Number of Exposures to Sound Levels ≥120 dB re 1 µPa (rms)	
Species Group	**Based on Average Polar Pack Density**	**Based on Maximum Polar Pack Density**
Cetaceans	41	89
Seals	262	1046
Polar Bears	<1	2
Total	***303***	***1137***

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APPENDICES TO:

MARINE MAMMAL MONITORING AND MITIGATION DURING A MARINE GEOPHYSICAL SURVEY IN THE ARCTIC OCEAN, AUGUST–SEPTEMBER 2010: 90-DAY REPORT

by

Joseph Beland and Darren Ireland

LGL Alaska Research Associates, Inc.
1101 East 76th Ave., Suite B, Anchorage, AK 99518, U.S.A.

for

U.S. Geological Survey
345 Middlefield Rd.
Menlo Park, CA 94025

and

National Marine Fisheries Service
Office of Protected Resources
1315 East-West Hwy, Silver Spring, MD 20910-3282

and

U.S. Fish and Wildlife Service, Marine Mammals Management Office
1101 E. Tudor Rd., Anchorage, AK 99503-6199

LGL Report P1123-1

December 2010

APPENDIX A: NATIONAL MARINE FISHERIES SERVICE IHA

APPENDIX B: DETERMINATION OF THE NEED FOR AN ESA CONSULTATION

APPENDIX C: ESA SECTION 7 CONSULTATION/LETTER OF CONCURRENCE

APPENDIX D: POLAR BEAR INTERACTION PLAN

APPENDIX E: DEVELOPMENT AND IMPLEMENTATION OF SAFETY RADII

APPENDIX F: DESCRIPTION OF THE *LOUIS S. ST-LAURENT* AND ITS EQUIPMENT

APPENDIX G: DESCRIPTION OF THE *HEALY* AND ITS EQUIPMENT

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

APPENDIX I: BEAUFORT WIND FORCE DEFINITIONS

APPENDIX J: BACKGROUND ON MARINE MAMMALS IN THE PROJECT REGION

APPENDIX K: MONITORING EFFORT AND MARINE MAMMAL MONITORING RESULTS

APPENDIX L: LIST OF ALL MARINE MAMMAL DETECTIONS

APPENDIX A: *NATIONAL MARINE FISHERIES SERVICE IHA*

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Silver Spring, MD 20910

AUG 11 2010

Jonathan R. Childs
Geophysicist
U.S. Geological Survey
Pacific Coastal and Marine Science Center
Mail Stop 999
345 Middlefield Rd.
Menlo Park, California 94025

Dear Dr. Childs:

Enclosed is an Incidental Harassment Authorization (IHA) issued to the U. S. Geological Survey, under the authority of Section 101(a)(5)(D) of the Marine Mammal Protection Act (16 U.S.C. 1361 *et seq.*), to harass small numbers of marine mammals, by Level B harassment, incidental to the marine seismic survey conducted from the Canadian Coast Guard vessel CCGS *Louis S. St. Laurent*, which will be accompanied by the U.S. Coast Guard Cutter *Healy*, in the Arctic Ocean during August to September, 2010.

You are required to comply with the conditions contained in the IHA. In addition, you must cooperate with any Federal, state, or local agency monitoring the impacts of your activity and submit a report to the National Marine Fisheries Service's (NMFS) Office of Protected Resources within 90 days of the completion of the cruise. The IHA requires monitoring of marine mammals by qualified individuals before, during, and after seismic activities and reporting of marine mammal observations, including species, numbers, and behavioral modifications potentially resulting from this activity.

If you have any questions concerning the IHA or its requirements, please contact Howard Goldstein or Jolie Harrison, Office of Protected Resources, NMFS, at 301-713-2289.

Sincerely,

James H. Lecky
Director
Office of Protected Resources

Enclosures

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Silver Spring, MD 20910

DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NATIONAL MARINE FISHERIES SERVICE

Incidental Harassment Authorization

U.S. Geological Survey (USGS), Pacific Coastal and Marine Science Center, Mail Stop 999, 345 Middlefield Road, Menlo Park, California 94025, is hereby authorized under section 101(a)(5)(D) of the Marine Mammal Protection Act (MMPA) (16 U.S.C. 1371(a)(5)(D)) and 50 CFR 216.107, to harass small numbers of marine mammals incidental to a marine geophysical survey conducted from the Canadian Coast Guard vessel CCGS *Louis S. St. Laurent* (*St. Laurent*), and accompanied by the U.S. Coast Guard Cutter *Healy* (*Healy*), in portions of the Arctic Ocean, August to September, 2010:

1. This Authorization is valid from August 11 through October 21, 2010.

2. This Authorization is valid only for the *St. Laurent* and *Healy*'s activities associated with seismic survey operations that will occur in the area bounded approximately by 145° to 158° West longitude and 71° to 84° North latitude within the Exclusive Economic Zones (EEZ) of the United States and international waters, as specified in USGS's Incidental Harassment Authorization application and Environmental Assessment. The Geological Survey of Canada (GSC) has written a Categorical Declaration stating that "while in U.S. waters, the GSC operators will comply with any and all environmental mitigation measures required by the U.S. National Marine Fisheries Service and/or the U.S. Fish and Wildlife Service."

3. Species Authorized and Level of Takes

(a) The incidental taking of marine mammals, by Level B harassment only, is limited to the following species in the waters of the Arctic Ocean:

(i) Mysticetes – see Table 3 (attached) for authorized species and take numbers.

(ii) Odontocetes – see Table 3 (attached) for authorized species and take numbers.

(iii) Pinnipeds – see Table 3 (attached) for authorized species and take numbers.

(iv) If any marine mammal species are encountered during seismic activities that are not listed in Table 3 (attached) for authorizing taking and are likely to be exposed to sound pressure levels (SPLs) greater than or equal to 160 dB re 1 µPa (rms) for seismic airgun operations or greater than or equal to 120 dB re 1 μPa (rms) for icebreaking activities, then the Holder of this Author zation must alter speed or course, power-down, or shut-down the airguns to avoid take.

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

4. The taking of any marine mammal in a manner prohibited under this Authorization must be reported immediately to the Alaska Regional Administrator at 907-586-7221 or designee in Anchorage 907-271-3023, and the Office of Protected Resources, National Marine Fisheries Service (NMFS), at 301-713-2289.

5. The Authorization for taking by Level B harassment is limited to the following acoustic sources without an amendment to this Authorization:

(i) a three Sercel G-airgun array (two 500 in^3 and one 150 in^3 airguns) with a total capacity of 1,150 in^3 (or smaller);
(ii) chirp echosounder (i.e., Knudsen 320BR);
(iii) multi-beam echosounder (i.e., Kongsberg EM122);
(iv) sub-bottom profilers (i.e., Towed 3-5 kHz, Knudsen 320BR));
(iv) a piloting echosounder (i.e., ODEC Bathy-1500);
(v) two acoustic Doppler current profilers (i.e., RD Instruments Ocean Surveyor 75 and 150 Hz); and
(vi) icebreaking

6. The Holder of this Authorization is required to cooperate with NMFS and any other Federal, state or local agency monitoring the impacts of the activity on marine mammals.

7. Mitigation and Monitoring Requirements

The Holder of this Authorization is required to implement the following mitigation and monitoring requirements when conducting the specified activities to achieve the least practicable adverse impact on affected marine mammal species or stocks:

(a) During operations in U.S. EEZ waters, a complement of five Protected Species Observers (PSOs) will work on the source vessel, the *St. Laurent*, and two will be stationed on the *Healy*. Three PSOs will board the *St. Laurent* in Canada. Three PSOs and one Alaska Native community observer will be aboard the *Healy* at the outset of the project. Before survey operations begin in U.S. waters, two of the PSOs on the *Healy* will transfer to the *St. Laurent* to provide additional PSOs during airgun operations. When not surveying in U.S. waters, the distribution of PSOs will return to three on the *St.*

Laurent and four on the *Healy*. PSOs on the *Healy* will report sightings to the PSOs on the *St. Laurent* to alert them of possible needs for mitigation.

(b) Utilize two, NMFS-qualified, vessel-based PSOs (except during meal times and rest room breaks, when at least one PSO will be on watch) to visually watch for and monitor marine mammals near the seismic source vessel during daytime airgun operations (from nautical twilight-dawn to nautical twilight-dusk) and before and during start-ups of airguns day or night in U.S. waters. The *St. Laurent* and *Healy*'s vessel crew will also assist in detecting marine mammals, when practicable. The crew will be given instruction on mitigation requirements and procedures for implementation of mitigation prior to the start of the seismic survey. Members of the *Healy* crew will be trained to monitor for marine mammals and asked to contact the *Healy* PSOs for sightings that occur while the PSOs are off-watch. PSOs will have access to reticle binoculars (7x50), laser range finding binoculars, and night vision devices. PSO shifts will last no longer than 4 hours at a time. PSOs will also make observations during daytime periods when the seismic system is not operating for comparison of animal abundance and behavior, when feasible.

(c) PSOs will conduct monitoring while the airgun array and streamers are being deployed or recovered from the water.

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

> (i) species, group size, age/size/sex categories (if determinable), behavior when first sighted and after initial sighting, heading (if consistent), bearing and distance from seismic vessel, sighting cue. apparent reaction to the airguns or vessel (e.g., none, avoidance, approach, paralleling, etc., and including responses to ramp-up), and behavioral pace; and
>
> (ii) time, location, heading, speed, activity of the vessel (including number of airguns operating and whether in state of ramp-up or power-down), sea state, visibility, and sun glare; and
>
> (iii) the data listed under 7(d)(ii) will also be recorded at the start and end of each observation watch and during a watch whenever there is a change in one or more of the variables.

(e) Visually observe the entire extent of the exclusion zone (190 dB for pinnipeds, 180 dB for cetaceans; see Table 1 [attached] for distances) using NMFS-qualified PSOs, for at least 30 minutes (min) prior to starting the airgun (day or night) on the *St. Laurent* and *Healy*. If the PSO finds a marine mammal within the exclusion zone, USGS must delay the seismic survey until the marine mammal(s) has left the area. If the PSO sees a marine mammal that surfaces, then dives below the surface, the PSO shall wait 30 min. If the PSO sees no marine mammals during that time, they should assume that the animal has moved beyond the exclusion zone. If for any reason the entire radius cannot be seen for the entire 30 min (i.e., rough seas, fog, darkness), or if marine mammals are near, approaching, or in the exclusion zone, the airguns may not be started up. If one airgun is already running at a source level of at least 190 dB, USGS may start the second airgun without observing the entire exclusion zone for 30 min prior, provided no marine mammals are known to be near the exclusion zone (in accordance with condition 7(g) below).

(f) Establish a 180 dB and 190 dB exclusion zone for marine mammals before the three G-airgun array (1,150 in^3) is in operation; and a 180 dB and 190 dB exclusion zone before a single airgun (150 in^3) is in operation, respectively. See Table 1 (attached) for distances and exclusion zone radii.

(g) Implement a "ramp-up" procedure when starting up at the beginning of seismic operations or anytime after the entire array has been shut-down for more than 10 min, which means start the smallest airgun first and add airguns in a sequence such that the source level of the array will increase in steps not exceeding approximately 6 dB per 5-min period. During ramp-up, the PSOs will monitor the exclusion zone, and if marine mammals are sighted, a course/speed alteration, power-down, or shut-down will be implemented as though the full array were operational. Therefore, initiation of ramp-up procedures from shut-down requires that the PSOs be able to view the full exclusion zone as described in 7(e) (above).

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

(i) Power-down or shut-down the airgun(s) if a marine mammal is detected within, approaches, or enters the relevant exclusion zone (as defined in Table 1, attached). A shut-down means all operating airguns are shut-down. A power-down means reducing the number of operating airguns to a single operating 150 in^3 airgun, which reduces the exclusion zone to the degree that the animal(s) is outside of it.

(j) Following a power-down, if the marine mammal approaches the smaller designated exclusion zone, the airguns must then be completely shut down. Airgun activity will not resume until the PSO has visually observed the marine mammal(s) exiting the exclusion zone and is not likely to return, or has not been seen within the radius for 15 min for species with shorter dive durations (small odontocetes and pinnipeds) or 30 min for species with longer dive durations (mysticetes and large odontocetes, including killer whales). Within international waters, the PSOs will apply a 30 min period for all species.

(k) Following a power-down or shut-down and subsequent animal departure, airgun operations may resume following ramp-up procedures described in 7(g).

(l) Marine geophysical surveys may continue into night and low-light hours if such segment(s) of the survey is initiated when the entire relevant exclusion zones are visible and can be effectively monitored.

(m) No initiation of airgun array operations is permitted from a shut-down position at night or during low-light hours (such as in dense fog or heavy rain) when the entire relevant exclusion zone cannot be effectively monitored by the PSOs on duty.

(n) The use of a helicopter to conduct ice reconnaissance flights and vessel-to-vessel personnel transfers is likely to occur during survey activities in U.S. waters. Collection of spot bathymetry data or on-ice landings, both of which required low altitude flight patterns by helicopters, will not occur in U.S. waters.

8. Reporting Requirements

The Holder of this Authorization is required to:

(a) Submit a draft report on all activities and monitoring results to the Office of Protected Resources, NMFS, within 90 days of the completion of the *St. Laurent* and *Healy*'s Arctic Ocean cruise. This report must contain and summarize the following information:

(i) Dates, times, locations, heading, speed, weather, sea conditions (including Beaufort sea state and wind force), visibility, sun glare, and associated activities during all seismic operations and marine mammal sightings.

(ii) Species, number, location, distance from the vessel, and; behavior of any marine mammals, as well as associated seismic activity (number of power-downs and shut-downs), observed throughout all monitoring activities.

(iii) An estimate of the number (by species) of marine mammals that: (A) are known to have been exposed to the seismic activity (based on visual observation) at received levels greater than or equal to 120 dB re 1 μPa (rms) (for icebreaking activities), greater than or equal to 160 dB re 1 μPa (rms) (for seismic airgun operations), and/or 180 dB re 1 μPa (rms) (for cetaceans) and 190 dB re 1 μPa (rms) (for pinnipeds) with a discussion of any specific behaviors those individuals exhibited; and (B) may have been exposed (based on modeling results) to the seismic activity at received levels greater than or equal to 120 dB re 1 μPa (rms) (for icebreaking activities), greater than or equal to 160 dB re 1 μPa (rms) and/or 180 dB re 1 μPa (rms) (for cetaceans) and 190 dB re 1 μPa (rms) (for pinnipeds) with a discussion of the nature of the probable consequences of that exposure on the individuals that have been exposed.

(iv) A description of the implementation and effectiveness of the monitoring and mitigation measures of the Incidental Harassment Authorization.

(b) Submit a final report to the Chief, Permits, Conservation, and Education Division, Office of Protected Resources, NMFS, within 30 days after receiving comments from NMFS on the draft report. If NMFS does not provide comments, the draft report will be considered to be the final report.

9. In the unanticipated event that any taking of a marine mammal in a manner prohibited by this Authorization occurs, such as an injury, serious injury or mortality, and is judged to result from these activities, USGS will immediately report the incident to the Alaska Regional Stranding Department at Protected Resources Division, Alaska Region, NMFS, at 907-586-7236, and Chief of the Permits, Conservation, and Education Division, Office of Protected Resources, NMFS, at 301-713-2289. USGS will postpone the survey activities until NMFS is able to review the circumstances of the take. NMFS will work with USGS to determine whether modifications in the activities are appropriate and necessary, and will notify the permit holder when they may resume sound source operations.

In the event that USGS discovers an injured or dead marine mammal that is judged to not have resulted from these activities, USGS will contact and report the incident to the Chief of the Permits, Conservation, and Education Division, Office of Protected Resources, NMFS, at 301-713-2289 within 24 hours of the discovery.

10. Implement the Plan of Cooperation 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.

11. A copy of this Authorization must be in the possession of all contractors and PSOs operating under the authority of this Incidental Harassment Authorization.

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

AUG 11 2010
Date

Attachments

Attachment

Table 1. Exclusion Zone Radii for Triggering Mitigation.

Source and Volume	Tow Depth (m) Ice/Open Water	Water Depth	Predicted RMS Distances (m)		
			Shut-down Zone for Pinnipeds 190 dB	Shut-down Zone for Cetaceans 180 dB	Level-B Harassment Zone (Impulsive) for Marine Mammals 160 dB
Single G-airgun 150 in^3	11/6-7	Deep (>1,000 m)	30	75	750
three G-airguns 1,150 in^3 (two 500 in^3 and one 150 in^3)	11/6-7	Deep (>1,000 m)	100	500	2,500

Table 2. Radii for Monitoring Take from Icebreaking.

Source	Predicted RMS Distances (m): Level B Harassment Zone (Continuous) for Marine Mammals 120 dB
Healy Icebreaking	1,750 m (3,500 m swath)

APPENDIX B: DETERMINATION OF THE NEED FOR AN ESA CONSULTATION

United States Department of the Interior

FISH AND WILDLIFE SERVICE
1011 E. Tudor Road
Anchorage, Alaska 99503-6199

IN REPLY REFER TO:

AFES/MMM

Dr. Deborah Hutchinson, Ph.D.
U.S. Geological Survey
384 Woods Hole Road
Woods Hole, Massachusetts 02543

Dear Dr. Hutchinson:

This responds to your May 07, 2010, request that the U.S. Fish & Wildlife Service (Service) review the operations for the summer 2010 Arctic Ocean geophysical experiment for potential impacts on Pacific walruses and polar bears. The primary purpose of the expedition is to collect bathymetric and seismic data in support of defining the respective extended continental shelves of the U.S. and Canada as defined in Article 76 of the United Nations Convention on the Law of the Sea (UNCLS). This year's expedition differs from previous years in that for approximately seven days, out of the total 35 days, two icebreaking ships will collect seismic and bathymetric data within the U.S. Exclusive Economic Zone (EEZ).

The U.S. icebreaker *USCGC Healy* will collect bathymetric and gravity data as well as break ice (when required) from August 02–September 06, 2010. The Canadian ice breaker *CCGS Louis S. St. Laurent (Louis)* will collect seismic data as well as break ice (when required) during the two-ship operations. Although the majority of proposed vessel tracks are beyond the U.S. 200-nmi EEZ limit, two lines with a connecting line are proposed within this zone to connect the offshore data with existing data on the Alaska margin, as set forth in the guidelines for Article 76 UNCLS. For these two lines and the connector, the closest planned approach to the Alaska shoreline is approximately 100 km in waters greater than 1900 m deep.

Given our understanding of polar bear and walrus distribution, the planned travel routes and locations of the activity we believe that it is unlikely the proposed studies will result in any major disturbances or impacts to individual polar bears or walruses. Disturbance will most likely be in the form of noise events or the unusual presence of a ship in such remote icebound areas. In the event that any bears or walruses are encountered, the most likely response of the animals will be avoidance, including walking, diving and/or swimming away. These typical behaviors would not be expected to have any impact on the fitness of survival of the individual animals and will be limited in scope and short term in duration. The Service feels the probability of level B Harassment is small, in part, due to the observations from last year's cruise where no Pacific walrus and approximately ten polar bears were observed. In addition, interactions between polar bears and/or walruses and the vessels will be minimal due to the limited overlap of the location of thc activity and thc distribution of polar bcars and walruses during this time of year.

Both vessels can minimize any potential interactions by following the monitoring and mitigation measures described in your May 07, 2010 letter; attachment 2, "Proposed Monitoring and Mitigation (from draft IHA)" and attachment 3, "Polar Bear Interaction Plan". A copy of these plans and the included observation forms must be available at all times to ship's personnel for reference.

In the event that polar bears or Pacific walrus are observed, the Service requests that the *Healy* limit interactions with observed animals by maintaining at least 800 m (½ mile) distance from all observed polar bears and walruses in vessel operations. During aerial observations flight paths will avoid observed polar bears and walruses by at least 800 m (½ mile) and 300 m (1,000 feet) above ground level (AGL).

The Service requests any sightings of bears or walruses be recorded on the appropriate observation sheets by the MMOs and be submitted to the Marine Mammals Management Office in Anchorage via email (craig_perham@fws.gov) or fax within 24 hours of the observation. We further request that a summary report of polar bear and Pacific walrus sightings be submitted to the Marine Mammals Management Office no later than 90 days after the completion of the expedition.

Considering the relatively low likelihood of encountering polar bears or walruses, along with the limited impact and anticipated responses by affected animals that would likely ensue from an encounter with either or both vessels, the Service has determined that an incidental take authorization is not necessary for this project. Included below is a list of common stipulations the Service requires when issuing a Letter of Authorization (LOA) for incidental take of Pacific walruses and polar bears. These are included for your information so you are aware of the Service's current requirements for industrial operators in the Beaufort Sea. By following your "Polar Bear Interaction Plan" and using the common stipulations below as guidelines you can limit your possibility of incidental take of polar bears of Pacific walruses. The common stipulations include:

1. Intentional take of polar bears and Pacific walruses is prohibited under this authorization.

2. Your interaction, avoidance and mitigation plans are approved and all provisions must be complied with unless specifically noted otherwise in this authorization.

3. A copy of this authorization and the approved interaction and avoidance plans listed above must be posted and available for all personnel and in the possession of the operators of all vessels and aircraft engaging in the activities approved under the authority of this authorization.

4. Operations managers, or their designates, must be fully aware, understand and be capable of implementing the conditions of this authorization.

5. This authorization is valid only for those activities and locations identified in your request for a Letter of Authorization and described in your plan of operations.

6. Polar bear and walrus monitoring, reporting, and survey activities must be conducted in accordance with 50 CFR section 18.128 and must comply with the following monitoring, mitigation, and reporting requirements:

   a. LOA holder and designates must cooperate with the Fish and Wildlife Service (Service), and other designated Federal, State, or local agencies to monitor the impacts of oil and gas exploration activities on polar bears and walruses.

   b. If any changes develop in the project during the period approved under this authorization, such as activities, location or methods, notify the Marine Mammals Management Office prior to the implementation of such changes.

   c. Avoid concentrations or groups of walruses and individuals or groups of polar bears hauled out onto land or ice by all vessels under the management of LOA holder. Operators of vessels should, at all times, conduct their activities at the maximum distance possible from known or observed concentrations of marine mammals. Under no circumstances, other than an emergency, should vessels operate within 800 meters (½ mile) of walruses or polar bears observed on land or ice.

   d. Take every precaution to avoid encroachment upon or harassment of walruses or polar bears in water when a vessel is operated near these animals. Maintain an 800 meter (½ mile) distance, when practicable. Vessels must reduce speed and steer around walruses or polar bears observed in water when able to do so. Vessels may not be operated in such a way as to separate members of a group of walruses or polar bears from other members of the group. Vessels will avoid multiple changes in direction and speed when walruses or polar bears are present.

   e. Restricting or affecting walrus or polar bear movements, by any means, in sea, on land or on ice, is prohibited. Separation distances will be enforced until animals have left the area of their own volition.

   f. LOA holder must designate a qualified individual or individuals as Marine Mammal Observers (MMO) to observe, record, and report the effects of project activities on polar bears and walruses to the Service within 24 hours of visual observation.

   g. For each walrus or polar bear sighting, an MMO or designated crew member will record at least the following:

      i. a unique sighting identification number;
      ii. observer name and contact information (phone, email, etc.)
      iii. time, location (with latitude, longitude, and datum), heading, speed, activity and identity of the observation vessel;
      iv. action taken by vessel operator in response to sighting (describe);

v. for all other vessels visible within 5 km of the observation vessel, when polar bears or walruses are sighted, record the identification, bearing, distance, heading, speed and activity of the other vessel(s);
vi. Species (polar bear or walrus);
vii. group size (approximate number of individuals);
viii. age/size/sex categories (if determinable);
ix. behavior or activity of animals sighted (describe);
x. reaction of animal(s) to any vessel(s) (describe):
xi. substrate (water, ice and/or land),
xii. heading (if determinable), bearing and distance from vessel of animal(s);
xiii. sighting cue (what caught MMOs attention);
xiv. environmental conditions including:
   - weather
   - air temperature
   - visibility, provide: 1) distance (km, mi or nm), 2) light/dark/twilight and 3) glare (none, little, moderate, severe);
   - water depth (meters, feet or fathoms),
   - sea state (Beaufort scale),
   - ice condition, provide: 1) estimated % ice cover in vicinity of sighting (10% increments), 2) estimated distance to pack ice (km, mi or nm);

xv. estimated range (m, km, mi or nm) at first sighting, estimated range (m, km, mi or nm) at closest approach;
xvi. MMO comments or notes

7. Any incidental lethal take or injury of a polar bears or walruses must be reported to the Service immediately.

8. All evidence of polar bears and walruses, such as tracks, carcasses or haul out sites, if applicable, will also be reported;

9. At the discretion of the Service, LOA holder must allow Service to place an observer on site, including any facilities, vessels, aircraft or vehicles, to monitor the impacts of the activity on marine mammals, when requested;

10. LOA holder must submit an annual monitoring report to the Marine Mammals Management Office (MMM) as required under 50 CFR 18.128(f), a draft of which will be received by MMM no later than 90 days after completion of the project. The report will describe in detail:

    a. the operations that were conducted;
    b. the methods, results, and interpretation pertaining to all monitoring tasks;
    c. the results of the 2010 shipboard marine mammal monitoring;
    d. marine mammal sightings (species, numbers, dates, times and locations; age/size/gender, environmental correlates, activities, associated survey activities);
    e. estimates of the amount and type of potential take (exposure) of walruses and polar bears (by species) to project activities;

f. an analysis of the effects of operations (e.g., on sighting rates, sighting distances, behaviors, movement patterns of walruses and polar bears);
g. provide an analysis of factors influencing detectability of walruses and polar bears during project operations;
h. provide summaries of communications with hunters and potential effects on subsistence uses.

11. The draft report will be subject to review and comment by the Service. Any recommendations made by the Service must be addressed in the final report prior to acceptance by the Service. The draft report will be considered the final report for this activity under this Authorization if the Service has not provided comments and recommendations within 90 days of receipt of the report.

12. 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.

13. Per the "Programmatic Biological Opinion for the Beaufort Sea Incidental Take Regulations for Polar Bear (June 2008)", your request also triggers the second of the two-tiered programmatic process. In order for incidental take of the polar bear to be exempted from the prohibitions of the ESA, the LOA also serves as an "Incidental Take Statement" (ITS), required under section 7 of the Endangered Species Act of 1973 (ESA). Issuance of the LOA/ITS fulfills the requirements for Tier 2 Consultation of the Programmatic Biological Opinion for the activities described in this letter.

14. This Authorization is valid for the period indicated on this authorization, unless extended or terminated in writing by the U.S. Fish and Wildlife Service, Marine Mammals Management Office.

Should you have any further questions contact Mr. Craig Perham of our Marine Mammals Management Office, at (907) 786-3800 or 786-3810.

Sincerely,

Rosa Meehan, Ph.D.
Chief, Marine Mammals Management

cc: Fairbanks Fish and Wildlife Field Office (FFWFO)
USFWS Office of Law Enforcement (OLE)

APPENDIX C: ESA SECTION 7 CONSULTATION/LETTER OF CONCURRENCE

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Silver Spring, MD 20910

JUL 07 2010

James F. Devine
Senior Advisor for Science Applications
USGS, 12201 Sunrise Valley Drive
Reston, VA 20192

Dear Mr. Devine:

On May 21, 2010, we received a request for concurrence under section 7 of the Endangered Species Act for a marine seismic survey in the Arctic Ocean for the 2010 extended continental shelf experiment. This year is the last year in a joint United States-Canada effort to explore the extended continental shelf in the Arctic Ocean. The United States Geological Survey (USGS) along with NOAA's Office of Atmospheric Research is proposing to fund the United States' participation in the experiment which will take place from approximately August 3, 2010, to September 4, 2010. As part of this experiment the USGS will conduct a bathymetric survey aboard the United States Coast Guard Cutter *Healy*. The *Healy* will be operated by the United States Coast Guard and perform ice breaking activities as needed. The Geological Survey of Canada in conjunction with the USGS' bathymetric survey will conduct a seismic survey aboard the Canadian Coast Guard Vessel *CCGS Louis S. St-Laurent*. Experiment activities will occur within international waters, the U.S. Exclusive Economic Zone (EEZ) and the Canadian EEZ within the Arctic Ocean and the Beaufort Sea.

Based on the following information we concur with your determination that the activities conducted during the experiment may affect, but are not likely to adversely affect endangered bowhead, fin, humpback or sperm whales or steller sea lions. No designated critical habitat occurs within the action area for this experiment, therefore, no critical habitat will be affected by the bathymetric and seismic surveys and other experiment activities.

Description of Proposed Action
The USCG *Healy* and the CCCGS *St-Laurent* will each leave port to rendezvous at the survey site within the Arctic Ocean to begin the bathymetric and seismic surveys. The *Healy* will leave Dutch Harbor, Alaska around August 3, 2010, and return to Barrow, Alaska around September 4, 2010. The *St-Laurent* will leave Kugluktuk, Canada around August 2, 2010, and return there around September 16, 2010. During the surveys the two vessels will operate either in tandem with the *Healy* breaking and clearing ice as needed for the *St. Laurent* or the two vessels may diverge and operate independently in open water. Helicopter transfers of crew from the *Healy*

are also planned for ~1 day during a ship-to-shore crew change at Barrow at the end of the survey.

The majority of the seismic and bathymetric surveys will occur beyond Alaska's continental shelf in the deeper, international waters of the Arctic Ocean. Both ships carry equipment for the experiment. Seismic survey equipment aboard the *St. Laurent* includes an airgun array and a Knudsen 320BR "Chirp" pulse echo sounder operating at 12 kHz. The airgun array consists of three Sercel G-guns (two 500 in^3 and one 150 in^3 airguns) for an overall discharge of 1150 in^3. The airgun array has a source level of 235 (0-pk) and 225 rms. The single 150 in3 G-gun will be used if a power down is necessary.

The *Healy* will use a Kongsberg EM122 multibeam bathymetric sonar which operates at 10.5–13 (usually 12) kHz, a Knudsen 3.5 kHz Chirp sub-bottom profiler and an ODEC 1500 "piloting" echo sounder (with available frequencies of 12, 24, 33, 40, 100, and 200 kHz) while underway and during the seismic data acquisition. Acoustic Doppler current profilers operating at 75-kHz and 150-kHz may also be used on the *Healy*.

In addition to the hydrophone streamer, two marine sonobuoys will be deployed to acquire wide angle reflection and refraction data for velocity determination to convert seismic reflection travel time to depth. Sonobuoys will be deployed off the stern of the *St. Laurent* approximately every eight hours during seismic operations with as many as three deployments per day. The sonobuoy's hydrophone will start receiving seismic signals at a water depth of ~60 m and transmit those signals via radio to the *St- Laurent*. The sonobuoys are pre-set to scuttle eight hours after activation.

The Canadians will deploy a helicopter from the *St-Laurent* for ice reconnaissance, spot bathymetry and crew transfers between the two vessels during survey operations. The spot bathymetry data will be collected by a 12 kHz transducer that will be slung by the helicopter and placed in the water. Daily helicopter operations are anticipated pending weather conditions. The proposed tracklines for the 2010 survey are show below (Figure 1). The entire survey area will be bounded approximately by 71° to 84° N latitude and 145° to 158° W longitude in water depths ranging from ~1900–4000 m.

Figure 1: Proposed Tracklines for the 2010 Seismic Survey for USGS/Geological Survey of Canada 2010 Extended Continental Shelf Survey in the northern Beaufort Sea and Arctic Ocean.

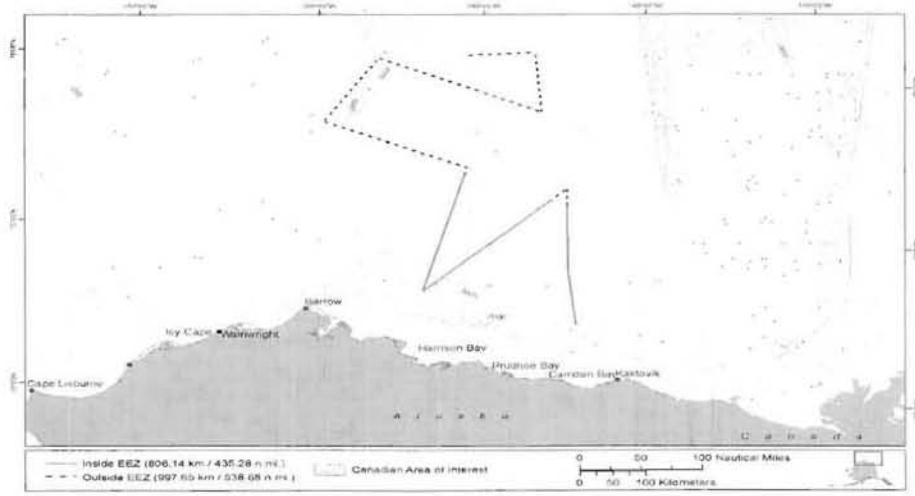

Table 1. Proposed U.S. tracklines for USGS/Geological Survey of Canada (GSC) 2010 Extended Continental Shelf Survey in the northern Beaufort Sea and Arctic Ocean.

Location	End Point 1	End Point 2	km	n.mi.
NS in central EEZ	71.22° N ; 145.17° W	73.92° N ; 145.30° W	300	162
Central-western EEZ connector	73.92° N ; 145.30° W	71.84° N ; 151.82° W	317	171
NS in western EEZ	71.84° N ; 151.82° W	74.32° N ; 150.30°W	281	152
South Northwind Ridge	74.32° N ; 150.30°W	74.96° N ; 158.01° W	239	129
Northwind Ridge connector	74.96° N ; 158.01° W	76.30° N ; 155.88° W	161	87
Mid-Northwind Ridge	76.30° N ; 155.88° W	75.41° N ; 146.50° W	274	148
Northwind Ridge connector	75.41° N ; 146.50° W	76.57° N ; 146.82° W	129	70
Mid-Northwind Ridge	76.57° N ; 146.82° W	76.49° N ; 150.73° W	102	55
		Totals	1803	974

Surveys will occur inside U.S. waters as well as outside U.S. waters using airguns, eco sounders, sub-bottom and Doppler profilers, a hydrophone streamer and sonobuoys. The two tracklines proposed to enter US waters (with a connector line between them) occur in the Beaufort Sea and are included as part of the solid lines in Figure 1 above. The portions of the tracklines contained within U.S. waters include the southern 263.8 km of the line that runs North-South (NS) in the western EEZ, the southern 264.5 km of the line that runs NS in the central EEZ, and the 277.7 km connector line (Central-western EEZ connector). These portions of the tracklines represent the closest approaches to the shoreline for the entire cruise. The NS in western EEZ trackline has its closest approach to land in about 2500 m water depth at about 120 km from the shoreline. The NS in central EEZ trackline has its closest approach to land about 116 km from the shoreline in about 1900 m water depth. The two tracklines and connector are scheduled for data acquisition from August 7 to August 12, 2010. The remainder of the survey will occur outside of the US EEZ and farther away from the shoreline and continental shelf in deeper, international waters within the Arctic Ocean.

Estimated Sound Level Radii

Sound level radii of the airgun array were measured in 2009 during a seismic calibration experiment (Mosher et al. 2009; Roth and Schmidt 2010) to aid estimation of the peak sound pressure levels as a function of range. A transmission loss model was then constructed assuming spherical (20LogR) spreading and using the source level estimate (235 dB re 1 μPa 0-peak; 225 dB re 1 μPa rms) from the measurements. The use of 20LogR spreading fit the data well out to ~1 km where variability in measured values increased. Additionally, the Gundalf® modeling package was used to model the airgun array and estimated a source level of 236.7 dB 0-peak (226.7 dB rms). Using this slightly stronger source level estimate and 20LogR spreading the received levels of sound were estimated at the 190 dB, 180 dB and 160 dB isopleths and are expected to occur at 68 m, 216 m and 2,157 m, respectively.

The anticipated sound-level radii for the lower energy sound sources including the Chirp echo sounder (on the *St. Laurent*) and bathymetric sonar (on the *Healy*) are less than that for the airgun configuration. It is assumed that during simultaneous operations of the airgun array and sounder, any marine mammals close enough to be affected by the sounder would already be affected by the airguns.

Listed Species in the Action Area

The action area is defined as "all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action" (50 CFR §402.02). The action area for the 2010 experiment encompasses the areas through which the *Healy* and *St-Laurent* transit to arrive at the Arctic Ocean rendezvous point as well as the areas around and adjacent to the survey sites. Transits will occur through the Bering, Chukchi and Beaufort Seas. The bathymetric and seismic surveys will occur within the Beaufort Sea and Arctic Ocean. Listed bowhead, fin, humpback and sperm whales and steller sea lions will occur in portions of the action area as summarized below.

Bowhead whales winter in the central and western Bering Sea and many of them summer in the Canadian Beaufort Sea. Some bowheads arrive in coastal areas of the eastern Canadian Beaufort Sea and Amundsen Gulf in late May and June, but most may remain among the offshore pack ice of the Beaufort Sea until mid-summer. After feeding primarily in the Canadian Beaufort Sea and

Amundsen Gulf, bowheads migrate westward across the Beaufort Sea from late August through mid- or late October. Westbound bowheads typically reach the Barrow area in mid-September but can arrive as early as August, and are in that area until late October. Bowheads tend to migrate west in deeper water (farther offshore) during years with higher-than-average ice coverage than in years with less ice (Moore 2000; Treacy et al. 2006). The migration corridor ranged from ~30 km offshore during light ice years to ~80 km offshore during heavy ice years (Treacy et al. 2006). In addition, the sighting rate tends to be lower in heavy ice years (Treacy 1997). During fall migration, most bowheads migrate west in water ranging from 15 to 200 m deep (Miller et al. 2002 as cited in NMFS 2008; Richardson and Thomson 2002).

Fin whales have been known to occur in the northern Gulf of Alaska and southeastern Bering Sea from May to October, with some movement through the Aleutian passes into and out of the Bering Sea. There have been only rare observations of fin whales in the Chukchi Sea and no observations in the Beaufort Sea since 1979.

Humpback whale sightings in the Bering Sea have been recorded southwest of St. Lawrence Island, the southeastern Bering Sea, and north of the central Aleutian Islands. Historic and recent information indicated that humpback whales did not inhabit the northern portions of the Chukchi Sea or enter the Beaufort Sea, however, four humpback whales were reported during vessel-based surveys in the Chukchi Sea in 2007 and two sightings were reported in 2008. National Marine Mammal Laboratory observers also recorded one humpback whale during aerial surveys in the Chukchi Sea in 2009. A humpback whale cow/calf pair was also reported in the Beaufort Sea east of Barrow, Alaska near Smith Bay in 2007.

The approximate distribution of sperm whales in the North Pacific includes deep waters south of 62°N (the southern Bering Sea in Alaska) to the equator. Only older, male sperm whales move north in the summer to feed in the Gulf of Alaska, southern Bering Sea, and waters around the Aleutian Islands while females and young remain in tropical and temperate waters.

Steller sea lions range along the North Pacific Rim from northern Japan to California, with centers of abundance and distribution in the Gulf of Alaska and Aleutian Islands, respectively. The species is not known to migrate, but individuals disperse widely outside of the breeding season (late May-early July). During fall and winter in Alaska, steller sea lion may occur at rookeries and haulouts used during the summer and they are also seen near sea ice and islands in the northern Bering Sea.

Effects of the Proposed Action

The proposed experiment consists of vessel transits, helicopter use, bathymetric and seismic surveys and ice breaking. The majority of the activities conducted as part of the proposed action will have no effects on listed species because the activity and the effects on the environment from these activities will not overlap in time or space with listed species. These activities include vessel operations and crew transfers via helicopter during the surveys and spot bathymetry operations. These activities occur in areas where listed species do not occur.

Vessel transit, transfer of crew at the end of the project, seismic and bathymetric surveys and ice breaking activities either occur in areas where listed species occur or as in the case of airgun noise, may propagate to areas where listed species may occur.

Bowhead, fin, humpback and sperm whales and steller sea lions may occur in portions of the Bering, Chukchi and Beaufort Seas as the two vessels transit from port to the rendezvous site in the Arctic Ocean. Sounds emanating from the vessels' engines are expected to be short term as the vessels head north to the rendezvous point. Disturbance from vessels may cause whales to slightly and temporarily alter their habitat use. All such effects are expected to be of short duration and whales are expected to resume their behavior as the vessels move out of their immediate area without impairment of feeding, migration, or other behaviors. We would, therefore, expect any effects to listed species to be minor and insignificant. Although the *Healy* and *St-Laurent* transits from port to the rendezvous site occur in areas where fin, humpback and sperm whales and steller sea lions may occur, these transits head north through and out of the extreme northern ranges of these animals. Whale and steller sea lion abundance through these areas are expected to decrease significantly and the vessels are less likely to encounter whales as they transit. The majority of bowhead whales are expected to occur on the feeding grounds in the Beaufort Sea. Given this, the probability that the vessels would interact with a whale or sea lion en route to the rendezvous site is discountable.

At the end of the survey the Healy will change crew in Barrow, Alaska. Several helicopter trips will occur to transfer crew to shore. Whales could be temporarily harassed or disturbed by low-flying helicopters during ship to shore transfers. Cetacean reactions to helicopters depend on several variables including the animal's behavioral state, activity, group size, habitat, and the flight patterns used, among other variables (Richardson et al. 1995a). Reactions to helicopter disturbance are difficult to predict and may range from no reaction at all to minor changes in course or (infrequently) leaving the immediate area of the activity. During spring migration in the Beaufort Sea, beluga whales reacted to helicopter noise more frequently and at greater distances than did bowhead whales (38% vs. 14% of observations, respectively). Most reactions occurred when the helicopter passed within 250 m lateral distance at altitudes ≤150 m. Neither species exhibited noticeable reactions to single passes at altitudes >150 m. Belugas within 250 m of stationary helicopters on the ice with the engine running showed the most overt reactions (Patenaude et al. 2002). Whales were observed to make only minor changes in direction in response to sounds produced by helicopters, so all reactions to helicopters were considered brief and minor. The crew of the Healy will coordinate with community observers aboard the ship to schedule the helicopter trips when whales are not likely to be in the vicinity of the helicopter's path to shore. This coordination is expected to minimize any adverse effects the ship to shore transfer may have on bowhead whales as well as humpback whales which occur on rare occasions in the Beaufort Sea.

Historically, bowhead whales and more recently small numbers of humpback whales have occurred on the Alaskan shelf in the Beaufort Sea during the August to September time period in which the surveys are scheduled. While the actual paths of the vessels conducting seismic and bathymetric surveys will not overlap with bowhead whales and humpback whales since these whales are expected to occur further towards shore on the continental shelf, the sound levels associated with the surveys could propagate to areas where the whales could hear the sounds associated with the airguns. Fin and sperm whales are not expected to occur in the Beaufort Sea and the Arctic Ocean and will not be affected by survey activities.

Because whales are most sensitive to noise at the frequencies at which they vocalize we assume that whales can also hear best in these frequencies. Most bowhead vocalizations are at 50-400 Hz, although components may reach as low as 35 Hz or as high as 5 kHz (Burns et al. 1993). Humpback whale vocalizations range from 20 Hz to at least 10 kHz (Silber 1986). However, based on a study conducted by Au et al. (2006) which recorded humpback whale songs having high-frequency harmonics extending up to at least 24 kHz, humpbacks are believed to hear to at least 25 kHz. The dominant sounds emitted by airguns are in the low frequency range (25 to 100 Hz) and are audible to bowhead and humpback whales.

The anticipated sound-level radii for the lower sound sources (bathymetric sonar, the Knudsen 3.5 kHz Chirp sub-bottom profiler, and the piloting echo sounder) are less than that for the airgun configuration. Based on their assumed hearing abilities bowhead whales would be able to hear the 3.5 kHz frequencies of the sub-bottom profiler and humpback whales would be able to hear the sub-bottom profiler as well as the 12 and 25 kHz frequencies of the piloting echsounder if whales were to pass close enough to or through the beam emitted by these sound sources. Sound pressure levels are highest within the beam and diminish rapidly outside the beam of these types of sound sources. Kremser (2005) found during testing of a Hydrosweep multibeam swath mapping echo sounder and a Parasound sub-bottom profiler in Antarctic waters that the sound pressure level within the horizontal propagation of the sounds (horizontal lobes) emitted by the two sources and close to the beam is about 20 db less than the level found in the center of the beam (Wendt 2001 as cited in Kremser et al 2005) and the sound levels outside the beam decrease rapidly with distance (Kremser et al 2005). The USGS plans to operate the bathymetric sonar, sub-bottom profiler and piloting echo sounder independently from the airguns while underway and at other times during the survey as well as simultaneously with the airguns. Neither bowhead nor humpback whales are expected to pass through the beam of these sound sources or occur in the vicinity of the surveys which will occur further offshore in the Beaufort and Arctic Ocean. Although some sound may propagate horizontally from the echo sounder, bathymetric sonar and sub-bottom profiler, bowhead whales and humpback whales are not expected to hear these sounds and are not expected to be adversely affected by their operation because of the characteristics of these sources (downward directed beam and highest energy levels near the center of the beam with rapidly attenuating energy levels with distance).

The *Healy* will operate a 75 kHz and a 150 kHz acoustic Doppler current profiler. Both of these profilers operate above the hearing ranges of bowhead and humpback whales, and will not affect these whales. The streamer, sonobuoys and the transducer are listening/recording devices, not acoustic sources and, therefore, will also not affect bowhead and humpback whales.

Throughout the survey the 180 dB isopleth for the airguns is estimated to occur 500 meters from the seismic vessel while the 160-dB isopleth is estimated to occur approximately 2.5 km from the seismic vessel. Bowhead and possibly humpback whales could migrate through the Beaufort Sea while the seismic and bathymetric surveys are occurring in the survey area. The closest survey tracklines will occur approximately 116 km from the Alaskan shoreline in the Beaufort Sea for a 5-day duration, then the survey will move to approximately 397 km from the Alaskan shoreline [NS in western EEZ trackline distance from shore (116 km)+ length of western trackline (281 km)=397 km] and continue north.

It is assumed that during simultaneous operations of the airgun array, bathymetric sonar, sub-bottom profiler and piloting echo sounder, any marine mammals close enough to be affected by those lower sound sources would already be affected by the higher source levels of the airguns. Because of the higher source level and resulting propagation distances, the airguns are assumed to have the largest potential to affect bowhead and humpback whales. Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to pulses from large arrays of airguns at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, baleen whales exposed to strong noise pulses from airguns often react by deviating from their normal migration route and/or interrupting their feeding and moving away. In the case of the migrating gray and bowhead whales, the observed changes in behavior appeared to be of little or no biological consequence to the animals. They simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors.

Studies of gray, bowhead, and humpback whales have determined that received levels of pulses in the 160–170 dB re 1μPa rms range seem to cause obvious avoidance behavior in a substantial fraction of the animals exposed. In many areas, seismic pulses from large arrays of airguns diminish to those levels at distances ranging from 4.5 to 14.5 km from the source. A substantial proportion of the baleen whales within those distances may show avoidance or other strong disturbance reactions to the airgun array. Subtle behavioral changes sometimes become evident at somewhat lower received levels, and some species of baleen whales, notably bowhead and humpback whales, at times show strong avoidance at received levels lower than 160–170 dB re 1µPa rms. Bowhead whales migrating west across the Alaskan Beaufort Sea in autumn, in particular, are unusually responsive, with substantial avoidance occurring out to distances of 20–30 km from a medium-sized airgun source (Miller et al. 1999as cited in NMFS 2008; Richardson et al. 1999). The seismic survey will be conducted during fall migration, but at locations starting at > 100 nautical miles offshore, well north of the known bowhead migration corridor and well beyond the 20-30 km distance cited in the two studies.

Data on short-term reactions (or lack of reactions) of cetaceans to impulsive noises do not necessarily provide information about long-term effects. It is not known whether impulsive noises affect reproductive rate or distribution and habitat use in subsequent days or years. However, gray whales continued to migrate annually along the west coast of North America despite intermittent seismic exploration and much ship traffic in that area for decades (Appendix A in Malme et al. 1984). Bowhead whales continued to travel to the eastern Beaufort Sea each summer despite seismic exploration in their summer and autumn range for many years (Richardson et al. 1987). Populations of both gray whales and bowhead whales grew substantially during this time. At the distances of these surveys to the bowhead migration route sound pulses from the airguns may be too weak to be heard at the location of the animal, (i.e., lower than the prevailing ambient noise level) or the noise may be audible but not strong enough to elicit any overt behavioral response. In any event, the brief exposures to sound pulses from the proposed airgun source are highly unlikely to result in any more than temporary effects and we conclude that any effects from the airguns will be insignificant and are not likely to adversely affect bowhead and humpback whales.

Icebreakers produce more noise while breaking ice than ships of comparable size due, primarily, to the sounds of the propeller cavitating (Richardson et al. 1995a). Multi-year ice, which is expected to be encountered in the northern and eastern areas of the proposed survey, is thicker than younger ice. Icebreakers commonly back and ram into heavy ice until losing momentum to make way. The highest noise levels usually occur while backing full astern in preparation to ram forward through the ice. Overall, the noise generated by an icebreaker pushing ice was 10-15 dB greater than the noise produced by the ship underway in open water (Richardson et al. 1995b).

When seismic survey vessels are attended by icebreakers additional disturbance and noise will be introduced by the noise of the icebreaker. There are no observations of bowhead or humpback reactions to icebreaking activities. It is likely that response distances would vary, depending on the amount of icebreaking activities and sound propagation conditions. In general, the Arctic Ocean is a noisy environment. Greening and Zakarauskas (1993), reported ambient sound levels of up to 180 dB $\mu Pa^2/Hz$ under multi-year pack ice in the central Arctic pack ice.

Based on models, bowhead whales likely would respond to the sound of the icebreakers at distances of 2-25 km (1.24-15.53 mi) from the icebreakers (Miles et al. 1987). This study predicts that roughly half of the bowhead whales show avoidance response to an icebreaker underway in open water at a range of 2-12 km (1.25-7.46 mi) when the sound-to-noise ratio is 30 dB. The study also predicts that roughly half of the bowhead whales would show avoidance response to an icebreaker pushing ice at a range of 4.6-20 km (2.86-12.4 mi) when the sound-to-noise ratio is 30 dB.

Richardson et al. (1995b) found that bowheads migrating in the nearshore lead during the spring migration often tolerated exposure to playbacks of recorded icebreaker sounds at received levels up to 20 dB or more above the natural ambient noise levels at corresponding frequencies. The source level of an actual icebreaker is much higher than that of the projectors (projecting the recorded sound) used in this study (median difference 34 dB over the frequency range 40-6,300 Hz). Over the two-season period (1991 and 1994) when icebreaker playbacks were attempted, an estimated 93 bowheads (80 groups) were seen near the ice camp when the projectors were transmitting icebreaker sounds into the water, and approximately 158 bowheads (116 groups) were seen near there during quiet periods. Some bowheads diverted from their course when exposed to levels of projected icebreaker sound greater than 20 dB above the natural ambient noise level in the one-third octave band of the strongest icebreaker noise. However, not all bowheads diverted at that sound-to-noise ratio, and a minority of whales apparently diverted at a lower sound-to-noise ratio. The study concluded that exposure to a single playback of variable icebreaker sounds can cause statistically but probably not biologically significant effects on movements and behavior of migrating whales in the lead system during the spring migration east of Point Barrow. The study indicated the predicted response distances for bowheads around an actual icebreaker would be highly variable; however, for typical traveling bowheads, detectable effects on movements and behavior are predicted to extend commonly out to radii of 10-30 km (6.2-18.6 mi). Predicting the distance a whale would respond to an icebreaker like the *Healy* is difficult because propagation conditions and ambient noise vary with time and with location. However, because the closest survey activities and icebreaking are approximately 116 km away and are of limited duration (5 days), and the next closest survey activities are 397 km away to the north and west in the Arctic Ocean, we do not anticipate that ice breaking activities would have biologically significant effects on the movements and behavior of bowhead and humpback whales; therefore we conclude that ice breaking activities are insignificant and are not likely to adversely affect these whale species.

This concludes section 7 consultation for the 2010 extended continental shelf experiment. No further consultation is required at this time. If project plans change, or if you have questions or concerns regarding this consultation or the consultation process in general, please contact me or Kellie Foster at 301-713-1401 x131.

Sincerely,

James H. Lecky
Director,
Office of Protected Resources

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APPENDIX D: POLAR BEAR INTERACTION PLAN

ATTACHMENT 3

Polar Bear Interaction Plan

I. Summary

In support of Law of the Sea studies, a joint two-ship experiment will be conducted by Canada and the United States in August - September, 2010 in portions of the western Arctic Ocean north of Alaska and west of the Canadian continental margin. In tandem, USCGC *Healy* will collect multibeam bathymetry and gravity data and CCGS *Louis S. St. Laurent (Louis)* will collect seismic reflection and single-beam bathymetry data. This polar bear interaction plan was requested by FWS for *Healy* operations throughout the cruise, and *Louis* operations during operations inside the US Exclusive Economic Zone (EEZ). Chief Scientist aboard *Healy* will be Dr. Brian Edwards, U.S. Geological Survey. *Healy* will leave from Dutch Harbor, AK, on 2 August, 2010, and return to Barrow, AK on 6 September, 2010. Seismic data collection from *Louis* inside the U.S. 200 nautical mile limit will occur from approximately 7-12 August, 2010. Both *Louis* and *Healy* are self-contained icebreaker vessels with the crew living aboard the vessel for the entire cruise. There are no on-ice operations planned. The strategy outlined in this polar bear interaction plan utilizes US NOAA/NMFS strategy for marine mammal monitoring and mitigation while in the US EEZ. Each country uses its own monitoring and mitigation strategies when operating in international waters. In general, the Protected Resource Observers (PROs) use consistent approaches in their work. The *Healy* science crew will abide by the experimental approach and PRO responsibilities set forth in this document, as will Louis while it is operating in US waters.

II. Cruise Overview

During the summer of 2010, the Interagency Task Force for the U.S. Extended Continental Shelf (ECS) is conducting a geophysical data collection cruise in the Arctic Ocean from the U.S. Coast Guard vessel *USCGC Healy*. Much of the cruise will be cooperative with a similar ECS group in Canada using *CCGS Louis S. St-Laurent*. The purpose of the two-icebreaker experiment is to collect bathymetric data from the *Healy* and seismic data from the Canada Coast Guard vessel *Louis S. St-Laurent (Louis)* in support of defining the respective extended continental shelves of the U.S. and Canada in the Arctic Ocean per Article 76 of the Convention on the Law of the Sea. Proposed track lines for the 2010 experiment are shown in **Figure 1.** This collaboration saves millions of dollars for both countries, ensures data is collected only once over the same area, maximizes respective strengths, and increases scientific and diplomatic cooperation. The 2010 experiment is the third two-icebreaker survey conducted for ECS. The U.S. Geological Survey is the lead U.S. agency in the *Healy* cruise.

Healy and *Louis* will acquire data in the Canada Basin and along its edges (Alaskan margin, Northwind Ridge, Alpha Ridge, Canadian continental margin). In general, Healy will break ice ahead of *Louis*. In this configuration, the priority data collection is seismic reflection and refraction data from *Louis*. For the heaviest ice conditions expected in the northern and easternmost areas of surveying, the ships will reverse position so that *Louis* breaks ice for

Healy. In this configuration, the priority data collection is multibeam bathymetry data from *Healy*.

Healy Cruise: 2 August – 6 September, 2010 (Dutch Harbor – Barrow)
At the beginning of the cruise, Healy and Louis will rendezvous and operate for ~5-7 days inside the US 200-nmi limit in water depths greater than ~2000 m and more than 100 km from the Alaskan shoreline (**Figure 1**). While inside the US 200-nmi limit, *Healy* will break ice ahead of Louis if ice conditions require this configuration. Otherwise, Healy will collect multibeam data independently along the Alaskan Beaufort continental margin in water depths deeper than ~2000 m. The two ships will rejoin when ice conditions require a two-icebreaker configuration.

USCGC Healy will operate a multibeam echosounder, (Kongsberg EM122), a sub-bottom profiler (Knudsen 3.5 kHz Chirp) and a "piloting" echosounder (ODEC 1500) continuously when underway. Acoustic Doppler current profilers (75-kHz and 150-kHz) may be used on the *Healy*. In addition, as time and ice conditions permit, Healy may conduct coring near southern Alpha Ridge to sample the shallow seafloor sediments along survey lines.

Louis Cruise: 4 August – 15 September (Kugluktuk, NWT – Kugluktuk, NWT)
After *Louis* and *Healy* rendezvous (and marine mammal observers from *Healy* are transferred to *Louis*), seismic operations will commence for the cruise tracks that go within the US 200-nmi limit. The program within the U.S. 200-nmi limt consists of three lines totaling ~806 km (**Figure 1; Table 1**). U.S. priorities include another 997 km of survey lines north of the U.S. 200-nmi limit, for a total of 1803 km of tracklines of interest to the U.S. Table 1 lists all U.S. priority tracks. Water depths within the U.S. study area will range from ~1900 to 4000 m (Fig. 1). There may be additional seismic operations associated with airgun testing, start up, and repeat coverage of any areas where initial data quality is sub-standard. The tracklines that will be surveyed in U.S. waters include the southern 263.8 km of the line that runs North-South in the western EEZ, the southern 264.5 km of the line that runs North-South in the central EEZ, and 277.7 km trackline of the line that connects the two (**Figure 1; Table 1**).

Once these data are collected, *Louis* and *Healy* will proceed north to acquire data along the other proposed US-priority tracks and then proceed to collect data of Canadian priority (**Figure 1**). After *Healy* departs the two-icebreaker experiment to return to Barrow, *Louis* will proceed to collect seismic data independently where ice conditions allow, most likely along the southernmost lines within the Canadian 200-nmi limit.

Acoustic sources on board *Louis* will include an airgun array comprised of three Sercel G-guns and a Knudsen 320BR "Chirp" pulse echo sounder operating at 12 kHz. The airgun array consists of two 500 in^3 and one 150 in^3 airguns for an overall discharge of 1150 in^3. The airgun array is fired approximately every 20 s. The recorders are a 100-m long 16-channel multichannel streamer towed behind Louis, and sonobuoy hydrophones that are deployed approximately once every 8 hours behind the vessel during seismic shooting.

Coordination
In preparation for these cruises, a series of meetings have been held in both the U.S. and Canada between scientists, diplomats, and ship operators to ensure maritime safety and a successful mission compliant with all U.S. and Canadian law and practices. During the past

three years of Canadian seismic operations in the Arctic, Natural Resources Canada has conducted an assessment and subsequently received an authorization from the Canadian Department of Fisheries and Oceans for their seismic work. During the two-icebreaker experiments of 2008 and 2009 which were conducted outside the U.S. 200-nmi limit, both a native community observer and a protected resources observer were included in the science crew of *Healy*. For 2010, USGS is proposing three protected resource observers aboard *Healy* together with the three observers already aboard *Louis*. During operations in the US EEZ, two of the protected resource observers aboard *Healy* will transfer to *Louis* so that she is operating with five observers.

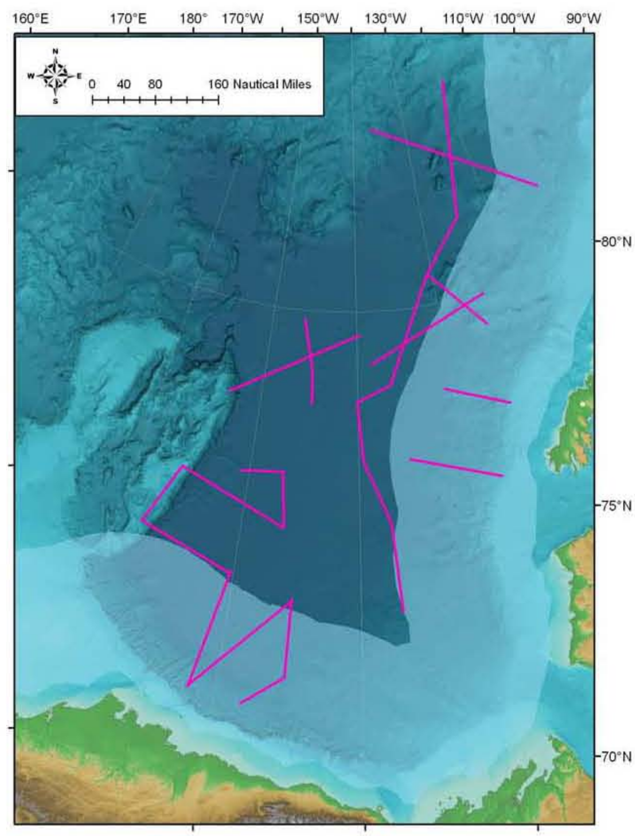

FIGURE 1. Proposed location of the USGS August–September 2010 seismic survey area. Light blue shading indicates the Exclusive Economic Zone out to 200 nmi.

TABLE 1. Proposed U.S. priority tracklines for USGS/Geological Survey of Canada (GSC) 2010 Extended Continental Shelf Survey in the northern Beaufort Sea and Arctic Ocean.

Location	End Point 1	End Point 2	km	n.mi.	Time (h) @ 4 n.mi./hr
NS in central EEZ	71.22° N ; 145.17° W	73.92° N ; 145.30° W	300	162	41
Central-western EEZ connector	73.92° N ; 145.30° W	71.84° N ; 151.82° W	317	171	43
NS in western EEZ	71.84° N ; 151.82° W	74.32° N ; 150.30°W	281	152	39
South Northwind Ridge	74.32° N ; 150.30°W	74.96° N ; 158.01° W	239	129	32
Northwind Ridge connector	74.96° N ; 158.01° W	76.30° N ; 155.88° W	161	87	22
Mid-Northwind Ridge	76.30° N ; 155.88° W	75.41° N ; 146.50° W	274	148	37
Northwind Ridge connector	75.41° N ; 146.50° W	76.57° N ; 146.82° W	129	70	17
Mid-Northwind Ridge	76.57° N ; 146.82° W	76.49° N ; 150.73° W	102	55	14
		Totals	1803	974	245

III. Polar Bears in the Study Area

Nineteen discrete populations of polar bears exist in the circumpolar North American Arctic (Aars et al., 2006). The proposed 2008 Healy cruise will occur within the range of two of these populations: the southern and northern Beaufort polar bear populations (Figure 2). The most up-to-date information about the southern Beaufort population is summarized in Regehr et al. (2006); information for the northern Beaufort polar bear population is summarized in Stirling et al. (2007). Much of the following information derives from these two reports.

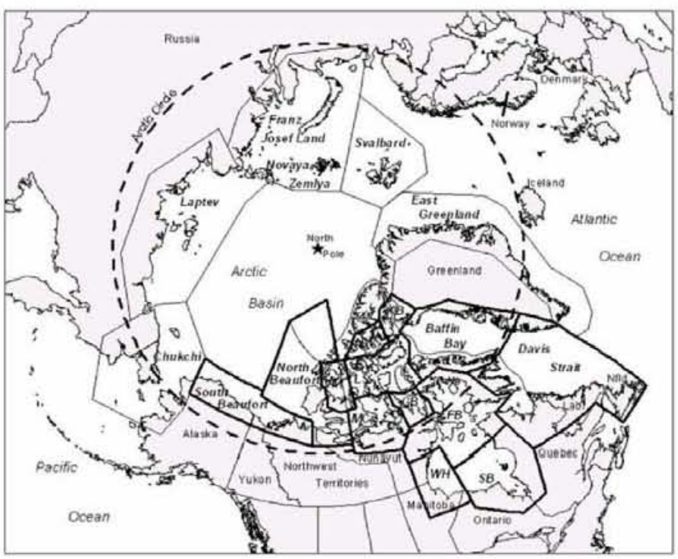

Figure 2: Circum-Arctic polar bear populations according to U.S. Fish and Wildlife Service (source: http://alaska.fws.gov/fisheries/mmm/polarbear/images/circumpolar-maplg.gif). GB=Gulf of Boothia; FB=Foxe Basin; KB = Kane Basin; LS=Lancaster Sound; MC=M'Clintock Channel; NW=Norweigian Bay; SB=Southern Hudson Bay; WH=Western Hudson Bay.

Polar bears are dependent upon sea ice for their survival, using it to hunt their primary food source, seals (Stirling, 1974; Stirling and Latour, 1978; Smith, 1980). Polar bear populations are generally most abundant on the annual ice over the relatively shallow waters of the continental shelf, which are more biologically productive than the offshore deep waters (Stirling et al., 1982; Kingsley et al., 1985; Stirling and Oritsland, 1995). Both the southern and northern Beaufort polar bear populations move north with the ice as it melts in the summer (Amstrup et al., 2000; Mauritzen et al., 2003; Wiig et al., 2003). More polar bears in the Beaufort Sea are also being found on land during the summer season, indicating not all bears move north with the ice (Schliebe et al., 2006).

On May 14, 2008, the polar bear was listed as a threatened species under the Endangered Species Act of the United States. Canada has not listed the polar bear as a threatened species. For many years, the United States and Canada have cooperatively managed hunting polar bears of the southern Beaufort population that encompasses northern Alaska, the Yukon, and

Northwest Territories (Brower et al., 2002). In response to the U.S. listing polar bears as threatened, U.S. Secretary of the Interior, Dirk Kempthorne, and his Canadian counterpart, John Baird, Minister of the Environment, have signed a Memorandum of Understanding for both conserving and managing polar bear populations that are shared by both countries.

Population Estimates

The total estimated size of the southern Beaufort polar bear population based on longterm capture/recapture statistics and population models is 1,526 individuals (±315, 95% CI) (Regehr et al., 2006). Because of uncertainties, this value can not be statistically differentiated from previous estimates of population size, suggesting that the population is stable. However, declining cub survival rates, and decreasing skull and body weight measurements for adult males from this population suggests these southern Beaufort polar bears are nutritionally stressed (Regeher et al., 2007).

Similar capture/recapture models used to estimate the northern Beaufort polar population give an estimate of 980 individuals (±155, 95% CI) (Stirling et al., 2007). These size estimates are also statistically indistinguishable from earlier estimates of the size of the northern Beaufort population. This population, however, is interpreted to be stable (Stirling et al., 2007). The smaller number of polar bears in this northern area (980 individuals versus 1,526 in the southern area), together with the larger areal size of the northern area (compare southern and northern Beaufort areas in Figure 2) indicates that the average density of polar bears in this northern area is considerably less than that of the southern area.

According to Lunn et al. (2002), the total population of circum-Arctic polar bears is ~21,000 - ~25,000. Therefore, the southern and northern Beaufort populations (±2506 individuals) comprise ~ 10 - ~12 % of the total polar bear population.

Potential Encounters

Healy may encounter polar bears from the southern Beaufort population while departing from and returning to Barrow at the start and end of the cruise, although open water conditions during this time of year when ice thaw is at its greatest will contribute to minimizing encounters. For the duration of the cruise, the tracks are primarily within the area of the distribution of the northern Beaufort population.

Polar bears expected to be encountered during the *Healy* 2008 cruise are likely to be few in number. On the *Healy* 2005 cruise with marine mammal observers, three polar bear were sighted along ~2,400 km of observed trackline during 14 days from 70° N to 81° N (Haley and Ireland, 2006). Similarly, for the 2007 Louis 42-day cruise in the Canada basin just north of the U.S. 200 nautical mile limit, less than 30 polar bears were sighted along the ~3,000 km of tracklines (H.R. Jackson, Chief Scientist aboard *Louis,* personal communication).

Effects on the polar bear are anticipated to be minor. Encounters are expected to be when the polar bears are on the ice, where underwater signals from *Healy* multibeam, Chirp systems, or engine noise will not be heard. The sea surface is an efficient reflecting horizon and underwater sound generally does not pass into the air. If any of the encountered polar bears are in the water, levels of *Healy* sound systems would be attenuated by the pressure release effect at the air/water interface (Greene and Richardson, 1988; Richardson et al., 1995). Polar bears generally do not dive much below the water's surface.

The icebreaking operation may change the geometry or width of open-water leads, and therefore affect habitat, but these changes are expected to be minor. *Healy* will make every attempt to follow existing leads rather than creating new leads during the profiling. Depending on wind and current conditions, the ice often closes behind the vessel returning the track path to its previous ice-covered state.

IV. Subsistence Harvest Considerations (from the draft IHA, by LGL)

Marine mammals are legally hunted in Alaskan waters by coastal Alaska Natives; species hunted include bowhead and beluga whales; ringed, spotted, and bearded seals; walruses, and polar bears. The importance of each of the various species varies among the communities based largely on availability. Bowhead whales, belugas, and walruses are the marine mammal species primarily harvested during the time of the proposed seismic survey. Subsistence remains the basis for Alaska Native culture and community, and subsistence activities are often central to many aspects of human existence, including patterns of family life, artistic expression, and community religious and celebratory activities.

The community of Barrow hunts bowhead whales in both the spring and fall during the whales' seasonal migrations along the coast . Often the bulk of the Barrow bowhead harvest is taken during the spring hunt. However, with larger quotas in recent years, it is common for a substantial fraction of the annual Barrow quota to remain available for the fall hunt. The communities of Nuiqsut and Kaktovik participate only in the fall bowhead harvest. The fall migration of bowhead whales that summer in the eastern Beaufort Sea typically begins in late August or September. Fall migration into Alaskan waters is primarily during September and October. However, in recent years a small number of bowheads have been seen or heard offshore from the Prudhoe Bay region during the last week of August (Treacy 1993; LGL and Greeneridge 1996; Greene 1997; Greene et al. 1999; Blackwell et al. 2004).

The scheduling of the 2010 two-icebreaker seismic survey has been discussed with representatives of those concerned with the subsistence bowhead hunt, most notably the AEWC, the Barrow Whaling Captains' Association, and the North Slope Borough (NSB) Department of Wildlife Management. The timing of the proposed geophysical survey in early – mid-August will affect neither the spring nor the fall bowhead hunt. The *Healy* is planning to change crew after completion of the geophysical survey through Barrow via helicopter or boat. That crew change is scheduled ~5-6 September, well before the fall bowhead whaling which typically begins late September or early October. All of the proposed geophysical activities will occur offshore between 71° and 84°N latitude well north of Beaufort Sea whaling activities.

USGS continues to work with the people of Barrow to identify and avoid areas of potential conflict.

- The USGS initiated contact with NSB scientists and the chair of the AEWC in mid-December 2010 via an emailed description of the proposed survey that included components intended to minimize potential subsistence conflict.
- Invitations were extended on 31 December 2009 to members of the NSB, AEWC and North Slope Communities to attend a teleconference arranged for 11 January 2010. The teleconference served as a venue to promote understanding of the project and discuss shareholder concerns. Participants in the teleconference included Harry Brower, chair of the AEWC, and NSB wildlife biologist Dr. Robert Suydam.
- To further promote cooperation between the project researchers and the community, Dr. Deborah Hutchinson with USGS presented the proposed survey at a meeting of the AEWC in Barrow on 11 February 2010. Survey plans were explained to local hunters and whaling captains, including NSB Department of Wildlife Management biologists, Craig George and Robert Suydam. Dr. Hutchinson consulted with stakeholders about their concerns and discussed the aspects of the survey designed to mitigate impacts.
- Dr. Deborah Hutchinson of the USGS emailed a summary of the topics discussed during the teleconference and the AEWC meeting in Barrow to representatives of the NSB, AEWC and North Slope communities. These included:
    - Surveying within U.S. waters is scheduled early (~7-12 August) to avoid conflict with hunters
    - The EA and IHA application will be distributed as early as possible to NSB and AEWC
    - A community observer will be present aboard the *Healy* during the project
    - Mitigation of the one crew transfer near Barrow in early September will be arranged – probably through Barrow Volunteer Search and Rescue
- Representatives of the USGS attended the Arctic Open-water Meeting in Anchorage, 22-24 March.

- Dr. Deborah Hutchinson presented information regarding the proposed survey to the general assembly
- Dr.s Jonathan Childs and Deborah Hutchinson met with stakeholders and agency representatives while at the meeting

Subsequent meetings with whaling captains, other community representatives, the AEWC, NSB, and any other parties to the plan will be held if necessary to coordinate the planned seismic survey operation with subsistence hunting activity. The USGS has informed the chairman of the Alaska Eskimo Whaling Committee (AEWC), Harry Brower, Jr., of its survey plan.

In the unlikely event that subsistence hunting or fishing is occurring within 5 km (3 mi) of the project vessel tracklines, or where potential impacts could occur, the airgun operations will be suspended until the vessel is >5 km away and otherwise not interfering with subsistence activities.

V. Polar Bear Interaction Strategy

The objectives of the polar bear interaction strategy are to avoid situations where polar bears will be encountered at less than 1 km, and to minimize disturbance to their natural habitat. This strategy contains four parts: (a) survey designs that minimize encounters; (b) protected resource observer actions; (c) protected resource observer actions in support of *Louis* operations; and (d) steps to follow when an encounter occurs. Because no scientists are expected to work on the ice, there should be no human-bear interactions. Further, *Healy* does not have a helicopter aboard, so this interaction strategy does not include actions for hazing or moving polar bears on the ice.

Survey Designs that Minimize Encounters

- All of the proposed track lines are in water depths or greater than 1900 m, i.e., well beyond the continental margin and shallow-water habitats of the continental shelf where polar bear prefer to live (Stirling and Oritsland, 1995).
- The long, linear proposed tracks mean *Healy* (and *Louis)* will not be in any one area for an extended period of time. Therefore, any encounters with and presumed impacts on bears will be local and of short duration.
- Every attempt will be made to follow existing leads while fulfilling the objectives and safe operations of the cruise, and simultaneously avoiding any sighted polar bears. Conducting the experiment in existing leads should minimize disturbance of sea-ice habitat.
- The speed of proposed profiling (2-4 knots, depending on how heavy the sea ice is) should allow sufficient time to visually identify polar bears at a distance and take appropriate actions.
- The Chief Scientist of *Healy* will brief the ship and science crew of this plan at the beginning of the experiment and post copies of the plan on the bridge, lounge, and actively-used laboratories.

Protected Resource Observer (PRO) Actions

- There will be three protected resource observers aboard *Healy,* with training and background in biological research as required by NOAA/NMFS; and a fourth community observer with indigeneous/traditional knowledge, experienced in the Arctic landscape and a background in subsistence hunting.

- The PROs will record all polar bear observations using the attached polar bear observation form (Attachment C).
- A response strategy for when a polar bear is encountered will be followed, as outlined in the polar bear interaction notification diagram (Attachment D).

Protected Resource Observer Actions in Support of Louis *Operations*

- When *Louis* is in US waters, two *Healy* PROs will join the three *Louis* PROs to monitor and mitigate for marine mammals, including polar bears, from aboard *Louis*. The proposed safety zone within the US EEZ is 500 m.
- While the two icebreakers work in tandem in international or Canadian waters, *Healy* PROs will make observations in support of PROs aboard *Louis* who will be recommending actions to be taken for *Louis* seismic operations. The safety radius for Louis seismic operations and marine mammals will be 500 m – 1 km.
- A copy of portions of the 2009 Canadian Environmental Assessment relevant to marine mammals and polar bears is given at the end of this document.
- *Healy* PROs will be in regular communication with PROs aboard *Louis* regarding any polar bear sightings.
- A wireless network and radio communications between the two ships will facilitate regular and on-demand communications between the PROs on both vessels.

Steps to Follow when an Encounter Occurs

- For the sighting of a polar bear at a distance greater than 1 km, the PRO will record all relevant details about the sighting on the polar bear observation form (Attachment C).
- When *Louis* is operating in the US EEZ and a polar bear is sighted near the 500-m safety zone, the PROs aboard *Louis* will decide the appropriate course of action to be taken for the seismic operations (for example, shutting down the seismic operations or altering course). The PROs will also record all details of the incident on the polar bear observation form (Attachment C).
- When *Healy* is operating inside the US EEZ and a polar bear is sighted near the 500-m safety zone, the PROs aboard *Healy* will decide the appropriate course of action to be taken (for example, contacting Louis PROs). The PROs will also record all details of the incident on the polar bear observation form (Attachment C).
- When the two icebreakers are operating in tandem outside of the US EEZ and an incidental encounter with a polar bear occurs within 500 m of *Healy,* the PROs will immediately notify the PROs aboard *Louis* who will decide the appropriate course of action to be taken for the seismic operations (for example, shutting down the seismic operations or altering course). The PROs will also record all details of the incident on the polar bear observation form (Attachment C).
- If there are any lethal encounters with a polar bear as a result of *Healy* operations, the PROs will immediately notify the U.S. Fish and Wildlife Service (Craig Perham) as well as recording details, relevant witness statements, and other information. The entire carcass will be transported to shore (Barrow, AK). The U.S. Fish and Wildlife Service (Craig Perham) will decide disposal of the carcass.

U.S. Fish and Wildlife Contacts:
Primary: Craig Perham
Polar Bear and Incidental Take Coordinator
U.S. Fish and Wildlife Service
Marine Mammals Management
1011 E. Tudor Road
Anchorage, Alaska, 99503
907-786-3810
Craig.Perham@fws.gov

Alternate: Tom Evans
907-786-3814
Thomas_Evans@fws.gov

VI. 2009 *Louis* Marine Mammal Monitoring and Mitigation Strategy

This section gives relevant sections of the DFO environmental assessment with respect to polar bears or to marine mammals when polar bears are not specifically cites. The source of information is:

Hawkins, C.M., 2008, Canadian polar margin seismic reflection survey in waters offshore of the western Canadian Arctic Islands in support of the Law of the Sea, Environmental Assessment - 2009 Survey: Dartmouth, NS., Administrative Report prepared for D. Mosher, July, 2009, 122 pp.

3.3.7 Polar Bears

Taylor and Lee (1995) have discussed the distribution and abundance of Canadian Polar Bear Populations. For the Canadian Arctic they have determined that there are 12 discrete polar bear populations based on movements of marked and recaptured as well as killed bears (Figures 7,8). Two populations are important with respect to the CPMSRS-09, the southern Beaufort Sea and Northern Beaufort Sea populations. Based on their data, they have estimated that the density of southern Beaufort Sea polar bear population is in the order of 7 bears per 10,000 km^2 and for the northern Beaufort Sea population a density of about 6.5 bears per 10,000 km^2. Given that the total area to be surveyed in this study is about 350,000 km^2 there could be potentially 250 polar bears within the entire survey area.

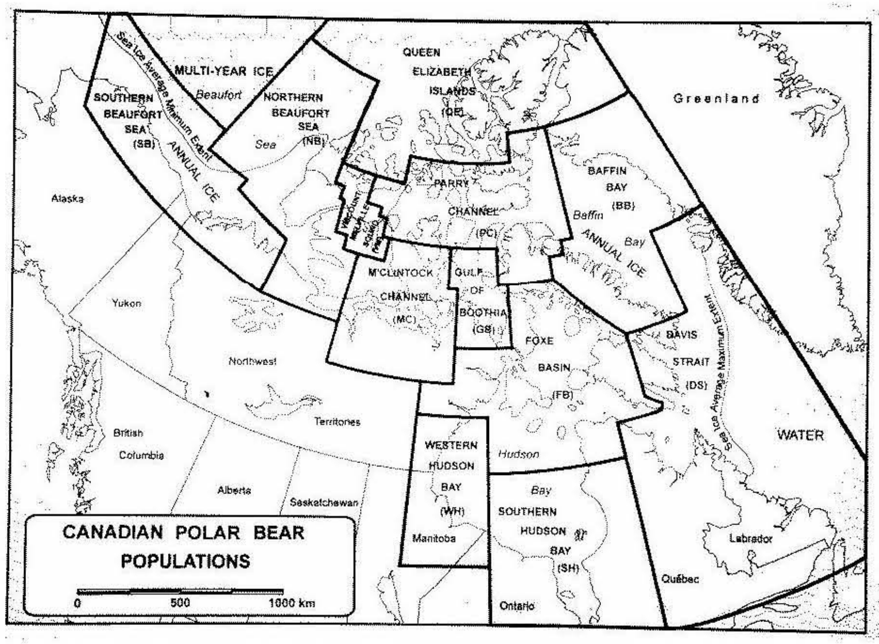

Figure 7. Polar Bear distribution in the Arctic, see text for discussion. (From Taylor and Lee 1995)

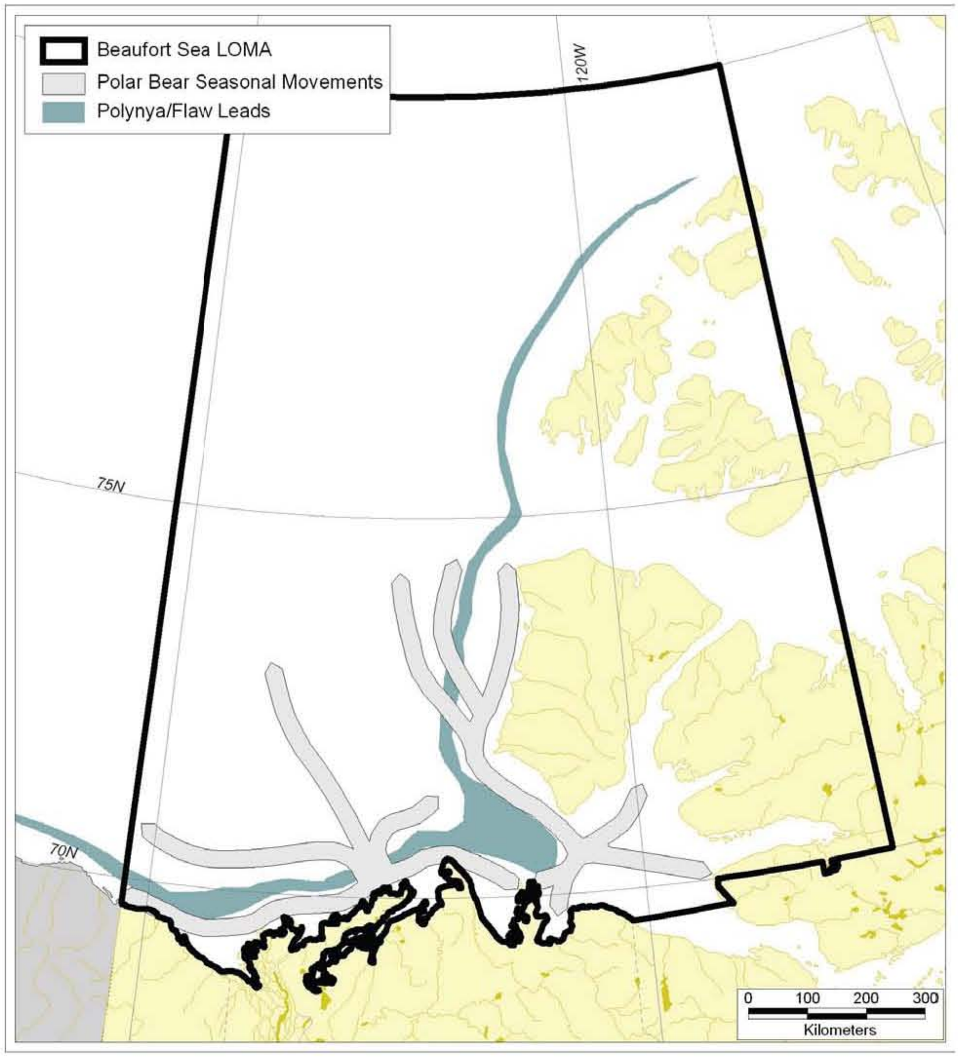

Figure 8. General pattern of seasonal polar bear movements in the Beaufort Sea (DFO 2007a).

4.4 Potential Impacts of Project ...

4.4.1 Marine Mammals
... With respect to polar bears, it is highly unlikely that the sub-sea sound produced will impact bears if they are encountered as the sound will be produced underwater.

8.0 Mitigation

...
All standard and industrially related mitigation measures pertaining to the use of seismic pneumatic energy source arrays for exploration will be adopted and followed by the CPMSRS-09. For the marine mammals, especially the whales, it has generally been accepted that a safety radius or zone of about 1000 m from the sound generating source be adopted to reduce received sound levels (LGL 2005, DFO 2007). This safety zone will be adopted for the CPMSRS-09. Note that this sound level of about 176_{rms} dB re 1 μPa at 500 m is about the same sound production level that is produced by cracking and breaking pack ice that is prevalent in this high Arctic environment (Greening and Zakarauskas 1984), and represents a background noise level. More mitigation measures with respect to potential marine mammal interaction with the project will be adopted. These include:

1 Alteration of vessel speed/course providing it will not compromise operational safety requirements.

2 Pneumatic energy sources will be shut down if any marine mammal enters or is anticipated to enter the 1000 m safety zone through observations by a trained marine mammal observer on the research vessel.

3 Pneumatic energy source start-up procedures will not commence unless a full 1000 m safety zone is clear of any marine mammal by visual inspection by a trained marine mammal observer for a continuous period of at least 30 minutes.

4 The pneumatic energy source array will be "powered down" during transit from one seismic line to another. All guns will be turned off except for one gun, which will function as a signal intended to alert marine mammals of the presence of a seismic vessel in the region.

5 Total shut down of all pneumatic energy source activity will occur and not resume until all marine mammals have cleared the 1000 m safety zone.

6 Pneumatic energy source start-up procedures will include a "ramping up" period. The rate of ramping up will be monitored so that it will not exceed more than 5 dB per 5 minute period.

7 The location of the CPMSRS-09 will not take place in the vicinity of any beluga harvest area or during the period of beluga harvest.

8 There will be 3 marine mammal observers on board the seismic research vessel. Note that there is about 24 hours of light in this region at the time of the proposed survey that will aid the observers.

With respect to polar bears, it is highly unlikely that the sub-sea sound produced will impact bears if they are encountered. If seen by a trained marine mammal observer within the 1000 m safety zone all of the above mitigation measures will be applied to ensure that no project interaction occurs.

…

Overall, by adopting all industrial mitigative standards as well as more stringent measures discussed above no anticipated measurable environmental impacts are predicted for the CPMSRS-09 project. .

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Attachment C: Polar Bear Observation Form

United States Department of the Interior

FISH AND WILDLIFE SERVICE
1011 E. Tudor Road
Anchorage, Alaska 99503-6199

POLAR BEAR SIGHTING REPORT

Date: _________ Observer name: ______________________________
Time: _________ Contact number/email: ________________________

Location: ____
____

Latitude: ___________________ Longitude_____________ Datum: ________

Weather conditions: Fog_____ Snow_____ Rain_____ Clear_____ Temperature_____F/C

Wind speed_____mph/kts Wind direction_________ Visibility: Poor
Fair
Good
Excellent_________

Number of bears:
_____ Adult M/F _______ Sow/cub(s)
_____ Sub-adult _______ Sow/yearling(s)
_____ Unknown _______ Sow/2YO(s)

Estimated distance of bear(s) from personnel_____ (meters) and facility: ____ (meters)

Possible attractants present: ______________________________________

Bear behavior: Curious_____ Aggressive_____ Predatory_____ Passing through ____ Other____

Description of encounter: ____
____
____
____

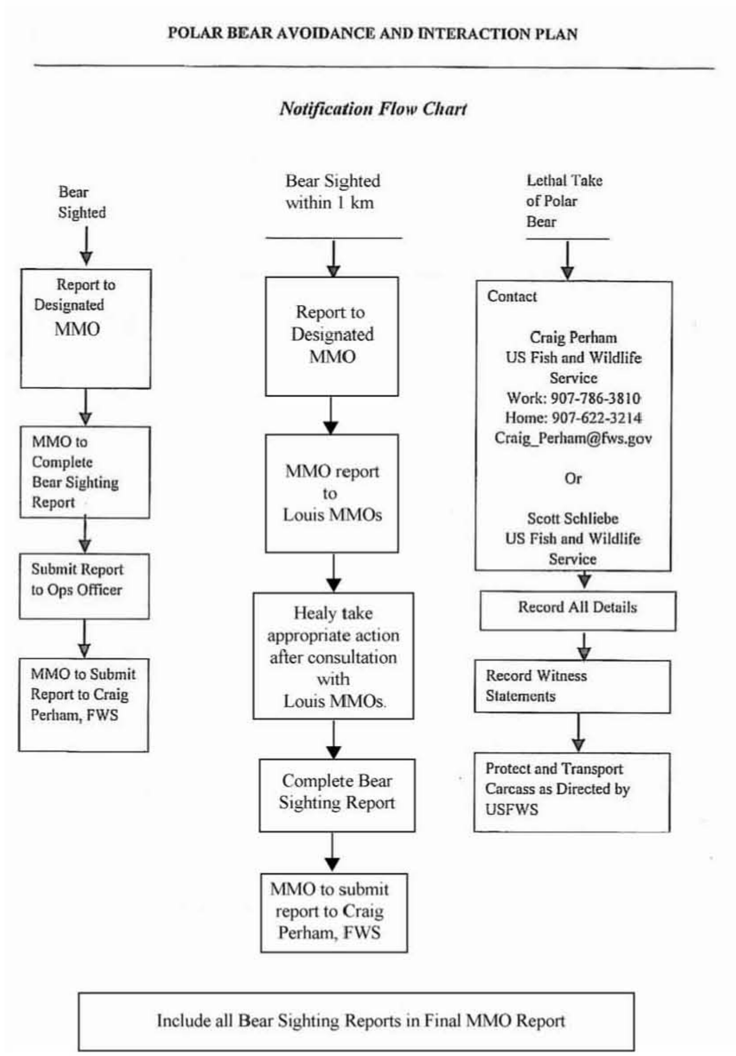
Duration of encounter: ____

Deterrents used/distance:
_____ Vehicle _____ Bean bag _____Other
_____ CrackerShell _____ Horn/siren ____________________
_____ Rubber bullet _____ Spotlight/Headlight

Agency/Contacts:

USFWS______________________________ Time______ Date________
ADF&G______________________________ Time______ Date________
CLIENT______________________________ Time______ Date________

Attachment D: Polar Bear Interaction Notification Diagram



APPENDIX E: DEVELOPMENT AND IMPLEMENTATION OF SAFETY RADII

This appendix provides additional background information on the development and implementation of safety radii as relevant to the USGS geophysical survey discussed in this report. Further information on these topics can be found in the IHA application and EA (USGS 2010; Haley et al. 2010).

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, 2000). 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.

Sound level radii within which received levels were expected to diminish to various values relevant to NMFS criteria mentioned above were estimated based on a combination of acoustic modeling and empirical measurements for the 2010 USGS geophysical survey. Empirical data were obtained by Mosher et al. (2009) for sounds from the 1150-in^3 G-gun array during a 2009 seismic calibration experiment in the Arctic Ocean. A transmission loss model was then constructed assuming spherical (20LogR) spreading and using the source level estimate (235 dB re 1μPa 0-peak; 225 dB re 1 μPa rms) from the measurements. The use of 20LogR spreading fit the data well out to ~1 km (0.6 mi) where variability in measured values increased (Fig. E.1). Additionally, the Gundalf® modeling package was used to model the airgun array and estimated a source level output of 236.7 dB 0-peak (226.7 dB rms). Using this slightly stronger source level estimate and 20LogR spreading the 180 and 190 dB rms radii are estimated to be 216 m (708 ft) and 68 m (222 ft), respectively. As a conservative measure for the safety radii, the sound-level radii indicated by the empirical data and source models were more than doubled to 500 m (1641 ft) for the 180-dB isopleth and increased by ~1.5 times to 100 m (327 ft) for the 190-dB isopleth (Table 3.1). These larger, more cautionary distances were used by PSOs for implementing mitigation measures during the survey.

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., delphinids, porpoises, 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.

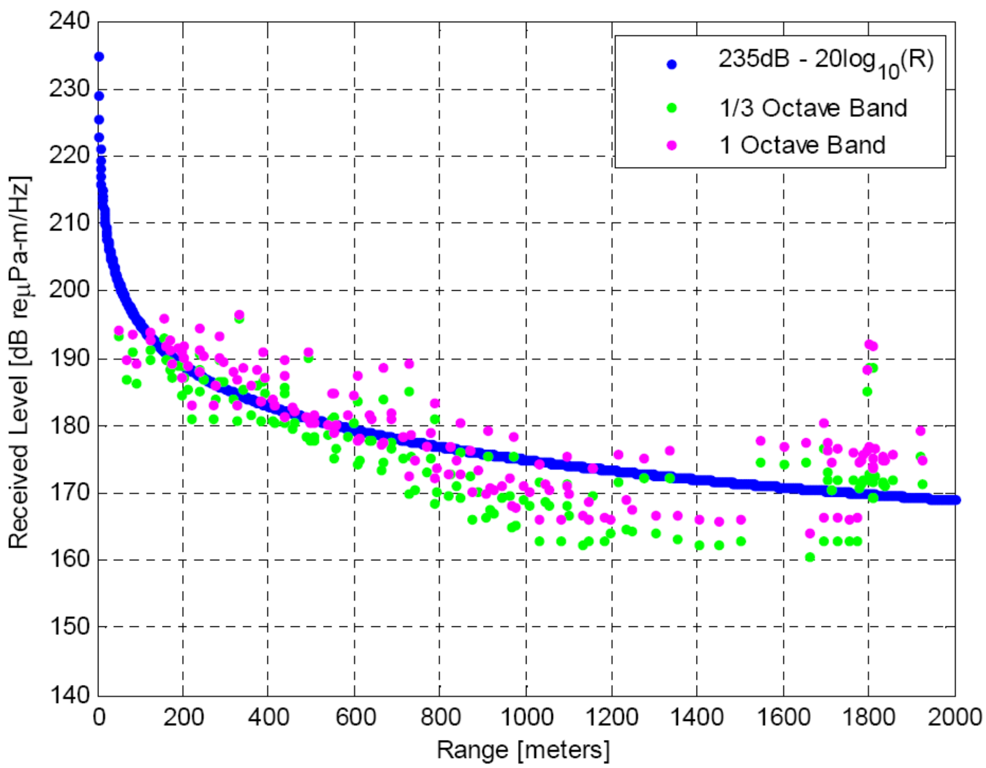


Figure E.1. Measured peak sound pressure levels as a function of range for 1/3 and full octave bands. The blue line shows theoretical spherical spreading loss for a 235 dB marine source as a comparison (Roth and Schmidt 2010).

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APPENDIX F: DESCRIPTION OF THE LOUIS S. ST-LAURENT AND ITS EQUIPMENT

Louis S. St-Laurent

Figure. F.1. Photo of *Louis S. St-Laurent* available online at: http://www.ccg-gcc.gc.ca/eng/Fleet/Vessels?id=1111&info=5&subinfo=4

USGS used the CCG cutter *Louis S. St-Laurent* for the seismic study to tow the airguns and hydrophone streamer. The *Louis S. St-Laurent* was built in 1969 by Canadian Vickers Ltd. in Montreal, Quebec, and underwent an extensive modernization in Halifax, Nova Scotia between 1988-1993. The *Louis S. St-Laurent* is based at CCG Base Dartmouth in Dartmouth, Nova Scotia. Current vessel activities involve summer voyages to the Canadian Arctic for sealifts to various coastal communities and scientific expeditions. The overall length of the *Louis S. St-Laurent* is 119.8 m and its gross registered tonnage is 11,345 with a draft of 9.91 m. The total fuel capacity of the *Louis S. St-Laurent is* 4800 m^3 with a fuel consumption rate of 24 m^3 per day. The *Louis S. St-Laurent* is equipped with fresh water making capabilities, and a sludge and waste oil incinerator.

Airgun Description

The seismic source used for the 2010 USGS geophysical survey consisted of three Sercel G-guns with a total volume of 1150 in3. The three-gun array was comprised of two 500 in^3 and one 150 in^3 G-guns in a triangular configuration (Fig. F.2). A 150-in^3 G-gun was used as a mitigation source during power downs when marine mammals were observed within or about to enter the applicable full array safety radius and during mechanical issues. The G-gun array was towed just behind the stern of the *Louis S. St-Laurent* at a depth of ~11.2 m (36.6 ft; Fig. F.3). One streamer ~300 m (984 ft) in length with a single hydrophone was also towed behind the airgun array. The distance from the source to the end of the multichannel hydrophone was ~232 m (762 ft). Air compressors aboard the *Louis S. St-Laurent* were the source of high pressure air used to operate the airgun array. Seismic pulses were emitted at various intervals depending on vessel speed (typically ~19.5 s) and recorded at a 2 ms sampling rate. The 19.5s spacing corresponds to a shot interval of ~44 m (144 ft) at the typical survey speed of 4.0-4.5 kts. In general, the *Louis S. St-Laurent* towed this system along a predetermined survey track, although adjustments were occasionally made during repairs to the equipment.

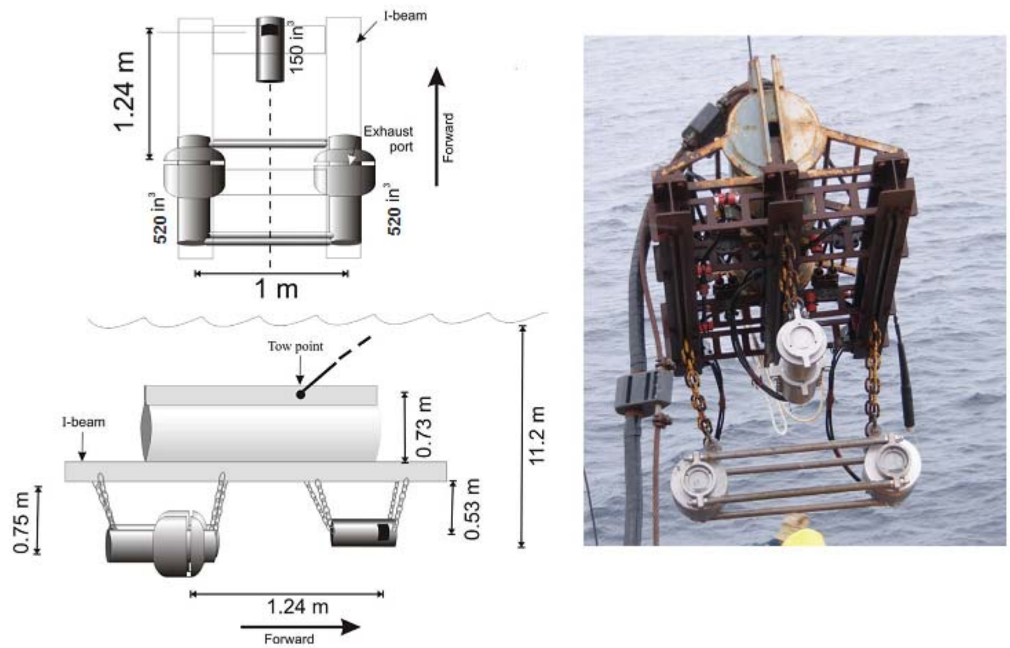

FIGURE F.2. Configuration of three Sercel G airguns during seismic operation from the *Louis S. St-Laurent* 2010.

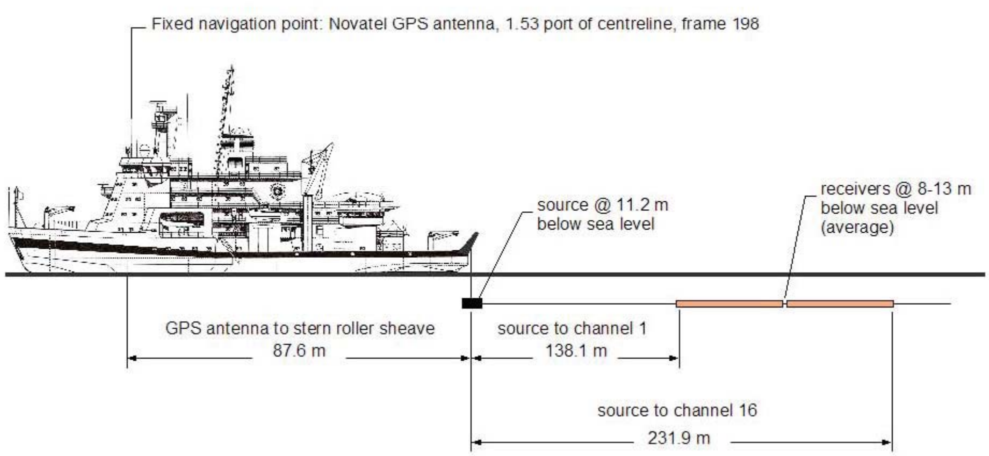

FIGURE F.3. Geometric arrangement of the seismic source and streamer (Mosher et al. 2009).

Bathymetric Sonar and Sub-bottom Profilers

Along with the airgun operations, two additional acoustic systems operated during the cruise. A 12-kHz echo sounder and a 3.5-kHz chirp sub-bottom profiler operated during portions of the cruise to provide information on the depth, bottom profile and sub-bottom conditions, as necessary to meet the geophysical science objectives. During seismic operations, the 12-kHz echo sounder typically operated simultaneously with the airgun array, whereas the 3–5 kHz chirp sub-bottom profiler was only used when the *Louis S. St-Laurent* was not working in tandem with the *Healy*.

Echo Sounder (Knudsen 320BR)

The Knudsen 320BR echo sounder was used on the *Louis S. St-Laurent* to provided information on depth and bottom profile. The Knudsen 320BR is a dual–frequency system with operating frequencies of 3.5 and 12 kHz, however, the unit only functioned at the higher frequency during the cruise, because the 3.5 kHz transducer was not installed. While the Knudsen 320BR operated at 12 kHz, its calculated maximum source level (downward) was 215 dB re 1 µPa at 1 m. Pulse intervals were typically 1.5 to 5 ms with a bandwidth of 3 kHz (FM sweep from 3 kHz to 6 kHz). The repetition rate was typically between 1/2 s (in shallow water) to 8 s in deep water.

A single 12 kHz (sub-bottom) transducer array, consisting of 16 elements in a 4 × 4 array was used for the Knudsen 320BR. The 12 kHz transducer (TC-12/34) emitted a conical beam with a width of 30°.

Towed 3–5 kHz Chirp Sub-bottom Profiler (Knudsen 3260)

The 3–5 kHz chirp sub-bottom profiler was towed by and operated from the *Louis S. St-Laurent* in open water when the *Louis S. St-Laurent* was not working in tandem with the *Healy*. The profiler provided information about sedimentary features and bottom topography. The chirp system had a maximum 7.2 kW transmitting capacity into the towed array. The energy from the towed unit was directed downward from an array of eight transducers in a conical beamwidth of 80°. The interval between pulses was no less than one pulse per second. Sub-bottom profilers of a similar frequency produce sound levels of 200-230 dB re 1 µPa at 1 m (Richardson et al. 1995).

APPENDIX G: DESCRIPTION OF THE HEALY AND ITS EQUIPMENT

Healy

Figure. G.1. Photo of the U.S. Coast Guard cutter *Healy*. A description with vessel specifications for the *Healy* is available online at: http://www.uscg.mil/pacarea/cgcHealy/default.asp

USGS used the USCG cutter *Healy* to collect bathymetric data and sediment and rock samples, as well as break and clear ice for the *Louis S. St-Laurent* during seismic operations in ice-covered areas. The *Healy* was self-contained, with the crew living aboard the vessel. The *Healy* has a length of 128 m, a beam of 25 m, and a full load draft of 8.9 m. The *Healy* is a USCG icebreaker, capable of traveling at 5.6 km/h (3 knots) through 1.4 m of ice. A "Central Power Plant", four Sultzer 12Z AU40S diesel generators, provides electric power for propulsion and ship's services through a 60 Hz, 3-phase common bus distribution system. Propulsion power is provided by two electric AC Synchronous, 11.2 MW drive motors, fed from the common bus through a Cycloconverter system that turn two fixed-pitch, four-bladed propellers. The *Healy* cruises at 22 km/h (12 knots) and has a maximum speed of 31.5 km/h (17 knots). She has a normal operating range of about 29,650 km (16,000 n. mi.) at 23.2 km/hr (12.5 knots).

Bathymetric Sonar and Sub-bottom Profilers

Five acoustic systems operated from the *Healy* during the 2010 USGS geophysical survey. A 10.5–13 (usually 12) kHz Kongsberg multibeam bathymetric echo sounder (MBES) and a 3.5-kHz sub-bottom profiler operated throughout most of the cruise to map the bathymetry and sub-bottom conditions, as necessary to meet the geophysical science objectives. An Acoustic Doppler Current Profiler operated constantly as an additional depth sounder, especially when the *Healy* was operating in shallow areas.

Multi-beam Echo Sounder (Kongsberg EM 122)

A Kongsberg EM 122 multi-beam 10.5-13 (usually 12) kHz echo sounder system was used on the *Healy*, with a maximum source output of 242 dB re 1 µPa at one meter. The transmitting beamwidth was 1° fore–aft and 150° athwartship. Each "ping" consisted of eight (in water >1000 m deep) or four (<100 m deep) successive fan-shaped transmissions, each of which ensonified a sector that extended 1° fore–aft. Continuous-wave (CW) pulses ranged in length from two to 15 ms in water depths up to 2600m, and FM chirp pluses lasted up to 100 ms long and were used in water depths >2600m. The successive transmissions spanned an overall cross-track angular extent of about 150°, with 2-ms gaps between the pulses for successive sectors.

Hydrographic Sub-bottom Profiler (Knudesen 320BR)

The Knudsen 320BR sub-bottom profiler provided information on sedimentary layering below the bottom, depending on bottom type and slope. It was operated with the multi-beam echo sounder system that simultaneously mapped the bottom topography. During normal operation, the operator adjusted the transmit level for optimum penetration into the seafloor. The energy from the sub-bottom profiler was directed downward from the transducer array mounted in the hull of the vessel. It was a dual–frequency system with operating frequencies of 3.5 and 12 kHz. Maximum output power at 3.5 kHz was 10 kW and at 12 kHz was 2 kW. Pulse lengths up to 24 ms and bandwidths to 5 kHz were available. Pulse intervals were typically 1/2 s to about 8 s depending upon water depth. The repetition rate was range-dependent with a maximum 1% duty cycle.

There was a single 12 kHz transducer plus one 3.5 kHz, low frequency (sub-bottom) transducer array, consisting of 16 elements in a 4 × 4 array used for the Knudsen 320BR. The 3.5 kHz transducer (TR109) emitted a conical beam with a width of 26° and the 12 kHz transducer (TC-12/34) emitted a conical beam with a width of 30°.

Piloting Echo Sounder (ODEC Bathy 1500)

The Ocean Data Equipment Corporation (ODEC) Bathy 1500 provided information on water depth below the vessel. The ODEC system had a maximum 2 kW transmitting capacity into the transducer and had two operating modes, single or interleaved dual frequency, with available frequencies of 12, 24, 33, 40, 100, and 200 kHz.

Acoustic Doppler Current Profiler (150 kHz)

The Acoustic Doppler Current Profiler (ADCP™) operated at 150 kHz and had a minimum ping rate of 0.65 ms. There were four beam sectors and each beamwidth was 3°. The pointing angle for each beam was 30° off from vertical with one each to port, starboard, forward and aft. The four beams did not overlap. The 150 kHz Broad Band ADCP™'s maximum depth range was 300 m. The ADCP™ also served as a depth sounder in shallow water.

Acoustic Doppler Current Profiler (R D Instruments Ocean Surveyor 75)

The Ocean Surveyor 75 was an ADCP™ operating at a frequency of 75 kHz, producing a ping every 1.4 s. The system was a four-beam phased array with a beam angle of 30°. Each beam had a width of 4° and there was no overlap. Maximum output power was 1 kW with a maximum depth range of 700 m.

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

This appendix provides details on the standard visual monitoring methods and data analysis techniques implemented for this project. Vessel-based protected species observers (PSOs) were stationed on both the *Louis S. St-Laurent* and the *Healy* during the entire 2010 USGS geophysical survey. Three trained PSOs, knowledgeable about marine mammals of the Arctic, were recruited through a Canadian Hunters and Trappers committee to work on the *Louis S. St-Laurent*. These observers boarded the *Louis S. St-Laurent* in Kugluktuk, Nunavut, Canada. Three experienced PSOs and an Alaska Native observer were also aboard the *Healy* at the outset of the project. Before survey operations began in U.S. waters, two of the PSOs on the *Healy* transferred to the *Louis S. St-Laurent*. Thus, during operations in the U.S. EEZ, a complement of five observes were on the source vessel, the *Louis S. St-Laurent*, and two were stationed on the *Healy*. When not surveying in U.S. waters, the distribution of PSOs returned to three on the *Louis S. St-Laurent* and four on the *Healy*.

All MMOs participated in a review meeting before the start of the study, designed to familiarize them with the operational procedures and conditions for the cruise, reporting protocols, and IHA stipulations. In addition, implementation of the IHA requirements was explained to the Operations Manager, Lead Marine Science Technicians, Head Airgun Operator and Chief Science Party PIs aboard the *Louis S. St-Laurent* prior to seismic operations. MMO duties included

- recording environmental and sightings data;
- searching for and identifying marine mammals, and recording their numbers, distance from the vessel, and behavior;
- recording possible reactions of marine mammals to the seismic operations;
- requesting mitigation measures be implemented, when appropriate.

Visual Monitoring for Marine Mammals

In U.S. waters, PSOs on the *Louis S. St-Laurent* monitored for marine mammals during all periods of airgun operations (all in daylight). Darkness was not encountered during the seismic survey in the U.S. EEZ. PSOs onboard the *Healy* also monitored for marine mammals during much of the time seismic operations were occurring in both U.S. and international waters. Seismic operations would have been suspended or amended if a marine mammal was observed within, or about to enter, designated safety radii described in the IHA. In general, observations for marine mammals followed these guidelines:

- Observations during daylight hours were conducted in good and poor visibility whenever the airguns were operating, and by two observers when possible.
- PSOs observed during periods without seismic operations to the maximum extent practicable, to obtain baseline data on marine mammal distribution and (in the case of less experienced observers) to become familiar with observation protocols.
- Two PSOs observed for 30 min prior to the planned start of seismic operations after an extended shut down (>10 min) and the entirety of the ≥180 dB radius was required to be visible for those 30 minutes.

From the duty station, PSO(s) systematically scanned the area around the vessel in a sweeping pattern, usually alternating scan sweeps between reticle binoculars and the unaided eye. Observations were focused forward and to the sides of the vessel, but PSOs also regularly checked for the presence of marine mammals astern of the vessel.

The duration of a single visual shift was typically no longer than 4 hr to minimize observer fatigue. Use of two observers simultaneously was desirable and scheduled when possible to increase detection of marine mammals near the source vessel. In addition to the dedicated PSOs, bridge personnel were instructed and assisted in detecting marine mammals, implementing mitigation requirements, and collecting data when possible.

While on watch, PSOs kept systematic written records of the vessel's position, activity, and environmental conditions using codes that were entered directly into a database using a hand-held computer. Vessel and environmental data were recorded onto the datasheet every 30 min or whenever conditions changed significantly. 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.

The following information was recorded for each marine mammal sighting: date, time, species, total number of individuals, bearing relative to bow of the vessel, direction of movement relative to the vessel, distance from the vessel, behavior when sighted, behavioral pace, reaction to the vessel, water depth, observer initials, and species identification reliability. On the *Louis S. St-Laurent*, distance to marine mammals was measured from the PSO's location on the bridge rather than from the nominal center of the seismic source. The distance of the animal from the airgun array was calculated using a GIS during data error checking and processing at the end of the season. 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 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 0-360°, with the bow of the vessel considered to be 0° and the stern 180°, regardless of the vessel's compass heading.

Operational activities that were recorded by PSOs onboard the *Louis S. St-Laurent* included the number of airguns in use, total volume of the airguns in use, and type of vessel/seismic activity. Intra-ship communication between geophysicists, seismic technicians and PSOs was conducted via radio or telephone and used to alert PSOs of any changes in operations. The position of the vessel was automatically logged every 60 seconds by the ships navigation system and these data were integrated with the marine mammal database to check for data recording errors. Details regarding the seismic activities (start and stop times, number of guns firing, etc.) was collected from the airgun operators log and also used to error check PSO data.

Marine Mammal Mitigation During Operations

The following mitigation measures were adopted for marine mammal sightings during the 2010 USGS geophysical program, provided that doing so did not compromise operational safety requirements: ramp ups, power downs, shut downs, and course alterations.

Ramp Up

A ramp up is a process commonly used by seismic vessels with large airgun arrays that involves a gradual increase in the number of airguns firing from none or one airgun until the full array is active. A ramp up was required when the full airgun array had not been operating for a period of >10 min. A 30 min watch period performed by at least two PSOs was required prior to a ramp up. The entire ≥180 dB safety radius for the full array must be visible for the entire 30-min pre-ramp up observation period before the ramp-up could commence. However, if the mitigation airgun had been operating during the break in full array activity, then a ramp up could be initiated at any time provided two PSOs were on active watch during the ramp up. If the airguns had been shut down or powered down because of the presence of a marine mammal within or near the applicable safety radius, a ramp up could not begin until that safety radius was clear of marine mammals. Following a marine mammal sighting the safety radius was considered clear when the marine mammal was observed to exit the safety radius, or if no marine mammals were seen in the safety radii for 15 min (for small odontocetes and pinnipeds) or 30 min (for mysticetes and large odontocetes). If a marine mammal was observed within the applicable safety radius during the 30-min pre-ramp up observation period, the airgun operator was informed and the ramp up was postponed.

Ramp ups of the airgun array began with firing the smallest airgun and increasing the number of airguns at a rate no greater than ~6 dB per 5-min period. During a ramp up, the safety zone for the full airgun array was maintained even though fewer airguns were operating.

PSOs informed the airgun operators when ramp up could proceed. If a marine mammal was observed within its applicable safety radius during the 30-min observation periods, or during the ramp up, the bridge and airgun operators were informed, as usual, of any necessary mitigation measures (power down, shutdown).

Power Down

A power down is a reduction in the number of operating airguns (usually from all airguns firing to a single mitigation gun firing). If marine mammals were detected outside the applicable safety radius of the full airgun array, 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), 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 the single mitigation airgun before the mammal(s) was within the full array safety radius. Likewise, if a mammal was first observed already within the full array safety radius, the airguns were immediately powered down. The single airgun continued firing at a source level of at least 180 dB re 1 μPa-m (rms) during the interruption of full array seismic operations. A shut-down (see below) was implemented only if a marine mammal was detected within or about to enter the smaller safety zone around the mitigation airgun. Full airgun activity did not resume (via a ramp up) until the marine mammal had cleared the safety zone for the full array.

Shut Down

A shut down is the cessation of all airgun activity, including the single mitigation airgun. If a cetacean or pinniped was detected within or about to enter the applicable safety radius of the mitigation gun, the airgun was shut down. After a shut down, the animal must have cleared the safety zone before start up procedures could begin. If the mitigation airgun was shut down for >10 min and no observer was on duty, then at least 30 min of observation by two PSOs was necessary prior to ramp up. PSOs informed the bridge when ramp up of the airgun(s) could proceed.

Vessel Course / Speed Alteration

If a marine mammal was detected outside the applicable safety radius and, based on its position and direction of travel, was likely to enter the safety radius, one mitigation measure was to adjust the ship track and/or speed to avoid close approach to the mammal. If the mammal appeared likely to enter the safety radius, further mitigation actions were taken, i.e., power or shut down of the airgun(s).

Data Analyses

Vessel Based Monitoring

This section describes the analyses of the marine mammal sightings and survey effort recorded during this project. It also describes the methods used to calculate densities and estimate the number of marine mammals potentially exposed to airgun and icebreaking sounds associated with USGS's geophysical survey.

The sightings and effort data were grouped into three categories to assess potential effects of seismic sounds on marine mammals. The categories were "seismic" (1 or more airguns operating and up to 3 minutes after airguns stopped firing), "post-seismic" (3 min to 1h for pinnipeds and 2 h for cetaceans after the airguns were turned off), and "non-seismic" (periods before seismic started or >1 or >2 h after airguns were turned off for pinnipeds and cetaceans, respectively). Unless specifically stated otherwise, comparison of seismic and non-seismic periods excluded the post seismic period. The justification for the selection of these criteria was based on the size of the array in use and is provided below. These criteria were also used and discussed in previous reports to NMFS (see Haley and Koski 2004; Smultea et al. 2004, 2005; MacLean and Koski 2005; Holst et al. 2005a,b):

- Mammal distribution and behavior during the short period up to 3 min after the last seismic shot 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 past 30 min) to sounds from the seismic survey. During at least part of the 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 PSOs. Given those considerations, plus the limited observed response of most marine mammals to seismic surveys (e.g., Stone 2003; Smultea et al. 2004; Haley and Koski 2005; MacLean and Koski 2005; Holst et al. 2005 a,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.

During periods when the *Healy* was outside U.S. waters or not within 75 km (47 mi) of the *Louis S. St-Laurent* in the U.S. EEZ, sightings and effort data were grouped into two categories to assess potential effects of icebreaking sounds on marine mammals. The categories were "icebreaking" (operating in areas with ≥80 ice cover), and "non-icebreaking" (operating in areas with <80% ice cover).

Estimation of Densities during Seismic Operations

There were too few sightings and too little observation effort within the U.S. EEZ to allow reliable calculations of densities from this survey alone. Therefore, we used densities reported or calculated from earlier marine mammal surveys in and near the Arctic Ocean. The following sections describe how the density estimates of marine mammals were calculated based on the sightings and effort data from available survey reports.

<u>Cetaceans</u>

Average and maximum densities for each cetacean species or species group reported to occur in U.S. waters of the Arctic Ocean, within the study area, are presented below. Densities were calculated based on the sightings and effort data from available survey reports. No cetaceans were observed during recent surveys near the project area in August/September 2005 (Haley and Ireland 2006), August 2006 (Haley 2006), August/September 2008 (Jackson and DesRoches 2010) or August/September 2009 (Mosher et al. 2009). Therefore, cetacean densities had to be obtained from available scientific literature.

Seasonal (summer and fall) differences in cetacean densities along the north coast of Alaska have been documented by Moore et al. (2000). The 2010 USGS/GSC project conducted seismic surveys in the U.S. EEZ from 12 Aug to 17 Aug and was considered to occur during the summer season.

The summer ***beluga*** density (Table H.1) was based on 41 sightings along 9022 km of on-transect effort that occurred over water >2000 m during the summer in the Beaufort Sea (Moore et al. 2000). A mean group size of 2.8 (CV=1.0) derived from BWASP data of August beluga sightings in the Beaufort Sea in water depths >2000 m was used in the density calculation. An *f*(0) value of 2.326 from Innes et al (2002) and a *g*(0) value of 0.419 from Innes et al. (2002) and Harwood et al. (1996) were also used in the density computation. The CV associated with group size was used to select an inflation factor of 2 to estimate the maximum density that may occur in the project area within U.S. waters. Most Moore et al. (2000) sightings were south of the seismic survey in the U.S. EEZ. However, Moore et al. (2000) found that beluga whales were associated with both light (1 – 10%) and heavy (70 – 100%) ice cover. Five of 23 beluga whales that Suydam et al. (2005) tagged in Kasegaluk Lagoon (northeast Chukchi Sea) travelled to 79 - 80°N into the pack ice and within the region of the survey. These and other tagged whales moved into areas as far as 1100 km (594 n.mi.) offshore between Barrow and the Mackenzie River delta, spending time in water with 90% ice coverage. Therefore, we applied the observed density calculated from the Moore et al. (2000) sightings as the average density for both "open water" and "ice margin" habitats. Because no beluga whales were sighted during the 2010 survey or other recent surveys in the survey area (Harwood et al. 2005; Haley and Ireland 2006; Haley 2006; Jackson and DesRoches 2010; and Mosher et al. 2009) the densities in Table H.1 are likely higher than the actual densities in the project area.

By the time the 2010 USGS survey started in August, most ***bowhead*** *whales* were expected to have traveled east of the project area to summer in the eastern Beaufort Sea and Amundsen Gulf. Industry aerial surveys off the continental shelf near Camden Bay in 2008 recorded eastward migrating bowhead whales until 12 July (Lyons and Christie 2009). No bowhead sightings were recorded again despite continued flights until 19 August. A summer bowhead whale density was derived from 9022 km of summer (July/August) aerial survey effort reported by Moore et al. (2000) in the Alaskan Beaufort Sea during which six sightings of bowhead whales were documented in water >2000 m deep. A mean group size for bowhead whale sightings in September, in waters >2000 m deep, was calculated to be 1.14 (CV=0.4) from BWASP data. An *f*(0) value of 2.33 and a *g*(0) value of 0.073, both from Thomas et al. (2002) were used to estimate a summer density for bowhead whales of 0.0122 whales/ km^2. This density falls within the range of densities, i.e. 0.0099 – 0.0717 whales/ km^2, reported by Lyons and Christie (2009) based on data from three July 2008 surveys.

Treacy et al. (2006) reported that in years of heavy ice conditions, bowhead whales occur farther offshore than in years of light to moderate ice. NSIDC (2009) reported that September 2009 had the third lowest sea ice extent since the start of their satellite records in 1979. The extent of sea ice at the end of the 2009 Arctic summer, however, was greater than in 2007 or 2008. During the lowest ice-cover year on record (2007), BWASP reported no bowhead whale sightings in the >2000 m depth waters far offshore.

Because few bowhead whales have been documented in the deep offshore waters of the survey area, half of the bowhead whale density estimate from Moore et al. (2000) was applied as the average density (0.0061 whales/km^2; Table H.1). The CV of group size and standard errors reported in Thomas et al (2002) for *f*(0) and *g*(0) correction factors suggest that an inflation factor of 2 is appropriate for estimating the maximum density from the average density. NSIDC did not forecast that 2010 would be a heavy ice year and we anticipated that bowheads would remain relatively close to shore, and in areas of light ice coverage. Therefore, we applied the same density for bowheads in open-water and ice-margin habitats. Bowhead whales were not sighted during the 2010 survey or during recent surveys in the Arctic Ocean (Haley and Ireland 2006; Haley 2006; Jackson and DesRoches 2010; Mosher et al. 2009), suggesting that the bowhead whale densities shown in Table H.1 are likely higher than actual densities in the survey area.

For ***other cetacean species*** that could have possibly been encountered in the Beaufort Sea, densities were expected to be very low in the summer when the survey occurred. Fin and humpback whales were unlikely to occur in the Beaufort Sea. No gray whales were observed in the Beaufort Sea by Moore et al. (2000) during summer aerial surveys in water >2000 m. Gray whales were not recorded in water >2000 m by the BWASP during August in 29 years of survey operation. Harbor porpoises were not expected to be present in large numbers in the Beaufort Sea during the fall although small numbers could have possibly been encountered during the summer. Neither gray whales nor harbor porpoises were likely to occur in the far-offshore waters of the survey area. Narwhals were not expected to be encountered within the survey area although a few individuals could have been present if ice was nearby. Because these species occur so infrequently in the Beaufort Sea, little to no data were available for the calculation of densities. Minimal cetacean densities were therefore assigned to these three species for calculation purpose and to allow for chance encounters (Table H.1). Those densities included “0” for the average and 0.0001 individuals/km^2 for the maximum.

Seals

Extensive surveys of ringed and bearded seals have been conducted in the Beaufort Sea, but most surveys were conducted over the landfast ice during aerial surveys, and few seal surveys have occurred in open water or in the pack ice. Kingsley (1986) conducted ***ringed seal*** surveys of the offshore pack ice in the central and eastern Beaufort Sea during late spring (late June). These surveys provide the most relevant information on densities of ringed seals in the ice margin zone of the Beaufort Sea. The density estimate in Kingsley (1986) was used as the average density of ringed seals that may be encountered in the ice-margin area of the survey. The average density was multiplied by 4 to estimate maximum density, as was done for all seal species expected to occur within the survey area. Ringed seals are closely associated with sea ice therefore the ice-margin densities were multiplied by a factor of 0.75 to estimate a summer open-water ringed-seal density for locations with water depth >2000 m (Table H.1).

Densities of ***bearded seals*** were estimated by multiplying the ringed seal densities by 0.051 based on the proportion of bearded seals to ringed seals reported in Stirling et al. (1982). Because bearded seals are associated with the pack ice edge and shallow water, their estimated summer ice-margin density was also multiplied by a factor of 0.75 for the open-water density estimate (Table H.1). Minimal values were used to estimate ***spotted seal*** densities because they are uncommon offshore in the Beaufort Sea and were not likely to be encountered.

Polar Bears

One polar bear sighting of two individuals were recorded along ~2,308 km of monitored trackline between 71°N and 74°N during previous surveys near the project area (Haley and Ireland, 2006; Haley, 2006; Jackson and DesRoches 2010) and all were hauled out on ice. This resulted in an average density of 0.0004 bears/ km^2 in ice-margin habitat, assuming all bears present within 1 km on either side of the vessel were observed. The maximum density in ice-margin habitat was assumed to be 4 times this value. The density of polar bears in open water was expected to be much lower, so a minimal average density estimate (0.0001 individuals/km^2) was assumed. The maximum density estimate in open-water was assumed to be the same as the average density estimate in ice-margin habitat (Table H.1).

Due to only a minimal amount of area occurring near the ice margin during seismic operations in the U.S. EEZ, the summer open-water densities were used for all marine mammals to estimate potential "takes" as a result of seismic activity. Methods for calculating "takes by harassment" are described below.

TABLE H.1 Expected summer densities of marine mammals, in open water and ice margin habitats in the Arctic Ocean. Densities are corrected for *f*(0) and *g*(0) biases.

	Open Water		Ice Margin	
Species	**Average Density (# / km^2)**	**Maximum Density (# / km^2)**	**Average Density (# / km^2)**	**Maximum Density (# / km^2)**
Cetaceans				
Beluga	0.0354	0.0709	0.0354	0.0709
Bowhead whale	0.0061	0.0122	0.0061	0.0122
Fin whale	0.0000	0.0001	0.0000	0.0001
Gray whale	0.0000	0.0001	0.0000	0.0001
Harbor porpoise	0.0000	0.0001	0.0000	0.0001
Humpback whale	0.0000	0.0001	0.0000	0.0001
Killer whale	0.0000	0.0001	0.0000	0.0001
Minke whale	0.0000	0.0001	0.0000	0.0001
Narwhal	0.0000	0.0001	0.0000	0.0001
Seals				
Bearded seal	0.0096	0.0384	0.0128	0.0512
Ringed seal	0.1883	0.7530	0.2510	1.0040
Spotted seal	0.0001	0.0004	0.0001	0.0004
Polar bears	0.0001	0.0004	0.0004	0.0016

Estimating Numbers Potentially Affected by the Seismic Survey

NMFS practice in situations with intermittent impulsive sounds like seismic pulses has been to assume that "take by harassment" (Level B) may occur if marine mammals are exposed to received levels of sounds exceeding 160 dB re 1 μPa rms (NMFS 2005, 2006). The reaction threshold for most toothed whales is unknown but presumably higher because of their poorer hearing sensitivity at low frequencies (NMFS 2005; NMFS 2006; Richardson et al. 1995; Richardson and Würsig 1997). However, the limited empirical data for beluga whales indicate that they may be relatively responsive to airgun sounds as compared with other toothed whales (Miller et al. 2005). When calculating the number of mammals potentially affected, we used the ≥160 dB rms radius shown in Table 3.1.

Two methods were used to estimate the number of pinnipeds and cetaceans exposed to airgun sound levels that might have caused disturbance or other effects. The methods were:

(A) minimum estimates based on direct observations during seismic activities; and

(B) maximum estimates based on pinniped and cetacean densities reported or calculated from earlier marine mammal surveys in and near the Arctic Ocean multiplied by the area of water exposed to seismic sounds ≥160 dB by the seismic survey.

The actual number of individuals exposed to, and potentially affected by, seismic survey sounds was likely between these minimum and maximum estimates resulting from methods ***(A)*** and ***(B)***.

Method ***(B)*** above provided an estimate of the number of animals that would have been exposed to airgun sounds at various levels if the seismic activities did not influence the distribution of animals near the activities. However, it is known that some animals are likely to 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 160 dB rms radii around the seismic source (i.e., 2.5 km [1.6 mi]), the distribution and behavior of cetaceans may have been altered as a result of the seismic survey. The distribution and behavior of pinnipeds may have been altered within some lesser distance. These effects could occur because of reactions to the active airgun array, or to other sound sources or other vessels working in the area.

The aforementioned densities were used to estimate the number of animals potentially affected by seismic operations (method ***(B)***). This involved using two approaches to estimate the extent to which marine mammals may have been exposed to given sound levels ≥160, ≥180, and ≥190 dB rms:

1. Estimates of the number of different *individual* marine mammals exposed; and
2. Estimates of the average number of *exposures* each individual may have received.

For the *Louis S. St-Laurent*, we used the 160, 180, and 190 dB rms distances summarized in Table 3.1. The following description of the two different methods refers only to the ≥160 dB rms sound level, but the same method of calculation was used for ≥180 and ≥190 dB rms sound levels.

The first method ("individuals") involved multiplying the following three values:

- km of seismic survey;
- width of area assumed to be ensonified to ≥160 dB (2 × 160 dB radius), with areas ensonified on more than one occasion counted *only once*; and
- densities of marine mammals estimated from earlier marine mammal surveys in and near the Arctic Ocean.

The second approach ("exposures") represented the average number of times a given area of water within the seismic survey area was ensonified to the specified level. If an animal remained in approximately the same location through the duration of the survey activities it could have been exposed an equivalent number of times. The value was calculated as the ratio of the area of water ensonified *including* multiple counts of areas exposed more than once to the area of water ensonified *excluding* multiple counts of areas exposed more than once. The 2010 USGS seismic survey had a very limited amount of overlap of ensonified areas due to the relatively small sound source and long survey lines, which led to a relatively low estimate of the number of exposures per individual (i.e. close to 1).

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., Funk et al. 2008; Ireland et al. 2007a,b; Patterson et al. 2007).

Estimation of Densities during Icebreaking Operations

As summarized in Chapter 3, two methods were used in estimating densities of marine mammals in the survey area during icebreaking operations. The methods were:

(A) estimates based on sightings data collected during the 2010 cruise; and

(B) estimates based on densities reported or calculated from earlier marine mammal surveys in and near the Arctic Ocean.

In method ***(A)***, we calculated densities for seals in water (i.e. not hauled out on ice) during icebreaking (defined as periods of ≥80 % ice cover) and non-icebreaking periods (<80 % ice cover). Densities were calculated using line-transect procedures for vessel-based surveys. However, these density estimates must be interpreted with caution because of the limited number of sightings from which they have been calculated and given the fact that ice could have bound sightability of animals in the water. To allow for animals missed during daylight, we corrected our visual observations using correction factors calculated with these procedures.

Corrections for Sightability

As is standard for line-transect estimation procedures, corrections for the following two parameters were included in the calculation of densities for the *Healy* seal sightings data:

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

The *g*(0) values for seals in water during icebreaking and non-icebreaking periods were taken from previously calculated values for pinniped species off California. This was necessary because of the low number of seal sightings during the 2010 survey, and the inability to assess sighting probability during a study of this type.

The *f*(0) factors used for seals in water during icebreaking and non-icebreaking were calculated from observations made during this study. Only seal sightings in water that were made during good sighting conditions were used for the calculations. These sightings were imported into the software program DISTANCE where the *f*(0) values were calculated separately for seals in water during icebreaking and non-icebreaking periods. The default analysis method was conventional distance sampling with a half-normal model and cosine expansion with no stratification.

Method ***(B)*** above estimated densities based on available data about marine mammal distribution and densities in the Arctic Ocean. No published densities of marine mammals were available for the region where the majority of icebreaking activities was expected to occur (between 74°N and 84°N) in 2010. However, vessel-based surveys through the general area in 2005, 2006, 2008 and 2009 encountered few marine mammals as described in the IHA application for this project. PSOs recorded 268 sightings of 291 individual seals along ~21,322 km of monitored trackline between 74°N and 84°N (Haley and Ireland 2006, Haley 2006, Jackson and DesRoches 2010, Mosher et al. 2009). No cetaceans were observed during the surveys between 74°N and 84°N.

Given the few sightings of marine mammals along the ~21,322 km vessel trackline in previous years, we estimated that the densities of marine mammals encountered while breaking ice would be 1/10 of the estimated densities of mammals that may be encountered within the ice margin habitat described above in *Estimation of Densities during Seismic Operations* (Table H.2).

TABLE H.2 Estimated summer densities of marine mammals, in ice margin and polar pack ice habitats in the Arctic Ocean. Densities are corrected for *f*(0) and *g*(0) biases.

	Ice Margin		Polar Pack	
Species	**Average Density (# / km^2)**	**Maximum Density (# / km^2)**	**Average Density (# / km^2)**	**Maximum Density (# / km^2)**
Cetaceans				
Beluga	0.0354	0.0709	0.0035	0.0071
Bowhead whale	0.0061	0.0122	0.0006	0.0012
Fin whale	0.0000	0.0001	0.0000	0.0000
Gray whale	0.0000	0.0001	0.0000	0.0000
Harbor porpoise	0.0000	0.0001	0.0000	0.0000
Humpback whale	0.0000	0.0001	0.0000	0.0000
Killer whale	0.0000	0.0001	0.0000	0.0000
Minke whale	0.0000	0.0001	0.0000	0.0000
Narwhal	0.0000	0.0001	0.0000	0.0000
Seals				
Bearded seal	0.0128	0.0512	0.0013	0.0051
Ringed seal	0.2510	1.0040	0.0251	0.1004
Spotted seal	0.0001	0.0004	0.0000	0.0000
Polar bears	0.0004	0.0016	0.0000	0.0002

Estimating Numbers Potentially Affected by Icebreaking Activities

120 dB rms Criteria

For purposes of the IHA, NMFS assumes that any marine mammal that might have been exposed to continuous icebreaking noise with received sound levels ≥120 dB re 1 µPa (rms) may have been appreciably disturbed and therefore "taken". We estimated the area potentially exposed to received levels ≥120 dB due to icebreaking operations by multiplying the distance traveled while breaking ice (conditions of 8/10 ice or greater) by the estimated cross-track distance to received levels of 120 dB caused by icebreaking. The 120 dB received sound level radius around the *Healy* while icebreaking was estimated using a spherical spreading model and a source level of 185 dB re 1 µPa-m. The model estimated that icebreaking sounds would diminish below 120 dB beyond 1750 m, resulting in a cross-track distance of 3500 m. To calculcate the number of marine mammals potentially exposed to received levels ≥120 dB re 1 µPa (rms) by icebreaking, we multiplied the estimated area ensonified to ≥120 dB, by the expected species density.

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APPENDIX I: BEAUFORT WIND FORCE DEFINITIONS

Wind Speed		Beaufort Wind Force	World Meteorological Organization Terms	Wave Height (m)	Description
Knots	m/s				
<1	<0.5	0	Calm	0	Glassy like a mirror
1-3	0.5-1.5	1	Light air	<0.1	Ripples with the appearance of scales but no whitecaps or foam crests
4-6	2.1-3.1	2	Light breeze	0-0.1	Small wavelets, crests have a glassy appearance but do not break (no whitecaps)
7-10	3.6-5.1	3	Gentle breeze	0.1-0.5	Smooth large wavelets, crests begin to break, occasional/scattered whitecaps
11-16	5.7-8.2	4	Moderate breeze	0.5-1.2	Slight; small fairly frequent whitecaps
17-21	8.7-10.8	5	Fresh breeze	1.2-2.4	Moderate waves becoming longer, some spray, frequent moderate whitecaps
22-27	11.3-13.9	6	Strong breeze	2.4-4	Rough, larger waves, longer-formed waves, many large whitecaps
28-33	14.4-17.0	7	Near gale	4-6	Very rough, large waves forming, white foam crests everywhere, spray is present
34-40	17.5-20.6	8	Gale		
41-47	21.1-24.2	9	Strong gale		
48-55	24.7-28.3	10	Storm	6-9	High
56-63	28.8-32.4	11	Violent storm	11-14	Very high

APPENDIX J BACKGROUND ON MARINE MAMMALS IN THE PROJECT REGION

TABLE J.1. The habitat, abundance, and conservation status of marine mammals inhabiting the project areas of the Arctic Ocean.

Species	Habitat	Abundance	ESA[1]	IUCN[2]	CITES[3]
Odontocetes Beluga whale *(Delphinapterus leucas)*	Offshore, Coastal, Ice edges	3710[4] 39,258[5]	Not listed	VU	II
Narwhal (*Monodon monoceros*)	Offshore, Ice edge	Rare[6]	Not listed	DD	II
Killer whale *(Orcinus orca)*	Widely distributed	Rare	Not listed	LR-cd	II
Harbor Porpoise *(Phocoena phocoena)*	Coastal, inland waters, shallow offshore waters	Common (Chukchi) Uncommon (Beaufort)	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] 20,110[9]	Not listed	LR-cd	I
Minke whale (*Balaenoptera acutorostrata*)	Shelf, coastal	Small numbers	Not listed	LR-cd	I
Fin whale (*Balaenoptera physalus*)	Slope, mostly pelagic	Rare (Chukchi)	Endangered	EN	I
Humpback whale (*Megaptera novaeangliae*)	Shelf, coastal	Rare	Endangered	–	–
Pinnipeds Bearded seal (*Erignathus barbatus*)	Pack ice, open water	250,000-300,000[10]	In review for listing	–	–
Spotted seal (*Phoca largha*)	Pack ice, open water, coastal haulouts	~59,214[11]	Not listed in U.S.	–	–
Ringed seal (*Pusa hispida*)	Landfast & pack ice, open water	18,000[12] ~208,000-252,000[13]	In review for listing	–	–
Ribbon seal (*Histriophoca fasciata*)	Pack ice, open water	90-100,000[14]	Not listed	–	–
Pacific Walrus (*Odobenus rosmarus*)	Coastal, Pack ice, ice floes	~200,000 to 246,000[15]	In review for listing	-	II
Ursids Polar Bear *(Ursus maritimus)*	Pack ice	4700[16]	Threatened		

[1] 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] Eastern Chukchi Sea stock based on 1989-1991 surveys with a correction factor (Angliss and Allen 2009)

[5] Beaufort Sea stock based on surveys in 1992 (Angliss and Allen 2009).

[6] DFO (2004) states the population in Baffin Bay and the Canadian arctic archipelago is ~60,000; very few of these enter the Beaufort Sea.

[7] Abundance of bowhead whales 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] Eastern North Pacific gray whale population (Rugh et al. 2008)

[10] Based on earlier estimates, no current population estimate available (Angliss and Allen 2009)

[11] Alaska stock based on aerial surveys in 1992 (Angliss and Allen 2009).

[12] Beaufort Sea minimum estimate with no correction factor based on aerial surveys in 1996-1999 (Frost et al. 2002 *in* Angliss and Allen 2009).

[13] Eastern Chukchi Sea population (Bengtson et al. 2005)

[14] Bering Sea population (Bruns 1981 in Angliss and Allen 2009).

[15] Pacific walrus population, 1975-1990 (Angliss and Allen 2009 and references therin).

[16] Chukchi Sea and northern and southern Beaufort Sea populations combined (Aars et al. 2006; USFWS 2008).

APPENDIX K: MONITORING EFFORT AND MARINE MAMMAL MONITORING RESULTS

TABLE K.1. Total marine mammal sightings (individuals) during the USGS geophysical survey from the *Louis S. St-Laurent* and the *Healy*. Only sightings from the *Louis S. St-Laurent* that occurred within the U.S. EEZ are reported. There were no Pacific walrus sightings during this survey.

Species	*St-Laurent*	*Healy*	*Total*
Cetaceans			
Gray Whale	0	1 (1)	***1 (1)***
Total Cetaceans	***0***	***1 (1)***	***1 (1)***
Seals in Water			
Bearded Seal	0	1 (1)	***1 (1)***
Ringed Seal	6 (6)	21 (22)	***27 (28)***
Unidentified Seal	0	9 (9)	***9 (9)***
Seals on Ice			
Bearded Seal	0	7 (7)	***7 (7)***
Ringed Seal	0	21 (23)	***21 (23)***
Unidentified Seal	0	11 (14)	***11 (14)***
Total Seals	***6 (6)***	***70 (76)***	***76 (82)***
Polar Bears			
In Water	0	0	***0***
On Ice	1 (2)	12 (14)	***13 (16)***
Total Polar bears	***1 (2)***	***12 (14)***	***13 (16)***
Grand Total of All Sightings	***7 (8)***	***83 (91)***	***90 (99)***

TABLE K.2. Cetacean observation effort for cetaceans during the USGS geophysical survey from the *Louis S. St-Laurent* and the *Healy*. Only observation effort from the *Louis S. St-Laurent* and the *Healy* that occurred within the U.S. EEZ are reported. Effort categories include kilometers and hours, subdivided by Beaufort wind force and seismic status. Ramp-up effort is included in the "Seismic" category. These data meet the criteria described in Chapter 3, *Data Analysis*.

Vessel Name and Seismic State	Beaufort Wind Force						
	0	**1**	**2**	**3**	**4**	**5**	***Total***
Louis S. St-Laurent							
Effort in km							
Seismic[a]	20.5	0.9	9.3	23.6	18.3	42.4	***114.9***
Non-seismic	0.0	0.1	0.4	70.3	38.0	124.3	***233.1***
Total	***20.5***	***1.0***	***9.7***	***94.0***	***56.3***	***166.7***	***348.1***
Effort in h							
Seismic[a]	2.9	0.1	1.3	3.0	2.7	5.5	***15.4***
Non-seismic	0.0	0.0	0.1	2.2	1.2	3.8	***7.3***
Total	***2.9***	***0.1***	***1.4***	***5.2***	***3.9***	***9.3***	***22.7***
Healy							
Effort in km							
Seismic	0.0	0.9	3.8	11.5	0.0	0.0	***16.2***
Non-seismic	0.0	0.0	24.0	77.2	0.0	0.0	***101.2***
Total	***0.0***	***0.9***	***27.8***	***88.7***	***0.0***	***0.0***	***117.4***
Effort in h							
Seismic	0.0	0.2	0.5	1.5	0.0	0.0	***2.1***
Non-seismic	0.0	0.0	2.9	5.8	0.0	0.0	***8.7***
Total	***0.0***	***0.2***	***3.4***	***7.3***	***0.0***	***0.0***	***10.8***

[a]Beaufort wind force was not recorded during 42.8 km (5.8 h) of cetacean effort

TABLE K.3. Pinniped observation effort during the USGS geophysical survey from the *Louis S. St-Laurent* and the *Healy*. Only observation effort from the *Louis S. St-Laurent* and the *Healy* that occurred within the U.S. EEZ are reported. Effort categories include kilometers and hours, subdivided by Beaufort wind force and seismic status. Ramp-up effort is included in the "Seismic" category. These data meet the criteria described in Chapter 3, *Data Analysis*.

	Beaufort Wind Force						
Vessel Name and Seismic State	**0**	**1**	**2**	**3**	**4**	**5**	***Total***
Louis S. St-Laurent							
Effort in km							
Seismic[a]	20.5	8.4	9.5	23.6	34.8	65.1	***161.9***
Non-seismic	0.0	4.3	0.4	70.3	38.0	124.3	***237.3***
Total	***20.5***	***12.7***	***9.9***	***94.0***	***72.8***	***189.4***	***399.3***
Effort in h							
Seismic[a]	2.9	1.2	1.3	3.0	4.9	8.3	***21.5***
Non-seismic	0.0	0.6	0.1	2.2	1.2	3.8	***7.9***
Total	***2.9***	***1.7***	***1.4***	***5.2***	***6.1***	***12.1***	***29.3***
Healy							
Effort in km							
Seismic	0.0	0.9	3.8	11.8	0.0	0.0	***16.5***
Non-seismic	0.0	0.0	24.0	94.3	0.0	0.0	***118.3***
Total	***0.0***	***0.9***	***27.8***	***106.2***	***0.0***	***0.0***	***134.9***
Effort in h							
Seismic	0.0	0.2	0.5	1.5	0.0	0.0	***2.1***
Non-seismic	0.0	0.0	2.9	7.0	0.0	0.0	***9.9***
Total	***0.0***	***0.2***	***3.4***	***8.5***	***0.0***	***0.0***	***12.0***

[a]Beaufort wind force was not recorded during 95.8 km (12.6 h) of pinniped effort

TABLE K.4. Numbers of sightings (number of individuals) of marine mammals observed by seismic state during the 2010 USGS geophysical survey from the *Louis S. St-Laurent* and the *Healy*. Only sightings from the *Louis S. St-Laurent* and the *Healy* that occurred within the U.S. EEZ are reported. These data meet the criteria described in Chapter 3, *Data Analysis*.

Seismic Status[a] and Species	***St-Laurent***	***Healy***	***Total***
Sesimic			
Seals in Water			
Ringed Seal	1 (1)	0	***1 (1)***
Seals on Ice			
Ringed Seal	0	1 (2)	***1 (2)***
Total Seals	***1 (1)***	***1 (2)***	***2 (3)***

[a] No sightings occurred during non-seismic periods

TABLE K.5. Numbers of sightings (number of individuals) of marine mammals observed by icebreaking state during the 2010 USGS geophysical survey from the *Healy*. Only sightings from *Healy* that occurred outside U.S. waters or not within close proximity (75 km; 47 mi) of the *Louis S. St-Laurent* in the U.S. EEZ are reported. These data meet the criteria described in Chapter 3, *Data Analysis*.

Species	**Icebreaking**	**Non-Icebreaking**	***Total***
Cetaceans			
Gray Whale	0	1 (1)	***1 (1)***
Total Cetaceans	***0***	***1 (1)***	***1 (1)***
Seals in Water			
Bearded Seal	1 (1)	0	***1 (1)***
Ringed Seal	10 (10)	7 (7)	***17 (17)***
Unidentified Seal	6 (6)	2 (2)	***8 (8)***
Seals on Ice			
Bearded Seal	5 (5)	2 (2)	***7 (7)***
Ringed Seal	13 (13)	2 (2)	***15 (15)***
Unidentified Seal	9 (12)	1 (1)	***10 (13)***
Total Seals	***44 (47)***	***14 (14)***	***58 (61)***
Polar Bears			
In Water	0	0	***0***
On Ice	6 (6)	4 (6)	***10 (12)***
Total Polar bears	***6 (6)***	***4 (6)***	***10 (12)***
Grand Total of All Sightings	***50 (53)***	***19 (21)***	***69 (74)***

APPENDIX L: LIST OF ALL MARINE MAMMAL DETECTIONS

TABLE L.1. Marine mammal detections within the U.S. EEZ from the *Louis S. St-Laurent* during the 2010 USGS geophysical survey, 12 Aug-17 Aug 2010. Heading codes are described in footnotes beneath the table.

Sighting ID[a]	Species	No.[b]	Date (AKDT)	Long (°W)	Lat (°N)	Initial Sightings Distance (m)[c]	CPA (m)[d]	Behavior[e]	Bf[f]	Water Depth (m)	Vessel Activity[g]	Airgun Volume (in^3)
1	Ringed seal	1	13/08/2010 21:35:30	-145.359	73.0445	200	269	FD	1	3632	LS	1150
2	Polar bear	2	13/08/2010 22:29:30	-145.356	73.102	1000	1047	LO	1	3645	LS	1150
3	Ringed seal	1	14/08/2010 00:18:30	-145.349	73.2207	150	198	SW	1	3651	LS	1150
4	Ringed seal	1	14/08/2010 08:45:30	-145.329	73.52	200	279	TH	1	3710	LS	1150
5	Ringed seal	1	14/08/2010 22:56:30	-146.574	73.5303	200	255	SW	0	3758	LS	1150
6	Ringed seal	1	15/08/2010 02:45:30	-147.153	73.3497	>50	100	SW	4	1001	LS	1150
7	Ringed seal	1	17/08/2010 22:32:30	-150.41	74.1643	150	237	TH	1	3874	LS	1150

[a] Sighting ID = Sequential number given to sightings

[b] No. = Number of individual marine mammal(s)

[c] Initial Sighting Distance (m) = distance of marine mammal(s) from the PSOs when initially detected

[d] CPA (m) = Closest Point of Approach of the maine mammal(s) to the airgun array

[e] Behavior = Initial behavior observed by PSOs, codes: FD = Front dive (included with dive in analyses), LO = Look, SW = Swim, TH= Thrash dive

[f] Beaufort Wind Force, See Appendix H for definitions

[g] Vessel Activity = Vessel activity at the time of initial detection, codes: DP = Deploying Survey Gear, LS = Survey Line Shooting, SH = Shooting Off Survey Line, OT= Other (e.g., transit), RC = Recovering Survey Gear, RU = Ramp-Up of Airgun Array

TABLE L.2. Marine mammal detections from the *Healy* during the 2010 USGS geophysical survey in the Arctic Ocean, 6 Aug–4 Sep 2010. Heading codes are described in footnotes beneath the table.

Sighting ID[a]	Species	No.[b]	Date (AKDT)	Long (°W)	Lat (°N)	Initial Sightings Distance (m)[c]	CPA (m)[d]	Behavior[e]	Bf[f]	Water Depth (m)	Vessel Activity[g]	Airgun Volume (in^3)
44	Ringed seal	1	06/08/2010 14:06:00	-153.642	71.9697	400	400	FD	1	911	OT	X
45	Unidentified seal	1	06/08/2010 14:54:00	-153.297	71.9482	500	500	FL	1	1242	OT	X
47	Polar bear	1	08/08/2010 04:28:00	-139.425	71.546	3000	3000	WK	2	2388	OT	X
48	Ringed seal	1	08/08/2010 05:18:00	-139.276	71.5982	500	500	RE	0	2061	OT	X
49	Unidentified seal	1	08/08/2010 05:29:00	-139.235	71.6105	1800	1800	RE	2	2427	OT	X
50	Polar bear	1	08/08/2010 12:19:00	-138.552	72.1726	620	620	FL	3	2604	OT	X
51	Unidentified seal	1	08/08/2010 22:43:00	-137.769	72.9848	50	50	LO	1	2913	OT	X
52	Polar bear	1	09/08/2010 12:40:00	-139.84	72.4896	2000	2000	OT	2	3032	OT	X
53	Polar bear	1	09/08/2010 15:54:00	-139.742	72.4557	1000	1000	UN	2	3000	OT	X
54	Polar bear	1	09/08/2010 15:55:00	-139.745	72.4541	1500	1500	WK	2	2998	OT	X
55	Polar bear	1	09/08/2010 18:33:00	-139.838	72.181	3500	3500	WK	2	2868	OT	X
56	Bearded seal	1	10/08/2010 06:11:00	-140.181	71.3945	1000	1000	LO	2	2432	OT	X
57	Ringed seal	1	14/08/2010 06:32:00	-145.333	73.43	100	100	OT	1	3696	OT	X
58	Ringed seal	2	14/08/2010 21:33:00	-146.39	73.5851	700	700	RE	1	3762	OT	X
59	Gray whale	1	16/08/2010 17:11:00	-155.888	71.5811	2500	2500	BL	1	223	OT	X
60	Ringed seal	1	16/08/2010 18:02:00	-155.985	71.6108	125	125	SW	1	195	OT	X
61	Ringed seal	1	16/08/2010 18:12:00	-156.093	71.6009	100	100	FD	1	188	OT	X
62	Ringed seal	1	16/08/2010 18:45:00	-156.449	71.5472	125	125	SW	1	162	OT	X
65	Polar bear	1	18/08/2010 18:55:00	-152.382	75.2505	3000	3000	WK	3	3896	OT	X
66	Polar bear	3	18/08/2010 19:17:00	-152.46	75.2673	2500	2500	WK	3	3896	OT	X
67	Unidentified seal	1	21/08/2010 05:48:00	-146.927	76.5699	200	200	DI	1	3861	OT	X
68	Polar bear	1	22/08/2010 00:06:00	-151.681	77.7793	2000	2000	LO	0	3880	OT	X
69	Ringed seal	1	22/08/2010 05:10:00	-153.095	78.1086	700	700	RE	1	2499	OT	X
70	Unidentified seal	1	22/08/2010 06:33:00	-152.695	78.1539	1000	1000	RE	1	3058	OT	X
71	Ringed seal	1	22/08/2010 07:33:00	-152.405	78.1869	200	200	SW	1	3879	OT	X
72	Ringed seal	1	22/08/2010 15:35:00	-150.761	78.387	200	200	LO	0	3876	OT	X
73	Bearded seal	2	22/08/2010 20:31:00	-149.84	78.4768	2500	2500	RE	1	3875	OT	X
75	Ringed seal	1	22/08/2010 21:10:00	-149.633	78.5006	1500	1500	NO	0	3874	OT	X
76	Ringed seal	1	22/08/2010 22:00:00	-149.357	78.5312	1500	1500	NO	0	3829	OT	X
77	Ringed seal	1	22/08/2010 22:00:00	-149.357	78.5312	1500	1500	RE	0	3829	OT	X

TABLE L.2 cont…. Marine mammal detections from the *Healy* during the 2010 USGS geophysical survey in the Arctic Ocean, 6 Aug–4 Sep 2010. Heading codes are described in footnotes beneath the table.

Sighting ID[a]	Species	No.[b]	Date (AKDT)	Long (°W)	Lat (°N)	Initial Sightings Distance (m)[c]	CPA (m)[d]	Behavior[e]	Bf[f]	Water Depth (m)	Vessel Activity[g]	Airgun Volume (in^3)
78	Ringed seal	1	23/08/2010 01:45:00	-148.168	78.6627	400	400	LO	0	3872	OT	X
79	Unidentified seal	1	23/08/2010 02:09:00	-148.056	78.6755	500	500	LO	0	3872	OT	X
83	Unidentified seal	1	23/08/2010 23:39:00	-140.585	79.9158	100	100	DI	0	3822	OT	X
84	Ringed seal	1	24/08/2010 16:42:00	-135.374	81.2541	2500	2500	RE	0	3762	OT	X
85	Ringed seal	1	24/08/2010 17:22:00	-135.084	81.3162	500	500	SW	0	3761	OT	X
86	Ringed seal	1	24/08/2010 17:29:00	-135.072	81.3327	1500	1500	RE	0	3761	OT	X
87	Ringed seal	1	24/08/2010 17:44:00	-135.046	81.3474	500	500	TH	0	3762	OT	X
88	Ringed seal	1	24/08/2010 19:23:00	-134.844	81.4427	3000	3000	RE	0	3701	OT	X
89	Ringed seal	1	24/08/2010 21:41:00	-134.891	81.4744	150	150	LO	0	3756	OT	X
90	Ringed seal	1	25/08/2010 05:41:00	-134.549	81.5497	2500	2500	RE	0	2835	OT	X
91	Ringed seal	2	25/08/2010 09:21:00	-134.54	81.5713	75	75	LO	0	2959	OT	X
92	Ringed seal	1	25/08/2010 12:27:00	-134.394	81.6015	250	250	LO	0	3251	OT	X
93	Ringed seal	1	25/08/2010 12:28:00	-134.405	81.6031	350	350	LO	0	3251	OT	X
94	Ringed seal	1	30/08/2010 21:09:00	-137.791	76.9921	300	300	LO	0	3740	OT	X
95	Ringed seal	1	30/08/2010 21:52:00	-137.951	76.9011	150	150	LO	0	3736	OT	X
96	Unidentified seal	1	31/08/2010 06:33:00	-140.011	75.6703	2000	2000	SW	1	3756	OT	X
97	Ringed seal	1	31/08/2010 08:41:00	-140.088	75.5812	150	150	LO	0	3750	OT	X
98	Ringed seal	1	01/09/2010 07:04:00	-133.945	74.4891	800	800	LO	0	3213	OT	X
99	Ringed seal	1	01/09/2010 07:30:00	-133.774	74.4822	600	600	SW	0	3200	OT	X
100	Ringed seal	1	01/09/2010 07:49:00	-133.617	74.4741	400	400	SW	0	3001	OT	X
101	Ringed seal	1	01/09/2010 08:55:00	-133.092	74.4468	125	125	LO	0	3084	OT	X
102	Ringed seal	1	01/09/2010 10:27:00	-132.473	74.407	1000	1000	LO	0	2964	OT	X
103	Ringed seal	1	01/09/2010 10:51:00	-132.351	74.3999	200	200	LO	0	2901	OT	X
104	Polar bear	1	01/09/2010 11:14:00	-132.158	74.3912	800	800	LO	0	2870	OT	X
105	Bearded seal	1	01/09/2010 11:49:00	-131.969	74.3828	500	500	LO	0	2812	OT	X
106	Polar bear	1	01/09/2010 16:17:00	-131.434	74.7734	2500	2500	WK	1	2453	OT	X
107	Bearded seal	1	01/09/2010 17:14:00	-131.477	74.8832	3000	3000	LO	1	2559	OT	X
108	Ringed seal	2	01/09/2010 18:05:00	-131.421	74.9794	2000	2000	RE	1	2505	OT	X
109	Unidentified seal	1	01/09/2010 18:11:00	-131.417	74.9905	200	200	SW	1	2505	OT	X
111	Ringed seal	1	02/09/2010 17:13:00	-128.484	76.5663	100	100	LO	0	2103	OT	X

TABLE L.2 cont…. Marine mammal detections from the *Healy* during the 2010 USGS geophysical survey in the Arctic Ocean, 6 Aug–4 Sep 2010. Heading codes are described in footnotes beneath the table.

Sighting ID[a]	Species	No.[b]	Date (AKDT)	Long (°W)	Lat (°N)	Initial Sightings Distance (m)[c]	CPA (m)[d]	Behavior[e]	Bf[f]	Water Depth (m)	Vessel Activity[g]	Airgun Volume (in[3])
112	Polar bear	1	02/09/2010 20:10:00	-129.141	76.5737	3000	3000	WK	0	2145	OT	X
113	Ringed seal	1	02/09/2010 20:25:00	-129.214	76.5788	100	100	SW	0	2249	OT	X
114	Ringed seal	1	02/09/2010 21:10:00	-129.435	76.5892	150	150	LO	0	2449	OT	X
115	Ringed seal	1	03/09/2010 06:04:00	-131.823	76.7097	1500	1500	SW	0	3159	OT	X
116	Ringed seal	1	03/09/2010 12:17:00	-133.659	76.7877	2000	2000	LO	0	3471	OT	X
117	Unidentified seal	1	03/09/2010 12:30:00	-133.721	76.7923	2500	2500	LO	0	3484	OT	X
118	Unidentified seal	1	03/09/2010 12:50:00	-133.8	76.795	3000	3000	LO	0	3491	OT	X
119	Unidentified seal	1	03/09/2010 13:39:00	-134.03	76.7972	3000	3000	FD	0	3514	OT	X
120	Ringed seal	1	03/09/2010 14:24:00	-134.235	76.8049	1500	1500	LO	0	3539	OT	X
121	Bearded seal	1	03/09/2010 14:35:00	-134.287	76.8066	2000	2000	LO	0	3545	OT	X
122	Unidentified seal	1	03/09/2010 15:10:00	-134.456	76.8146	1000	1000	LO	0	3567	OT	X
123	Bearded seal	1	03/09/2010 15:31:00	-134.546	76.8163	2500	2500	UN	0	3568	OT	X
124	Ringed seal	1	03/09/2010 15:50:00	-134.613	76.8179	2000	2000	LO	0	3568	OT	X
125	Unidentified seal	1	03/09/2010 15:54:00	-134.628	76.8184	2500	2500	RE	0	3568	OT	X
126	Bearded seal	1	03/09/2010 16:26:00	-134.759	76.8217	2500	2500	RE	0	3549	OT	X
127	Unidentified seal	2	03/09/2010 16:26:00	-134.759	76.8217	2500	2500	RE	0	3551	OT	X
128	Unidentified seal	1	03/09/2010 16:40:00	-134.825	76.8233	2500	2500	RE	0	3561	OT	X
129	Unidentified seal	3	03/09/2010 16:40:00	-134.825	76.8233	3000	3000	RE	0	3563	OT	X
130	Unidentified seal	1	03/09/2010 16:45:00	-134.851	76.8241	1500	1500	RE	0	3568	OT	X
131	Unidentified seal	1	03/09/2010 17:03:00	-134.947	76.8269	3000	3000	RE	0	3576	OT	X
132	Ringed seal	1	03/09/2010 17:18:00	-135.007	76.8284	2000	2000	RE	0	3582	OT	X
133	Unidentified seal	1	03/09/2010 17:31:00	-135.074	76.828	700	700	RE	0	3634	OT	X

[a] Sighting ID = Sequential number given to sightings, 1-43 and subsequent number gaps w ere observed during transits or in areas outside of the study area (e.g. Chukchi Sea)
[b] No. = Number of individual marine mammal(s)
[c] Initial Sighting Distance (m) = distance of marine mammal(s) from the PSOs w hen initially detected
[d] CPA (m) = Closest Point of Approach of the maine mammal(s) to the PSO/Vessel
[e] Behavior = Initial behavior observed by PSOs, codes: BL = Blow (cetacean surfacing), DI = Dive, FD = Front dive (included w ith dive in analyses), FL = Flee, LO = Look, OT = Other, RE= Rest, SW = Sw im, TH= Thrash dive, UN = Unknow n, WK= Walk (polar bears, on ice or land)
[f] Beaufort Wind Force, See Appendix H for definitions
[g] Vessel Activity = Vessel activity at the time of initial detection, codes: DP = Deploying Survey Gear, LS = Survey Line Shooting, SH = Shooting Off Survey Line, OT= Other (e.g., transit), RC = Recovering Survey Gear, RU = Ramp-Up of Airgun Array