MARINE MAMMAL MONITORING DURING UNIVERSITY OF TEXAS AT AUSTIN'S MARINE GEOPHYSICAL SURVEY OF THE WESTERN CANADA BASIN, CHUKCHI BORDERLAND AND MENDLEEV RIDGE, ARCTIC OCEAN, JULY–AUGUST 2006

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LIST OF ACRONYMS AND ABBREVIATIONS

~	approximately
ADCP™	Acoustic Doppler Current Profiler
Bf	Beaufort Wind Force
BO	Biological Opinion
CFR	(U.S.) Code of Federal Regulations
CITES	Convention on International Trade in Endangered Species
cm	centimeter
CPA	Closest (Observed) Point of Approach
CTD	conductivity, temperature, depth
dB	decibel
EA	Environmental Assessment
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
GI	Generator Injector
GIS	Geographic Information System
GMT	Greenwich Mean Time
$g(0)$	probability of seeing a group located directly on a survey line
h	hours
Hz	Hertz (cycles per second)
IHA	Incidental Harassment Authorization (under U.S. MMPA)
in^3	cubic inches
IUCN	International Union for the Conservation of Nature
kHz	kilohertz
km	kilometer
km^2	square kilometers
km/h	kilometers per hour
kt	knots
L-DEO	Lamont-Doherty Earth Observatory (of Columbia University)
LoA	Letter of Authorization
μPa	micro Pascal
m	meters
MBB	Multibeam Bathymetric (sonar)
MCS	Multi-Channel Seismic
min	minutes
MMO	Marine Mammal Observer
MMPA	(U.S.) Marine Mammal Protection Act
n	sample size
n.mi.	nautical miles

NMFS	(U.S.) National Marine Fisheries Service
No.	number
NSF	(U.S.) National Science Foundation
PD	Power down of the airgun array to one airgun (in this study, from an output of 2840 in^3 to 210 in^3)
pk-pk	peak-to-peak
re	in reference to
rms	root-mean-square
s	seconds
SD	Shut Down of airguns not associated with mitigation
s.d.	standard deviation
SCUBA	self-contained underwater breathing apparatus
SIS	sea ice seismometers
SZ	Shut Down of all airguns because of a marine mammal sighting near or within the safety radius
TTS	Temporary Threshold Shift
UNEP	United Nations Environmental Programme
USCG	United States Coast Guard
USCGC	United States Coast Guard cutter
"Useable"	Visual effort or sightings made under the following observation conditions: daylight periods within the study area, ***excluding*** periods 3 min to 2 h after airguns were turned off (post-seismic), poor visibility conditions (visibility <2 km), and periods with Beaufort Wind Force >5. Also excluded were periods when the Healy's speed was <3.7 km/hr (<2 kt) or with >60º of severe glare between 90º left and 90º right of the bow. Sightings of marine mammals hauled out on the ice were considered "useable" for analyses.
UTIG	University of Texas at Austin Institute for Geophysics

EXECUTIVE SUMMARY

Introduction

This document serves to meet reporting requirements specified in an Incidental Harassment Authorization (IHA) issued to the University of Texas at Austin Institute for Geophysics (UTIG) by the National Marine Fisheries Service (NMFS) on 14 July 2006; and an IHA issued to UTIG by the U.S. Fish and Wildlife Service (USFWS) on 24 July 2006. The IHAs (Appendices A and B) authorized non-lethal takes of certain marine mammals incidental to a marine seismic survey in the Arctic Ocean and Chukchi Sea. Behavioral disturbance to marine mammals is considered to be "take by harassment" under the provisions of the U.S. Marine Mammal Protection Act (MMPA). NMFS considers that marine mammals exposed to airgun sounds with received levels ≥160 dB re 1 μPa (rms) might be sufficiently disturbed to be "taken by harassment". "Taking" would also occur if marine mammals close to the seismic activity experienced a temporary or permanent reduction in their hearing sensitivity, or reacted behaviorally to the airgun sounds in a biologically significant manner.

It is not known whether seismic exploration sounds are strong enough to cause temporary or permanent hearing impairment in any marine mammals that occur close to the seismic source. Nonetheless, NMFS requires measures to minimize the possibility of any injurious effects (auditory or otherwise), and to document the extent and nature of any disturbance effects. In particular, NMFS requires that seismic programs conducted under IHAs include provisions to monitor for marine mammals, and to shut down or power down the airguns when mammals are detected within designated safety radii. The USFWS adopted similar guidelines for its IHA. In this project, a power down was a reduction of the operating airgun arrays' volume from 2840 in^3 to 210 in^3, whereas a shut down involved the complete cessation of firing by all airguns.

Seismic Program Described

The purpose of the seismic survey was to collect seismic reflection and refraction data and sediment cores that reveal the crustal structure and composition of submarine plateaus in the western Amerasia Basin in the Arctic Ocean. These data will assist in determining the tectonic evolution of the Amerasia Basin and Canada Basin, which is fundamental to such basic concerns as sea level fluctuations and paleoclimate in the Mesozoic era. The survey extended from north of Barrow, Alaska, to 79°N and then south toward the Chukchi Sea. Water depths within the seismic survey area were 35–3899 m. Forty-two percent of the seismic survey (~144 km) was conducted in water 100–1000 m deep, but most (57%) of the survey (~193 km) occurred in water deeper than 1000 m. Less than one percent (~0.6%) of seismic operations occurred in water less than 100 m deep when a single 210 in^3 G. gun was tested for two km. Most of the seismic survey was conducted far from any country's territorial waters. However, ~2 km of airgun operations occurred within 200 n.mi. (370 km) off the Alaska coast while testing the single G. gun.

The USCG cutter *Healy* departed from offshore Barrow, Alaska, on 19 July 2006 and began seismic operations north of Alaska on 26 July. The seismic study was concluded on 17 Aug. 2006, to the northwest of Barrow. The *Healy* sailed south to Barrow where three marine mammal observers (MMOs) disembarked on 19 Aug. The ship then continued to Nome where it arrived 23 Sept.

This seismic survey was conducted using a single array of four 210 in^3 G. guns plus four 500 in^3 Bolt airguns that discharged a total volume of 2840 in^3, deployed from the *Healy*. Because of technical

problems with the airgun system, the planned array was used only briefly (for 1 km of the 339 km surveyed) at the beginning of seismic operations. Either two or three of the Bolt airguns were operated with the four G. guns for, respectively, 25% and 36% of the total survey. Thus, the total discharge volumes were either 1840 or 2340 in^3. The IHAs issued by NMFS and USFWS also authorized exposing marine mammals to sounds from another airgun array consisting of four GI guns with a total discharge volume of 420 in^3. This was intended for use in shallow water (<100 m deep). However, seismic operations were not conducted in shallow water, and the 420 in^3 array was never employed. Sea ice seismometers were deployed from the *Healy* by helicopter to receive and relay seismic signals. The seismometers were placed on the ice, with a hydrophone suspended on the water through a hole in the ice. A streamer, ~200 m long, containing hydrophones was also towed behind the *Healy* to receive returning seismic signals. A multibeam bathymetric sonar and a lower energy 3.5 kHz sub-bottom profiler were operated from the *Healy* throughout all or much of the survey.

Monitoring and Mitigation Description and Methods

Four marine mammal observers (MMOs), including three biologists and one Inupiat, were aboard the *Healy* throughout the period of operations in order to conduct visual monitoring and to implement mitigation measures. The primary purposes of the monitoring and mitigation effort were the following: ***(A)*** Document the occurrence, numbers and behaviors of marine mammals near the seismic source based on visual observations. ***(B)*** Implement a power down or shut down of the airgun array when marine mammals were sighted near or within designated safety radii. ***(C)*** Monitor for marine mammals before and during ramp-up periods.

At least one MMO watched for marine mammals at all times while airguns operated during daylight periods. Two or more MMOs were on watch during 46% (200 h) of the total observation period, and during 43% of the time when airguns were operating. The observation schedule spanned 24 h per day because darkness was not encountered during the survey.

The MMOs used 7 x 50 binoculars, 25 x 150 Big-eye binoculars, and the naked eye to scan the surface of the water around the vessel for marine mammals. The distance from the observer to the sighting was estimated using reticles in the binoculars and angles from a clinometer. When a marine mammal was detected within or approaching the safety radius, the MMO(s) contacted the airgun operators to request a power down or shut down of the airguns.

Primary mitigation procedures, as required by the IHAs, included the following: ***(A)*** Ramp ups, consisting of an increase in the operating volume of the airguns not to exceed 6 dB per five minutes after periods without seismic operations. ***(B)*** Immediate power downs or shut downs of the airguns whenever marine mammals were detected within or about to enter the applicable safety radius. The safety radii used during the survey were based on the distances within which the received levels of airgun sounds were expected to diminish to 190 (for pinnipeds) or 180 (for cetaceans) dB re 1 µPa rms. Separate radii were used during operations in deep (>1000 m) water vs. intermediate-depth (100–1000 m) and shallow (<100 m) water. During operations with the airguns, the safety radii for pinnipeds were 230 and 500 m for deep and intermediate water depths; the corresponding safety radii for cetaceans were 716 and 1074 m, respectively. Only a single 210 in^3 G. gun was operated in shallow water; its safety radii, as required by the IHA were 1000 m for pinnipeds and as far as visibility allowed (at least an estimated 2 km) for cetaceans in shallow water.

Monitoring Results

The *Healy* traveled a total of 4391 km within the study area (Table ES.1). The airguns operated along 7.72% of that total ship track, and always during daylight. The actual number of kilometers traveled during seismic periods was significantly lower than anticipated in the IHA applications and EA (339 vs. 3625 km). Ramp ups of the airguns occurred on 27 occasions. No ramp ups were conducted at night; there was no darkness during the project given the high latitudes and dates of operation. In total, 2912 km of visual observations were conducted (Table ES.1). MMOs were on visual watch during all ramp ups and all periods with airgun operations.

Sighting data collected within the study area were acquired under varying conditions. Overall, ice conditions ranged between 10 and 98% cover and the ice thickness varied between extremely thin to several meters thick. The majority of marine mammal sightings (69%) occurred in areas where the ice cover was 80–95%; 45% of sightings occurred in areas where the ice cover was 80%. The effects of the variable ice conditions on the sightability of marine mammals were impossible to determine. Therefore, the sighting data from the Arctic Ocean survey were used with caution to estimate marine mammal density within the survey area. We also applied density data from previous marine mammal surveys in the study area, as assembled via a literature review, to estimate number of animals possibly exposed to different sound levels. Those previous results were summarized and used in the IHA applications and EA prepared for this project.

Analyses of pinniped and cetacean behavior during times with and without seismic operations focused on sightings and survey effort in the study area during periods with "useable" survey conditions. "Useable" effort represented ~61% of the total visual effort (in hours; Table ES.1). "Useable" effort excluded periods 3 min to 2 h after airguns were turned off (post-seismic), periods with poor visibility (<2 km), periods with Beaufort Wind Force >5, and periods when the *Healy* was traveling <2 kt (<3.7 km/hour). Also excluded were periods with >60° of severe glare between 90º left and right of the bow.

No walruses were observed within the study area; nor were any cetaceans observed within the study area.

Three groups of polar bears (nine individuals) were sighted throughout the study area, all on ice. No bears were observed during seismic operations either on the ice or in the water. Sounds produced by the airguns would be much more prominent in the water than in air.

A total of 149 pinnipeds (in 130 groups) were observed within the study area. Ringed seals are known to occur regularly in the deep Arctic waters of the Beaufort Sea and the great majority of identified seals were ringed seals (33 of 42). The remaining nine seals identified to species by observers were bearded seals. An additional 59 "unidentified" seals were sighted within the study area (Table ES.1). These animals were most likely ringed seals, given the ringed seal's relative abundance and distribution through the study area. No walruses were observed during the survey. All three power downs and five shut downs implemented during the study were a result of the presence of seals in the water within or about to enter the safety radius during periods with airgun operations. No injured pinnipeds were sighted at any time.

Marine mammals that are out of the water are not exposed to significant sounds from airguns operating below the surface. Therefore, pinniped sightings are separated into two categories (in water and on ice) throughout this report. As requested by USFWS, a power down or shut down would have been implemented if a walrus or polar bear had been observed out of the water within the 190 dB (underwater) radius around operating airguns. This precaution was called for because hauled-out walruses often enter

TABLE ES.1. Summary of *Healy* operations, observer and acoustic monitoring effort, and marine mammal sightings during the marine geophysical survey in the Arctic Ocean, 19 July – 23 Aug. 2006. No cetaceans were observed within the study area. Three power downs and five shut downs occurred due to the presence of pinnipeds.

	Non-Seismic			Seismic			
	Useable[a]	**Other**	**Post Seismic**	**Useable[a]**	**Other**	**Total Useable[a]**	**Total**
Total Operations in h							
Healy	**300**	**342**	**37**	**61**	**16**	**361**	**756**
Observer	**158**	**175**	**26**	**61**	**16**	**219**	**436**
Total Operations in km							
Healy	**2767**	**1187**	**98**	**272**	**67**	**3038**	**4391**
Observer	**1490**	**1033**	**50**	**272**	**67**	**1762**	**2912**
No. Pinniped Sightings In water (Indiv.)	32 (32)	8 (8)	4 (4)	11 (11)	-	43 (43)	55 (55)
No. Pinniped Sightings On Ice (Indiv.)	33 (37)	21 (32)	2 (2)	17 (21)	2 (2)	50 (58)	75 (94)
No. Polar Bear Sightings (Indiv.)	3 (9)	0	0	0	0	3 (9)	3 (9)
No. Power Downs / Shut Downs[b]	-	-	-	8	-	8	8

[a] See *Acronyms and Abbreviations* for the definition of "useable" effort.
[b]There were 3 power downs and 5 shut downs when seals were seen in the water within or approaching the designated safety radius.

the water when disturbed. In fact, no walruses were observed during the project and no polar bears were seen during seismic operations, so no shut downs or power downs were required for those species managed by USFWS. Neither shut downs nor power downs were requested by NMFS for seals that were out of the water.

In general, the relatively small number of "useable" sightings (n = 96) did not allow meaningful interpretation of sighting rates and behavior during seismic vs. non-seismic periods. However, the observed sighting rate trend was contradictory to trends during many other seismic surveys: during this Arctic Ocean seismic survey, marine mammal sighting rates of pinnipeds in the water were nearly twice as high during seismic activities as during non-seismic periods. During more typical seismic surveys, the rate of sightings is usually lower when the airguns are operating than when they are silent, and average distances of the sighted mammals from the vessel are usually greater when the airguns are operating. In those cases, it is assumed that many species tend to avoid the approaching noise source, sometimes before the mammals are detected by observers. During the 2006 *Healy* study, seismic operations were often conducted in areas of open water (leads and polynyas) to avoid ice-induced damage to the equipment. Seals tended to concentrate in these areas of open water, where they can feed and avoid polar bears. The polar bears also tended to congregate in these areas, presumably because of the higher seal concentrations. This association of both seismic surveys and marine mammals with leads and polynyas presumably accounted for the higher sighting rate during seismic surveys. This pattern was also observed during the 2005 *Healy* survey.

Number of Marine Mammals Present and Potentially Affected

During this project, the "sound level radii" called for by NMFS were, for pinnipeds, the best estimates of the 190 dB re 1 μPa (rms) radii for eight airguns with a total volume of 2840 in^3. Those radii were estimated to be 230 m in water >1000 m deep, and 345 m in water 100–1000 m deep. The 345 m safety radius was expanded to 500 m by UTIG as a conservative measure. In addition, the airgun array operated at full volume (2840 in^3) for less than one km of the survey, due to ice and equipment problems. Therefore, the applied 190 dB safety radius was an overestimation for the typically active array and reduced the likelihood of exposures to that sound level even further. The USFWS, which has jurisdiction over polar bears and walruses, also imposed a 190 dB safety radius for those two species. All 96 useable marine mammal sightings made within the study area were of seals and polar bears, and all eight shut downs or power downs were for seals.

Three power downs were requested on three separate occasions. All three power downs were implemented in deep water >1000 m deep when a bearded seal and two individual ringed seals were sighted approaching or within the safety radius (230 m) around the operating airguns (Table ES.1). The first power down was requested when a bearded seal was observed diving 191 m away from the active airguns in 1290 m deep water where the modeled 190 dB sound level radius was 200 m. The bearded seal may have been exposed briefly to sound levels ≥190 dB prior to the power down. One of the ringed seals was seen diving outside the 230 m safety zone (~236 m from the guns), and the other ringed seal was observed diving within the safety zone, 212 m from the array. Because the modeled 190 dB sound level was 200 m, it was unlikely that either of the two ringed seals was exposed to airgun sounds ≥190 dB re 1 μPa (rms).

One shut down for an unidentified seal was requested in deep water where the safety radius was 230 m around the sound source and the 190 dB sound level radius was 200 m. The unidentified seal was observed outside but approaching the safety radius when the shut down was implemented. The seal was unlikely to have been exposed to sounds greater than 190 dB. Four shut downs were implemented in intermediate depth water (100–1000 m) when individual ringed seals were observed within the 500 m safety radius. A single ringed seal, resting on the ice, dove into the water, 264 m from the sound source. Although it entered the "safety radius" it did not enter the 190 dB sound level radius (estimated to be 150 m for a 840 in^3 array) and it is unlikely that the seal was exposed to sounds ≥190 dB. Two ringed seals were observed 458 and 438 m, respectively, away from the operating airguns. The seals were near the edge of the safety zone, but outside the 190 dB radius (300 m for a 2340 in^3 array). It is unlikely that the seals were exposed to a sound level ≥190 dB. The final shut down in intermediate water was requested when a ringed seal was observed diving 250 m away from the source, within the 500 m safety radius and the 300 m 190 dB radius. It is likely that this seal was briefly exposed to sound levels greater than 190 dB before it surfaced or after it dove, although it would not have been exposed to those levels when at the surface.

Each of the five shut downs was implemented when a seal was sighted well beyond the anticipated 190 dB radius for a single G. gun (20 m in deep water and 30 m in intermediate water depths). Therefore, on each of these five occasions, a power down would have been sufficient to meet IHA requirements, and the implementation of full shut downs went beyond the minimum requirements for mitigation.

We used available data on densities of marine mammals in the area to calculate alternative estimates of the numbers of marine mammals (seen or unseen) that might have been exposed to various sound levels. As noted earlier, estimates of marine mammal densities along the trackline were calculated

with caution because the ice restricted the observers' lateral sighting distances. Accordingly, we also used densities from earlier surveys to estimate exposures. Any (unseen) large cetaceans that might have been exposed to received sound levels ≥160 dB re 1 μPa (rms), and any unseen delphinids or pinnipeds exposed to received levels ≥170 dB re 1μPa, were assumed to have been potentially disturbed during the seismic study. We also calculated estimated numbers of delphinids and pinnipeds that might have been exposed to ≥160 dB re 1 μPa (rms), as called for by NMFS.

Based on the sighting data from this project, seals might have been exposed to airgun pulses with received levels ≥160 dB re 1 μPa (rms) on 299–463 occasions, and ≥170 dB sound levels 67–104 times. The ranges of values result from calculating the estimates in two ways, based on visual surveys during (alternatively) "seismic" and "non-seismic" periods. These estimates were based on the area of ensonified **open** water. The area of open water was calculated by extrapolating the ice cover within ~2 km of the *Healy* out ~20 km (the extent of the 160 dB radius) into the ice pack in intermediate water depths (100 – 1000 m) or out to ~13 km from the *Healy* for deep water (>1000) sightings. The ship tended to follow open water leads, therefore, the ice cover further away from the vessel was typically heavier than that within 2 km. Extending the ice cover from within 2 km of the ship out to ~20 or 13 km overestimated the area of open water. Because the open water area is overestimated, the take estimates are believed to be inflated. Density estimates from prior surveys suggests that a total of 196 individual pinnipeds might have been exposed to airgun sound levels ≥160 dB, and ~52 pinnipeds might have been exposed to ≥170 dB. Similarly, density data from previous surveys suggest that, even though no walruses were observed during the present study, two walruses might have been exposed to ≥160 dB levels and perhaps one might have been exposed to ≥170 dB sounds. The 170 dB radius is considered a more realistic disturbance criterion for pinnipeds.

Although no cetaceans were sighted during the seismic survey, it is possible that some were present close to the trackline but not seen. Based on the density estimates from other projects, a total of six individual cetaceans (bowhead whales, beluga whales, and gray whales) might have been exposed to ≥160 dB re 1 μPa (rms) if they did not move away from the *Healy* before it was within the 160 dB radius.

No polar bears were observed during seismic operations, but it is possible that a few polar bears may have been in the water, unseen by the observers, within the nominal 190 dB radius. Density data from Moulton and Williams (2003) indicate that two polar bears may have been within such distances during airgun operations. However, polar bears in the water normally remain at or near the water surface, where received levels are lower than at depth. Therefore, it is very unlikely that any polar bears were exposed to received levels of airgun sound ≥190 dB re 1 μPa (rms).

In summary, the maximum estimated numbers of seals (ringed seals, bearded seals and spotted seals) and cetaceans (bowheads, belugas, and narwhals) potentially affected by UTIG's seismic survey were far lower than the respective numbers authorized by NMFS (8426 and 256 authorized to be exposed to ≥160 dB). The maximum number of walruses and polar bears potentially affected by the seismic survey are also far lower than the respective numbers authorized by USFWS (3960 walruses and 55 polar bears). Given this, and the mitigation measures that were applied, the effects were very likely localized and transient, with no significant impact on either individual marine mammals or their populations. Given the far-offshore location of the survey work, there was also no potential for any effects on the availability of marine mammals for subsistence hunting in Alaska.

1. BACKGROUND AND INTRODUCTION

The University of Texas at Austin Institute for Geophysics (UTIG) conducted a research-oriented seismic survey in the Arctic Ocean north of Alaska from 19 July to 23 Aug. 2006 (Fig. 1.1). Seismic operations were based from the United States Coast Guard (USCG) cutter *Healy*, a USCG icebreaker. The National Science Foundation (NSF), a U.S. Government agency, funded the research. Seismic operations occurred periodically from 26 July through 17 Aug. in conjunction with sediment coring.

The purpose of the study was to collect seismic reflection and refraction data and sediment cores that reveal the crustal structure and composition of submarine plateaus in the western Amerasia Basin in the Arctic Ocean. Past studies have led many researchers to support the idea that the Amerasia Basin opened about a pivot point near the Mackenzie Delta. The crustal character of the Chukchi Borderlands could determine whether that scenario is correct, or whether more complicated tectonic scenarios must be devised to explain the presence of the Amerasia Basin. These data will assist in determining the tectonic evolution of the Amerasia Basin and Canada Basin, which is fundamental to such basic concerns as sea level fluctuations and paleoclimate in the Mesozoic era.

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. Either behavioral/distributional effects or (if they occur) auditory effects could constitute "taking" under the provisions of the U.S. Marine Mammal Protection Act (MMPA) and the U.S. Endangered Species Act (ESA), at least if the effects are considered to be "biologically significant".

A total of 13 species of marine mammals are known to inhabit parts of the Arctic Ocean in or near the seismic survey area (§4. Marine Mammals). However, only two of those species, the bowhead and fin whale, are listed as "Endangered" under the ESA; and it would be unlikely for a fin whale to be encountered in the area of the survey. The marine mammals that were likely to be encountered during the project are under the jurisdiction of the National Marine Fisheries Service (NMFS; all cetaceans and pinnipeds other than walruses) and the U.S. Fish and Wildlife Service (USFWS; polar bears and walruses).

Other species of concern (birds) that might occur in the area close to Barrow are the spectacled (*Somateria fischeri*) and Steller's (*Polysticta stelleri*) eiders which are listed as "Threatened" under the ESA. Of the two species, spectacled eiders have been documented farther offshore (40 km) in the Barrow area. It was considered highly unlikely that either eider species would be encountered during the initiation of seismic operations that began ~85 km from Barrow and 50 km off the mainland (Fig 1.1).

On 7 March 2006, UTIG requested that NMFS issue an Incidental Harassment Authorization (IHA) to authorize non-lethal "takes" of marine mammals incidental to seismic operations in the Arctic Ocean (LGL Ltd. 2006a). UTIG also submitted a request to the USFWS on 14 March for an IHA to authorize non-lethal "takes" of walruses and polar bears incidental to the proposed seismic survey (LGL Ltd. 2006b). The IHAs were requested pursuant to Section 101(a)(5)(D) of the MMPA. An Environmental Assessment (EA) was also written to evaluate the potential impacts of the marine seismic survey in the Arctic Ocean (LGL Ltd. 2006c). That EA was adopted by NSF. An IHA was issued by NMFS on 14 July 2006 (Appendix A), and an IHA was issued by USFWS on 24 July (Appendix B). The

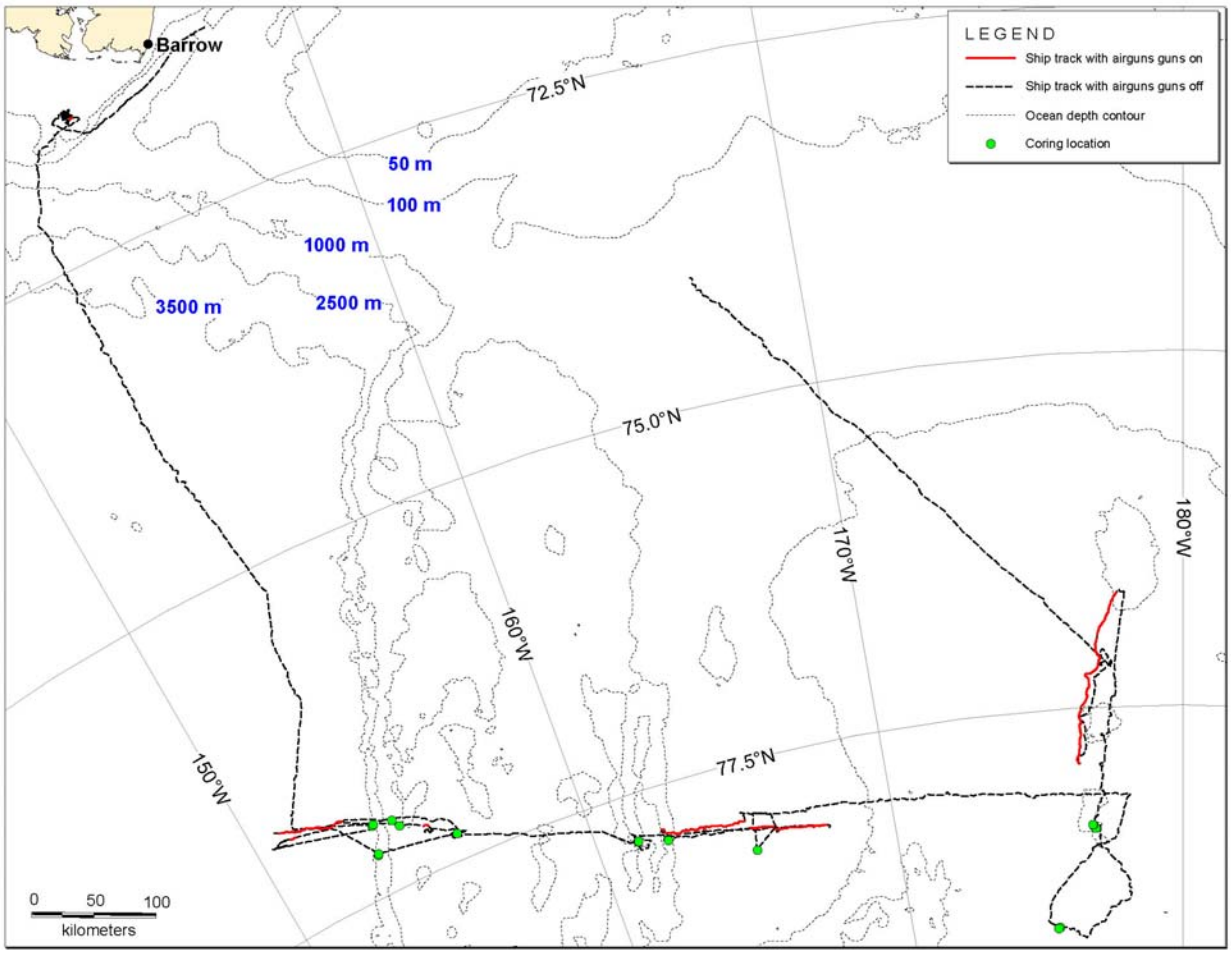

FIGURE 1.1. The *Healy's* trackline in the Arctic Ocean north of Barrow, Alaska, showing (in red) the parts of the track where seismic operations occurred. Coring locations are indicated by green circles.

IHAs authorized "potential take by harassment" of various cetaceans and pinnipeds during the marine geophysical cruise described in this report.

In addition to the aforementioned IHAs, on 3 May 2006, UTIG requested a Letter of Authorization (LoA) from USFWS for the intentional take of polar bears in regard to the proposed survey. An LoA is required under Section 101(c) of the MMPA when the take of a polar bear is "imminently necessary in self-defense or to save the life of a person in immediate danger" (Appendix C). Because the project necessitated that scientists spend considerable time on the ice deploying seismic equipment, the possibility of interaction with polar bears was high. Accordingly, UTIG took the precautionary step of requesting an LoA in the event that an intentional take of a polar bear became necessary. USFWS issued an LoA to UTIG on 26 July 2006 (Appendix C).

This document serves to meet reporting requirements specified in the IHAs and LoA. The purposes of this report are 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.

Incidental Harassment Authorizations

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 (G. guns and Bolt guns) used during the seismic study, a multibeam bathymetric (MBB) sonar, two sub-bottom profilers, an acoustic Doppler current profiler (ADCP™), and general vessel and helicopter operations. No serious injuries or deaths of marine mammals were anticipated from the seismic survey, given the nature of the operations and the mitigation measures that were implemented, and no injuries or deaths were attributed to the seismic operations. Nonetheless, the seismic survey operations described in Chapter 2 had the potential to "take" marine mammals by harassment. Behavioral disturbance to marine mammals is considered to be "take by harassment" under the provisions of the MMPA. Appendix E provides further background on the issuance of IHAs relative to seismic operations and "take".

Under current NMFS guidelines (e.g., NMFS 2006a), "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 these 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. In the USFWS IHA issued for the 2006 *Healy* cruise, a 190 dB safety radius guideline was established for polar bears and walruses.

Disturbance to marine mammals could occur at distances beyond the safety (shut down) radii if the mammals were exposed to moderately strong pulsed sounds generated by the airguns or perhaps by sonar (Richardson et al. 1995). NMFS assumes that marine mammals exposed to airgun sounds with received levels ≥160 dB re 1 μPa (rms) are likely to be disturbed appreciably. That assumption is based mainly on data concerning behavioral responses of various species 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). On the other hand, migrating bowhead whales and summering beluga whales show evidence of avoidance upon exposure to received levels of airgun pulses below 160 dB rms (Miller et al. 1999, 2005; Richardson et al. 1999). In general, disturbance effects are expected to depend on the species of marine mammal, the activity of the animal at the time of disturbance, distance from the sound source, the received level of the sound, and the

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[1] "rms" means "root mean square", and represents a form of average across the duration of the sound pulse as received by the animal. Received levels of airgun pulses measured on an "rms" basis are generally 10–12 dB lower than those measured on the "zero-to-peak" basis, and 16–18 dB lower than those measured on a "peak-to-peak" basis (Greene 1997; McCauley et al. 1998, 2000). The latter two measures are the ones commonly used by geophysicists. Unless otherwise noted, all airgun pulse levels quoted in this report are rms levels. 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, 2000), with considerable variability (Madsen et al. 2006). SEL (energy) measures may be more relevant to marine mammals than are rms values, but the current regulatory requirements are based on rms values.

associated water depth. Some individuals may exhibit behavioral responses at received levels 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.

A notice regarding the proposed issuance of an IHA for the survey in the Arctic Ocean was published by NMFS in the *Federal Register* on 15 May 2006 and public comments were invited (NMFS 2006a). On 14 July 2006, UTIG received the IHA from NMFS that had been requested for the Arctic Ocean project. On 1 Aug. 2006, NMFS published a second notice in the *Federal Register* to announce the issuance of the IHA (NMFS 2006b). A copy of the NMFS IHA is included in this report as Appendix A.

NMFS granted the IHA to UTIG on the assumptions that

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

The polar bear (*Ursus maritimus*) and Pacific walrus (*Odobenus rosmarus*) are managed by the NMFS). USFWS determined in 2006 that proponents of arctic seismic projects should operate under IHAs issued by USFWS. The process of obtaining an IHA from USFWS is very similar to that of obtaining one from the NMFS. A notice regarding the proposed issuance of an IHA for the survey in the Arctic Ocean was published by USFWS in the *Federal Register* on 22 June 2006 and public comments were invited (USFWS 2006). On 24 July 2006, UTIG received the IHA from USFWS. USFWS did not publish a second notice in the *Federal Register* to announce the issuance of the IHA. A copy of the USFWS IHA is included in this report as Appendix B.

Mitigation and Monitoring Objectives

The objectives of the mitigation and monitoring program were described in detail in UTIG's IHA applications (LGL Ltd. 2006a,b) and in the IHAs issued by NMFS and USFWS to UTIG (Appendices A and B). Explanatory material about the monitoring and mitigation requirements was published by NMFS and USFWS in the *Federal Register* (NMFS 2006a,b; USFWS 2006).

The main purpose of the mitigation program was to avoid or minimize potential effects of UTIG's seismic survey on marine mammals. This required that shipboard personnel 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 air volume. A shut down involves temporarily terminating the operation of all airguns. An additional mitigation objective was to detect marine mammals within or near the safety radii prior to starting the airguns, or during ramp up toward full power. In these cases, the start of airguns was to be delayed or ramp up discontinued until the safety radius was free of marine mammals insofar as this can be determined visually (see Appendices A and B and Chapter 3).

The primary objectives of the monitoring program were as follows:

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

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

Letter of Authorization for Intentional Take of Polar Bears

The LoA issued by USFWS permitted UTIG to intentionally haze polar bears if an interaction were to escalate to a dangerous level during the 2006 survey. No encounters with polar bears were anticipated during the project; however the possibility was present due to the fact that scientists were often on the ice deploying seismic receivers. The LoA was issued with the understanding that safeguards would be implemented to limit polar bear/human interactions and that qualified and trained personnel would be assigned the task of deterrence. The USFWS also requested reporting of any sightings or encounters within a 24 h period.

As per requirements of the LoA (and USFWS IHA), a Polar Bear Interaction Plan describing the interaction strategy was prepared by NSF for the UTIG project (Appendix D). UTIG worked with a representative of the USFWS Marine Mammal Management office to ensure that all aspects of the Plan were understood and approved by both parties. The Plan describes the main efforts of those tasked with deterring the bears to be (1) identify the presence of polar bears as early as possible, and (2) avoid/limit encounters.

Report Organization

The primary purpose of this report is to describe UTIG's 2006 Arctic Ocean seismic survey including the associated monitoring and mitigation programs, and to present results as required by the IHAs (Appendices A and B) and LoA (Appendix C). 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".

Those chapters are followed by Acknowledgements and Literature Cited sections.

In addition, there are 11 Appendices. Details of procedures that are more-or-less consistent across recent NSF-sponsored 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 UTIG for this study;

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

C. a copy of the USFWS LoA issued to UTG for this study;

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 *Healy*, its airguns and its sonars;

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

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

I. monitoring effort and list of marine mammals seen during this cruise;

J. marine mammal sightings with power downs and shut downs during this Arctic Ocean cruise;

K. marine mammal density estimates for the Arctic Ocean project survey area.

2. ARCTIC OCEAN SEISMIC SURVEY DESCRIBED

Procedures used to obtain seismic data during the Arctic Ocean survey were generally similar to those used during previous seismic surveys, especially University of Alaska Fairbank's trans-Arctic Ocean survey aboard the *Healy* in 2005 (Haley and Ireland 2006). Some specialized procedures were necessary in the 2005 and 2006 surveys to deal with the ice—most notably the use of an icebreaker as the source vessel. The Arctic Ocean survey used seismic refraction and reflection techniques to characterize the earth's crust, including an 8-airgun array as the energy source[2], and sea ice seismometers plus a towed hydrophone streamer (~200 m long) as the receiver systems. The sea-ice seismometers were deployed via helicopter onto the ice; a hydrophone was suspended in the water through an opening in the ice. In addition, sonars were used to map the bathymetry and sub-bottom conditions to obtain data needed for the geophysical studies.

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

Operating Areas, Dates, and Navigation

The track of the Arctic Ocean project in 2006 extended from northeast of Barrow, Alaska, over the western Canada Basin and then west to the Chukchi Borderland and Mendeleev Ridge. More specifically, seismic operations occurred from 71.5ºN to 79.1ºN, between 150.5º and 178.2ºW (Fig. 1.1). Water depth during the seismic survey ranged from 223 to 4873 m. Most of the seismic survey was conducted far outside any country's territorial waters. However, ~2.3 km of the seismic operations were conducted within 200 n.mi. (370 km) of the coast of Alaska. The science crew boarded the *Healy* off Barrow, Alaska, on 19 July 2006. The first seismic operations (brief equipment testing) were conducted ~85 km northeast of Barrow on 26 July. Thereafter, seismic operations occurred intermittently over ~24 days from 31 July until the last airgun operations on 17 Aug. 2006. There was 24-hour daylight throughout the project, and no seismic operations were conducted in darkness. After termination of the survey due to an accident in which two USCG crew members died, the *Healy* returned to Barrow, Alaska, on 19 Aug. 2006. The *Healy* then continued to Nome where most of the science crew disembarked on 23 Aug. A chronology of the study is presented in Table 2,1. A summary of the total distances traveled by the *Healy* during the survey, distinguishing periods with and without seismic operations, is presented in the Executive Summary (Table ES.1).

Periodically throughout the Arctic Ocean survey, seismic activities were suspended for coring operations which were an integral part of the project. This occurred at 17 locations (Table 2.2). Depending on water depth and the number of cores to be collected, the *Healy* was at each coring site between 0.75 and 5.2 hours.

Throughout the survey, position, speed, and water depth of the *Healy* were logged digitally every ~1 s. In addition, the position of the *Healy*, water depth, and information on the airgun array were logged for every minute while the *Healy* was on a seismic line and collecting geophysical data. The geophysics crew kept a manual log of events, as did the marine mammal observers (MMOs) while on duty. The MMOs also recorded the number and volume of airguns that were firing when the *Healy* was offline (e.g., prior to shooting at full volume) or was online but not recording data (e.g., during airgun or computer problems).

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[2] The intended seismic source consisted of 8-airguns array, but due to technical problems with the airgun system, the full array was used for only 1 km of the 339 km survey. Either six or seven guns were used most of the time (25% and 36% of the total survey, respectively).

TABLE 2.1. Chronology in Greenwich Mean Time (GMT) of events during the July–Aug. 2006 Arctic Ocean seismic survey.

Date (2006)	Time	Event Description
19 Jul		*Healy* departed Barrow area
20 Jul		Backed and rammed to transit through thick ice
20 Jul	23:00	Helicopter flight for ice recon – BH[a] onboard; 1 polar bear sighted @ 71° 50´N; 153° 53´W
21 Jul	17:10	*Healy* in the same position as on 20 July; helicopter flight for ice recon – CF[b] onboard; 1 bearded seal sighted @ 71° 43´N; 153° 62´W
22 Jul		Drifted with ice
22 Jul	20:30	Helicopter flight for ice recon – AS[c] onboard; 1 unidentified seal sighted
23 Jul		Worked way out of thick ice; moved East; first sightings from vessel
24 Jul	01:00	Sampled dirty ice
24 Jul	17:36-18:09	Seismic gear deployed for test; no seismic operations
24 Jul	22:00-22:30	Workboat launched to test seismometer deployment on ice
25 Jul		Traveled East
25 Jul	00:00	Ice landing test flight
26 Jul	01:57-02:11	Tested airgun - 1 G. gun at 210 in^3
26 Jul		Traveled ENE
27 Jul		Traveled
28 Jul		Traveled
29 Jul	09:50	Coring station HLY0602-01GC[d]
29 Jul	20:29	Helicopter operations, deployed seismometers
29 Jul	23:38	*Healy* stopped for crane test
30 Jul	12:33	Coring station HLY0602-02GC
30 Jul		Worked on airguns
31 Jul	12:00 – 13:53	Seismic operations
31 Jul	23:00	Coring Station HLY0602-03BB[e]
1 Aug	02:55	Coring Station HLY0602-04BB
1 Aug	10:30 – 23:51	Seismic operations
2 Aug	04:44	Coring Station HLY0602-05BB
2 Aug	15:18	Coring Station HLY0602-06JC[f]
2 Aug	18:30	Helicopter operations to look for lost seismometer
3 Aug	09:30 – 22:14	Seismic operations
3 Aug	16:30	Helicopter operations to retrieve seismometers
4 Aug	00:30	Helicopter operations to retrieve seismometers
4 Aug	10:00	Traveled to coring
4 Aug	20:55	Coring Station HLY0602-07JC
5 Aug	01:38	Coring Station HLY0602-08JC
5 Aug	03:51	Helicopter operations to retrieve seismometers
6 Aug	07:18	Coring Station HLY0602-09JC
6 Aug	12:37	Rendezvous with another icebreaker practicing maneuvers in area
6 Aug	15:50	Helicopter launched to take pictures
6-7 Aug	17:00 – 0:30	Helicopter operations to deploy seismometers
7-8 Aug	09:30 – 05:01	Seismic operations
8 Aug	10:12	Coring Station HLY0602-10JC
8 Aug	19:25 – 23:59	Seismic operations

TABLE 2.1 (continued).

Date (2006)	Time	Event Description
9 Aug	10:41	Coring Station HLY0602-11JC
9 Aug	16:57	Coring Station HLY0602-12 JC
9-10 Aug	20:22 – 08:26	Seismic operations
10-11 Aug	20:00 – 02:00	Helicopter sorties to retrieve seismometers (total 3)
12 Aug	00:48	Coring Station HLY0602-13JC
12 Aug	03:57	Coring Station HLY0602-14JC
13 Aug	23:12	Coring Station HLY0602-15GC
14 Aug	01:14	Coring Station HLY0602-16GC
14 Aug	02:03	Coring Station HLY0602-17GC
14 Aug	15:00	Helicopter operations to deploy seismometers
15 Aug	02:00	Helicopter operations to deploy seismometers
15-16 Aug	08:34 – 01:41	Seismic operations
16 Aug	06:39	Helicopter operations to deploy seismometers
16 Aug	10:45 – 22:05	Seismic operations
17 Aug	00:53 – 11:27	Seismic operations
17 Aug	16:00	Helicopter operations to retrieve seismometers
18 Aug	00:10	Ice liberty; project terminated due to accident
18 Aug	08:30	Traveling to Barrow
19 Aug		Arrived in Barrow
20 Aug		Traveling to Nome
21 Aug		Traveled to Nome
22 Aug		Traveling to Nome
23 Aug		Arrived in Nome

[a]BH = MMO Beth Haley
[b]CF = MMO Claudio Fossati
[c]AS = MMO Alejandro Sayegh
[d]GC = 2.5" gravity core
[e]BB = "Big Bertha", or 4" gravity core
[f]JC = 4" piston core

Airgun Characteristics

A portable Multi-Channel Seismic (MCS) system was installed on the *Healy* for this cruise. The source vessel towed an 8-gun array with a total discharge volume of 2840 in^3 and a streamer containing hydrophones along predetermined lines. However, because of technical problems with the airguns, 6-airgun (1840 in^3) and 7-airgun (2340 in^3) arrays were used for the majority of the time (25% and 36% of the survey, respectively). A 4-GI gun array with a total discharge volume of 420 in^3 was also available for use, but was never employed. Seismic pulses were emitted at intervals of ~60 s and recorded at a 2 ms sampling rate. The 60 s spacing corresponds to a shot interval of ~120 m at the anticipated typical cruise speed.

The 8-airgun array was configured as a 4-G. gun cluster with a total discharge volume of 840 in^3 and a 4-Bolt airgun cluster with a total discharge volume of 2000 in^3 (Fig. 2.1). The smaller 6- and 7-airgun configurations consisted of the 4-G. gun cluster and a cluster of either 2 or 3 Bolt airguns. The 2 clusters were 4 meters apart. The clusters were operated simultaneously for a total discharge volume of 2840 in^3 for the full, 8-airgun array. The 6-airgun configuration discharged 1840 in^3; the 7-airgun configuration discharged 2340 in^3. The energy source was towed as close to the stern as possible (<5 m

TABLE 2.2 Coring dates, stations and locations during the *Healy* 2006 Arctic Ocean survey.

Date (GMT, 2006)	Coring Station	Location	Depth (m)
29 July	HLY0602-01GC[a]	77° 01.016 N, 153° 34.935 W	3600
30 July	HLY0602-02GC	77° 00.783 N, 153° 38.071 W	3363
31 July	HLY0602-03BB[b]	77° 13.436 N, 153° 20.439 W	3534
1 Aug.	HLY0602-04BB	77° 13.013 N, 153° 22.480 W	3543
2 Aug.	HLY0602-05BB	77° 06.036 N, 154° 21.896 W	1147
3 Aug.	HLY0602-06JC[c]	77° 02.539 N, 154° 13.487 W	1243
4 Aug.	HLY0602-07JC	77° 19.366 N, 155° 55.821 W	1295
5 Aug.	HLY0602-08JC	77° 51.103 N, 161° 22.707 W	2225
6 Aug.	HLY0602-09JC	77° 50.966 N, 161° 23.188 W	2630
8 Aug.	HLY0602-10JC	78° 09.020 N, 165° 10. 675 W	451
9 Aug.	HLY0602-11JC	77° 54.073 N, 162° 20.995 W	2395
9 Aug.	HLY0602-12JC	77 54.450 N, 162° 21.066 W	2301
12 Aug.	HLY0602-13JC	79° 03.666 N, 175° 24.714 W	1826
12 Aug.	HLY0602-14JC	79° 04.156 N, 175° 21.433 W	1998
13 Aug.	HLY0602-15GC	78° 22.253 N, 176° 56.579 W	813
14 Aug.	HLY0602-16GC	78° 20.690 N, 176° 51.049 W	808
14 Aug.	HLY0602-17GC	78° 20.676 N, 176° 50.752 W	815

[a]GC = 2" gravity core
[b]BB = "Big Bertha", or 4" gravity core
[c]JC = 4" piston core

away) to minimize ice interference. The 8-gun array was towed at a depth between 5 and 10 m depending on ice conditions; the preferred depth was ~7 m. The characteristics of the 8-airgun array used during the survey are summarized in Table 2.3.

Other Types of Seismic Operations

During the Arctic Ocean cruise, airguns operated during certain other periods besides those in which seismic data were being recorded. Airguns were operated during ramp ups, power downs, line changes, periods of equipment repair, and testing of the airguns. Ramp ups were required by the NMFS IHA and USFWS IHA (see Chapter 3 and Appendices A and B). Ramp ups involved an increase in the volume of compressed air being released by no more than 6 dB per 5 min period. For this array, ramp up began with one of the G. guns (210 in^3), a second G. gun was added after a period of 5 min, the remaining 2 G. guns were added after another 5 min, and then the 4 Bolt airguns were added after a final 5 minute period. During the ramp-up (i.e., when fewer than 8 airguns were operating), the safety zone for the full 8-airgun array was maintained. Ramp ups of the airguns occurred on 27 occasions during the seismic study, each involved a start up from no airguns operating.

TABLE 2.3. Specifications of the airguns used during UTIG's Arctic Ocean seismic survey, July–Aug. 2006.

8-airgun Array Specifications[a]	
Energy source	Four G. guns of 210 in^3 each, and four Bolt airguns of 500 in^3 each, firing simultaneously every 60 s
Source output[b] (downward)[c]	0-pk is 20.3 bar-m (246 dB re 1 μPa-m); pk-pk is 42.5 bar-m (253 dB)
Towing depth of energy source	~7 m
Air discharge volume	2840 in^3
Dominant frequency components	0–150 Hz

[a] Due to technical difficulties, the 8-airgun array was only used for 1 km of seismic survey. A 7-airgun array (three Bold airguns and 4 G. guns, 2340 in^3) or 6-airgun array (two Bolt airguns and 4 G. guns, 1840 in^3) were actually used.

[b]For source at 9 m depth.

[c]All source levels are for a filter bandwidth of approximately 0-150 Hz.

An alternative 4-GI gun array was available for use as a seismic source but was not operated during the project. UTIG's IHA applications described plans to use the 4-GI gun array with a volume of 420 in^3 exclusively over areas where water depth was 100 m and along a limited amount of the cruise track in deeper water. No seismic activities occurred in water <100 m deep and the 4-GI gun array was never used.

Multibeam Bathymetric Sonar and Echosounders

Along with the airgun operations, additional acoustic systems operated during the cruise. A 12-kHz SeaBeam multibeam bathymetric (MBB) sonar and a 3.5-kHz sub-bottom profiler operated throughout most of the cruise. These systems mapped the bathymetry and sub-bottom conditions, as necessary to meet the geophysical science objectives. During seismic operations, these sources typically operated simultaneously with the airguns. Another sub-bottom profiler (ODEC Bathy 200) was used infrequently as back-up. A depth-sounding sonar, in this case an Acoustic Doppler Current Profiler, was used occasionally for safety purposes when the *Healy* was operating in shallow areas. Depth-sounders are employed routinely by sea-going vessels to monitor water depths. The various sonars are described in further detail in Appendix F.

3. MONITORING AND MITIGATION METHODS

This chapter describes the marine mammal monitoring and mitigation measures used for UTIG's Arctic Ocean seismic study, addressing the requirements specified in the IHAs (Appendices A and B). The section begins with a brief summary of the monitoring tasks relevant to mitigation for marine mammals. The acoustic measurements and modeling results used to identify the safety radii for marine mammals are then described. A summary of the mitigation measures required by NMFS and USFWS is then presented. The section ends with a description of the monitoring methods implemented for this 2006 cruise from the *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 IHAs issued to UTIG by NMFS and USFWS were satisfied, effects on marine mammals were minimized, and residual effects on animals were documented. The objectives of the monitoring program were listed in Chapter 1, *Mitigation and Monitoring Objectives*. Tasks specific to monitoring are listed below (also see Appendix A):

- Provide qualified MMOs for the *Healy* source vessel throughout the Arctic Ocean seismic 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.
- Record (insofar as possible) the effects of the airgun operations and the resulting sounds on marine mammals.
- Use the visual monitoring data as a basis for implementing the required mitigation measures.
- Estimate the number of marine mammals potentially exposed to strong airgun sounds.

Safety and Potential Disturbance Radii

Under current NMFS guidelines (e.g., NMFS 2000), "safety radii" for marine mammals around airgun arrays are customarily defined as the distances within which received pulse levels are ≥180 dB re 1 μPa (rms) for cetaceans and ≥190 dB re 1 μPa (rms) for pinnipeds. The ≥190 dB re 1 μPa (rms) guideline was also employed by the USFWS for the animals under its jurisdiction (polar bears and walruses) in its IHA issued to UTIG. The safety criteria are based on an assumption that seismic pulses received at lower received levels will not injure these animals or impair their hearing abilities, but that 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 (see Chapter 1). On the other hand, migrating bowhead whales and summering beluga whales show evidence of avoidance upon exposure to received levels of airgun pulses below 160 dB rms (Miller et al. 1999, 2005; Richardson et al. 1999).

Radii within which received levels were expected to diminish to the various relevant values (i.e., 190, 180, 170 and 160 dB re 1 μPa rms) were estimated by L-DEO (Table 3.1). Estimates were based on a combination of acoustic modeling, as summarized in LGL Ltd. (2006a,b,c) and in Appendix E, and the results of empirical measurements of sounds from several airgun configurations (Tolstoy et al. 2004a,b). The acoustic modeling procedure did not allow for bottom reflections. Thus, it was directly applicable to

TABLE 3.1. Estimated distances to which sound levels ≥190, 180, 170, and 160 dB re 1 μPa (rms) might be received from a 210 in^3 G. gun, a 4-G. gun array, and 7- and 8-airgun arrays (3, or 4 x 500 in^3 Bolt airguns and 4 x 210 in^3 G. guns) operating during the seismic survey in the Arctic Ocean, 2006. (The array operated at full power, with all eight airguns only briefly, ~1 km.) The sound radii for the 6-airgun array was not modeled. The assumed sound level radii depended on water depth. Distances are based on model results provided by the Lamont-Doherty Earth Observatory of Columbia University.

		Estimated Distances for Received Levels (m)			
Seismic Source Volume	Water depth	**190 dB** (shutdown criterion for pinnipeds)	**180 dB** (shutdown criterion for cetaceans)	**170 dB** (alternate behavioral harassment criterion for delphinids & pinnipeds)	**160 dB** (assumed onset of behavioral harassment)
210 in^3 G. gun	>1000 m	20	78	222	698
	100–1000 m	30	117	333	1047
	<100 m	250	578	925	1904
840 in^3 (4-G. guns)	>1000 m	100	330	1025	3250
	100–1000 m	150	495	1538	4875
	<100 m	NA*	NA*	NA*	NA*
2340 in^3 (7-airgun array)	>1000 m	200	620	1900	6250
	100–1000 m	300	930	2850	9375
	<100 m	NA*	NA*	NA*	NA*
2840 in^3 (8-airgun array)	>1000 m	230	716	2268	7097
	100–1000 m	345	1074	3402	10646
	<100 m	NA*	NA*	NA*	NA*

* Not Applicable: Only the single 210 in^3 G. gun was operated in shallow (<100 m) water.

close ranges and, for deep water, somewhat longer ranges, but not to ranges where received levels would be significantly affected by bottom reflections. The results from the empirical study were also limited in various ways. However, the empirical data did show that (as expected) water depth can affect the distance at which received sound levels would exceed any specific level such as 180 or 170 dB re 1 μPa (rms). Therefore, three strata of water depth have been recognized during recent NSF-sponsored seismic cruises: deep (>1000 m), intermediate (100–1000 m), and shallow (<100 m), with associated differences in 160–190 dB radii (Smultea et al. 2004, 2005; Holst et al. 2005a,b; MacLean and Koski 2005; Ireland et al. 2005, Haley and Ireland 2006).

Empirical data demonstrated that the modeled sound level radii were actually greater than the sound radii generated in the field, in deep water. Therefore, the modeled sound level radii were applied directly as the "safety radii" in deep water. However, no empirical data with which the modeled radii can be adjusted to better reflect reality were available for intermediate water depths (100 – 1000 m). During previous cruises, the safety radii modeled for intermediate water depths have been adjusted by a factor of 1.5. As a conservative measure, UTIG expanded the modeled safety radii further. Adjusted by a factor of 1.5, the modeled 190 and 180 dB radii for the 2006 *Healy* survey were 345 and 1074 m, respectively (Table 3.1). UTIG expanded the safety radii for the survey to 500 m for the "190 dB" safety radius and to as far as one could see (with a minimum visibility of 2 km) for the "180 dB" safety radius (Table 3.2). This resulted in an adjustment factor of 2.2 for the 190 dB level and a factor of ~4.2 for the 180 dB received sound level safety radii around the full 8-airgun array in intermediate water depths. Because the airgun arrays in use during most of the survey were smaller (6- or 7-airgun arrays—see Chapter 2) than the 8-airgun array, the implemented safety radii were even more than 2.2× and 4.2× the 190 and 180 dB radii, respectively. The Arctic Ocean survey was conducted in water >100 m deep, so only intermediate and deep water radii were relevant. Testing of a single 210 in^3 G. gun was conducted in shallow water (<100 m) for 14 min over 2 km.

Airguns operating underwater do not produce strong sounds in air. However, USFWS required that shut downs or power downs be implemented for walruses or polar bears observed on the ice within the area where the underwater sound level was assumed to be ≥190 dB. This was in consideration of the fact that the animals under USFWS jurisdiction, walruses especially, might enter the water. In any case, no walruses were observed during the project and none of the sightings of polar bears on the ice were within the appropriate underwater safety radius.

Mitigation Measures as Implemented

The primary mitigation measures that were implemented during the Arctic Ocean 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 G. Mitigation also included those measures specifically identified in the IHAs (Appendices A and B) as indicated below.

Standard Mitigation Measures

Standard mitigation measures implemented during the study included the following:

1. Safety radii implemented for the Arctic Ocean cruise were specific for intermediate and deep water depths based on modeling and the acoustic calibration study conducted from the *Ewing* in the Gulf of Mexico in 2003 (Tolstoy et al. 2004a,b), as noted above and described in Appendix E.
2. Power-down or shut-down procedures were implemented when a marine mammal was sighted within or approaching the applicable safety radius while the airguns were operating.
3. A change in vessel course and/or speed alteration was identified as a potential mitigation measure if a marine mammal was detected outside the safety radius and, based on its position and motion relative to the ship track, was judged likely to enter the safety radius. However, substantial alteration of vessel course or speed was not feasible during the Arctic Ocean cruise given the ice conditions and speed of the vessel (average speed = 2.6 kt during seismic operations). Power downs or shut downs were the preferred mitigation measures when mammals were sighted within or about to enter the safety radii.

TABLE 3.2. Safety radii applied throughout the 2006 seismic survey in the Arctic Ocean for a 210 in^3 G. gun and an 8-gun array (4 x 500 in^3 Bolt airguns and 4 x 210 in^3 G. guns). The assumed safety radii depended on water depth, and the established safety radii for shallower water (<1000) were larger than the estimated 190 and 180 dB distances (see text and Table 3.1). Safety radii for the full 8-airgun array were applied even when the array was operating with fewer airguns and at lower volumes. Distances are based on model results provided by the Lamont-Doherty Earth Observatory of Columbia University.

		Estimated Distances for Received Levels (m)			
Seismic Source Volume	Water depth	**190 dB** (shutdown criterion for pinnipeds)	**180 dB** (shutdown criterion for cetaceans)	**170 dB** (alternate behavioral harassment criterion for delphinids & pinnipeds)	**160 dB** (assumed onset of behavioral harassment)
210 in^3 G. gun	>1000 m	20	78	222	698
	100–1000 m	[500]†	[Maximum visibility (2 -3 km)] †	333	1047
	<100 m	1000†	[Maximum visibility (2 -3 km)] †	925	1904
2840 in^3 (8-airgun array)	>1000 m	230	716	2268	7097
	100–1000 m	[500] †	[Maximum visibility (2 -3 km)]†	3402	10646
	<100 m	NA*	NA*	NA*	NA*

† Listed value is the established safety radius in intermediate-depth water. This radius is larger than the corresponding estimated 190 or 180 dB (rms) distance (Table 3.1).

* Not Applicable: Only the single 210 in^3 G. gun was operated in shallow (<100 m) water.

4. A ramp-up procedure was implemented whenever operation of the airguns were initiated. Ramp up began with one of the G. guns (210 in^3), a second G. gun was added after a period of 5 min, the remaining 2 G. guns were added after another 5 min, and then the 4 Bolt airguns were added after a final 5 minute period. This resulted in an increase in source level of no more than 6 dB per 5 minutes—the maximum ramp-up rate authorized by NMFS during past L-DEO seismic cruises.
5. In order for seismic operations to start up during day or night, the full applicable safety radius must be visible for at least 30 min. That precluded nighttime startups from a full shut-down, but in fact, there were no periods of darkness during the project.
6. Helicopters maintaned a minimum altitude of 1000 ft (305 m) when practicable, avoided landing within 1000 ft (305 m) of an observed animal, and followed the *Healy's* trackline.

Additional Mitigation Measures for the Arctic Ocean Cruise as required by USFWS

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

1. The *Healy* observe a 0.5-mi. (800 m) exclusion zone around walruses and polar bears sighted either on land or ice.
2. All polar bear or walrus sightings be reported to USFWS within 24 h.
3. NSF/UTIG should develop a polar bear interaction plan specific to the project area that met USFWS' approval.
4. No seismic operations be conducted within a 40-mi radius of communities to minimize potential interactions with walrus hunters.

Visual Monitoring Methods

Visual monitoring methods were designed to meet the requirements identified in the IHAs (see above and Appendices A and B). The primary purposes of MMOs aboard the *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 of pinnipeds to >190 dB. ***(2)*** Document numbers of marine mammals present, any reactions of marine mammals to seismic activities, and whether there was any possible effect on accessibility of marine mammals to subsistence hunters in Alaska. Results of the monitoring effort are presented in Chapter 4.

The visual monitoring methods that were implemented during this cruise were similar to those used during previous L-DEO seismic cruises since 2003. The standard visual observation methods are described in detail in Appendix G.

In summary, during the Arctic Ocean survey at least one MMO maintained a visual watch for marine mammals during all daylight hours while seismic surveys were underway. During this cruise, two visual observers were on duty for 46% of the time when visual watches were conducted. Visual observations were conducted from the *Healy*'s bridge (indoors; 95% of watch hours) and from the flying bridge (outdoors; 5%) during good weather. Nighttime watches were never necessary because there was no darkness until 23 Sept., and there were no seismic surveys during darkness. Observers focused their search effort forward of the vessel but also searched aft of the vessel while it was underway. Watches were conducted with the naked eye, Fujinon 7 × 50 reticle binoculars, and mounted 25 × 150 "Big-eye" binoculars. Appendix G provides further details regarding visual monitoring methods.

Analyses

Categorization of Data

Observer effort and marine mammal sightings were divided into several analysis categories related to vessel and seismic activity. The categories were similar to those used during other recent seismic studies (e.g., Haley and Koski 2004; MacLean and Koski 2005; Smultea et al. 2005; Holst et al. 2005a,b; Ireland et al. 2005, Haley and Ireland 2006). These categories are defined briefly below, with a more detailed description provided in Appendix G.

In general, data were categorized as "seismic" or "non-seismic". "Seismic" included all data collected while the airguns were operating. Non-seismic included all data obtained before the airgun(s) were activated (pre-seismic) or >2 h after the airguns were deactivated. Data collected during post-seismic periods from 3 min to 2 h after cessation of seismic activity were considered either "recently exposed" (3 –30 min) or "potentially exposed" (30 min–2 h) to seismic sound levels, and were excluded

from analyses. Thus, the post-seismic data (3 min to 2 h after cessation of seismic) were not included in either the "seismic" or "non-seismic" categories. The 3 min cutpoint, about twice as long as during previous NSF-sponsored seismic cruises, was considered appropriate because of the relatively slow speed during seismic operations (~2.6 kt or 4.8 km/h, average). The 2-h cut-off of the post-seismic period was the same cut-off used during several other NSF-sponsored seismic cruises: the Aleutian, SE Alaska, Eastern Tropical Pacific off Central America, northwest Atlantic, and Norway cruises (Haley and Koski 2004; MacLean and Koski 2005; Holst et al. 2005a; Ireland et al. 2005). However, the sources during this cruise (6 or 7 airguns totaling 1840 or 2340 in^3) were somewhat larger than were the sources during the cruises just mentioned.

This categorization system was designed primarily to distinguish potential differences in behavior and distribution of marine mammals during periods when seismic surveys might influence behavior and distribution, and during periods when seismic surveys are not likely to influence behavior and distribution. 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 so as to be sufficiently long (2 h) 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 by then. The reasoning behind these categories was explained in MacLean and Koski (2005) and Smultea et al. (2005) and is discussed in Appendix G. The 2-h post-seismic period was applied to this cruise rather than a longer period because all sightings were of pinnipeds, and pinnipeds are generally less responsive to seismic sounds than cetaceans.

Estimation of Densities

The sightings of marine mammals obtained during this project can only be used to estimate numbers and densities of marine mammals near the seismic vessel with caution, because of a significant bias. That bias was also present during the 2005 *Healy* project. 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 the side. The heterogeneity of habitat as a function of lateral distance discourages us from applying standard line-transect methodology to data on the lateral distances of the sightings from the trackline for purposes of estimating densities of hauled out and swimming seals. The variable presence of ice to the side of the trackline resulted in truncation of the in-water and on-ice sightings at variable and often unknown distances. The sighting distribution of swimming seals was right-truncated by solid ice at variable lateral distances. The sighting distribution of hauled-out seals was variably left-truncated by open water near the ship. However, the ice cover in the area of the 2006 *Healy* study was fairly uniform, much more so than that throughout the 2005 *Healy* project. Most of the "useable" pinniped sightings (n= 64, or 69%) occurred when ice cover was between 80 and 95%. Forty-two of the "useable" sightings (45%) were in areas where the ice cover was recorded as 80%. During the 2005 survey, the *Healy* took every opportunity to follow leads when it was surveying in otherwise 100% ice areas, which occurred above 80°N. The habitat consistency of the 2006 *Healy* survey was, in part, due to the fact that the majority of the study was limited in latitude (76.5°–78.5°N). Because of the relative consistency of the habitat during the 2006 *Healy* survey, we estimated animal densities within open water along the trackline to compare with densities from previous surveys.

Because the sighting data collected during the 2006 cruise could only be used with caution in estimating densities of marine mammals near the seismic activity, we also used the densities from earlier studies that were summarized in the IHA applications for this study (see Appendix K).

Estimation of Densities from Sighting Data

Marine mammal sightings during the "seismic" and "non-seismic" periods were used to calculate sighting densities (# of animals/km^2). Densities of pinnipeds were derived by first estimating the area of open water within which seals had been observed during useable sighting conditions. The open water area was calculated by multiplying the length of useable trackline by the swath of area surveyed around the *Healy* (2 km during useable sighting periods) and then correcting by the percent ice cover. This was done for both seismic and non-seismic periods. Densities (# of animals/km^2) were then estimated by dividing the number of sightings by the area of open water surveyed. Sightings of animals hauled out were not incorporated in this exercise. Only "useable" effort and sightings were included in density calculations. Effort and sightings were defined as "useable" when made under the following conditions: daylight periods ***excluding*** periods 3 min to 2 h after the airguns were turned off (post-seismic), or when ship speed <3.7 km/h (2 kt), or with seriously impaired sightability. The latter included daytime periods with one or more of the following: visibility <2 km, Bf >5, or >60º of severe glare between 90º left and 90º right of the bow.

A correction factor for missed animals, i.e., $g(0)$, was taken from other related studies, as summarized by Koski et al. (1998) and Barlow (1999). This was necessary because of the low number of sightings of any individual species, and the inability to assess sighting probability during a study of this type. The correction factor for $f(0)$ (probability of sighting an animal with increasing distance from the survey track) was not included in the density estimates because of the unpredictable variability of the surveyed swath due to changeable ice conditions. However, because open water formed a relatively small fraction of the habitat near the ship, and observation effort was concentrated on open-water areas, a higher proportion of animals would have been detected than during standard line transect surveys. Based on *Healy* 2006 sighting data, densities during the seismic and non-seismic periods [corrected by $g(0)$] were 0.157 and 0.243 animals/km^2, respectively.

Densities during non-seismic periods were used to estimate the numbers of animals that presumably would have been present in the absence of seismic activities. Densities during seismic periods were used to estimate the numbers of animals present near the seismic operation and exposed to various sound levels. The difference between the two estimates could be taken as an estimate of the number of animals that moved in response to the operating seismic vessel, or that changed their behavior sufficiently to affect their detectability to visual observers. However, because of the limited duration of seismic operations during this study, the reported densities during seismic periods are not reliable indicators of actual densities present at those times. Thus, a comparison of densities observed during seismic and non-seismic periods is not a valid method for estimating changes in distribution or behavior during this study. Further details on the methodology used during the survey are provided in Appendix G.

Estimating Numbers Potentially Affected

For purposes of the NMFS IHA, NMFS assumes that any marine mammal that might have been exposed to airgun pulses with received sound levels ≥160 dB re 1 µPa (rms) may have been disturbed. When calculating the number of mammals potentially affected, the nominal 160 dB radius for the depth of water in which the survey took place was used (Table 3.1).

Two approaches were applied to estimate the numbers of marine mammals that may have been exposed to sound levels ≥160 dB re 1 µPa (rms):

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

The first method ("exposures") involved multiplying the following three values for the airgun configuration in use: (A) km of seismic survey; (B) width of total area, or open water, assumed ensonified to ≥160 dB (2 × 160 dB radius); and (C) "corrected" densities of marine mammals from previous surveys or estimated during this survey. Thus, areas of water ensonified on more than one occasion, due to overlapping or adjacent tracklines, were counted in the area calculation as many times as they were ensonified. The areas of **open water** ensonified to different sound levels were calculated by applying the percent ice cover as recorded by MMOs to the overall areas ensonified.

The second approach ("individuals") involved multiplying the same three values, except that areas ensonified to ≥160 dB on more than one occasion, due to overlapping tracklines, were counted only once. The area of water considered ensonified in this calculation is therefore smaller than in the first calculation (Tables G.2 and G.3). We used density data from prior surveys, not the project's sighting data, to estimate the "individual" mammals exposed. "Individual" exposures were not estimated from this project's data because ice cover occasionally varied over an area of overlapping tracklines, and calculating the area of open water that had been ensonified was subjective. There was little area of trackline overlap, and the estimated numbers of individual marine mammals exposed were slightly lower than estimates of total takes.

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

It is expected that the use of sighting data from the study overestimated the number of seals exposed to ≥160 dB (rms). The *Healy* followed open water where densities of seals are expected to be higher than in heavy ice conditions. In addition, densities were applied to calculated areas of open water within the 160 dB distance, which assumes that the ice cover was consistent within ~2 km of the vessel. The ≥160 dB sound level extended to an estimated 7.1–10.6 km on either side of the ship (Table 3.1), or ~7–10 times wider than the area within 2 km of the ship for which the ice cover estimates were made. It is probable that the ice cover was, on average, higher in the pack ice away from the ship than in the 2-km swath near the *Healy* for which the ice cover estimate was made. Therefore, the areas of open water within the areas of ensonification are overestimated to an unknown degree. Application of the trackline densities for seals in more-or-less open water to the full area exposed to ≥160 dB will have resulted in an overestimate of numbers exposed to ≥160 dB (rms). This inflated value likely more than offsets the number of seals near the ship not observed by the MMOs.

4. MARINE MAMMALS

Introduction

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

Seismic survey activities occurred along 339 km of trackline over a total of 77 h (Fig. 1.1, 4.1; Table ES.1). In total, visual observations were conducted over 2912 km within the study area, including applicable effort during transit. "Useable" survey conditions occurred during 61% (in km; 50% in h) of the total visual effort (Table ES.1, Fig. 4.1). "Useable" effort excluded periods 3 min to 2 h after the airguns were turned off, i.e., "post-seismic"; poor visibility conditions, i.e., visibility <2 km or extensive glare; Bf >5; and ship speed <3.7 km/h (<2 kt). The project provided data on the summer occurrence, distribution, and abundance of marine mammals in intermediate depth (100–1000 m) and deep (>1000 m) waters of the Arctic Ocean. That is an area where few systematic survey data had been collected previously (but see, for example, Harwood et al. 2005; Haley and Ireland 2006). During the survey, the *Healy* was seldom in water <100 m deep. Useable data on marine mammal occurrence, distribution, and abundance in water <100 m deep were collected for only 170 of 1762 km, or 9.6%, during the project. One 210 in^3 G. gun was tested briefly (14 min or 2 km) in water <100 m deep and no animals were observed during that time.

The marine mammals known to occur along the cruise trackline in the Arctic Ocean belong to four taxonomic groups: odontocetes (toothed cetaceans, including the beluga), mysticetes (baleen whales), pinnipeds (seals and walruses), and the polar bear. Eight cetacean species and four species of pinnipeds are known to occur within the study area, along with the polar bear. Of the total 13 species, two (both cetaceans) are listed under the U.S. Endangered Species Act (ESA) as endangered: the bowhead and fin whales but fin whales are very unlikely to be encountered in the waters surveyed. Appendix H summarizes the abundance, habitat, and conservation status of the marine mammal species likely to occur in the cruise area.

Monitoring Effort and Marine Mammal Encounter Results

This section summarizes the visual monitoring effort and sightings from the *Healy* during the Arctic Ocean seismic survey from 19 July to 23 Aug. 2006. Summaries of results of visual monitoring are presented here, with more detailed data presented in Appendices I and J, including survey effort in both kilometers and hours. A general summary of effort and sightings is shown in Table ES.1.

Visual Survey Effort

All *Healy* survey tracks are plotted by seismic activity (airguns on or off) in Figure 1.1 and by visual survey effort (useable, non-useable, none) in Figure 4.1. Useable observations were conducted along 1762 km of the *Healy's* trackline which totaled 4391 km (Table ES.1). Useable survey effort, subdivided by airguns on or off and water depth strata, is shown in Appendix I.1. MMOs observed primarily from the bridge (96% of watch time), with the remaining observations conducted from the flying bridge.

Beaufort Wind Force (sea state) during observations ranged from 0 to 4 within the study area, with 42% (in km) of the observation effort occurring during conditions of Bf = 1. The prevailing low sea state

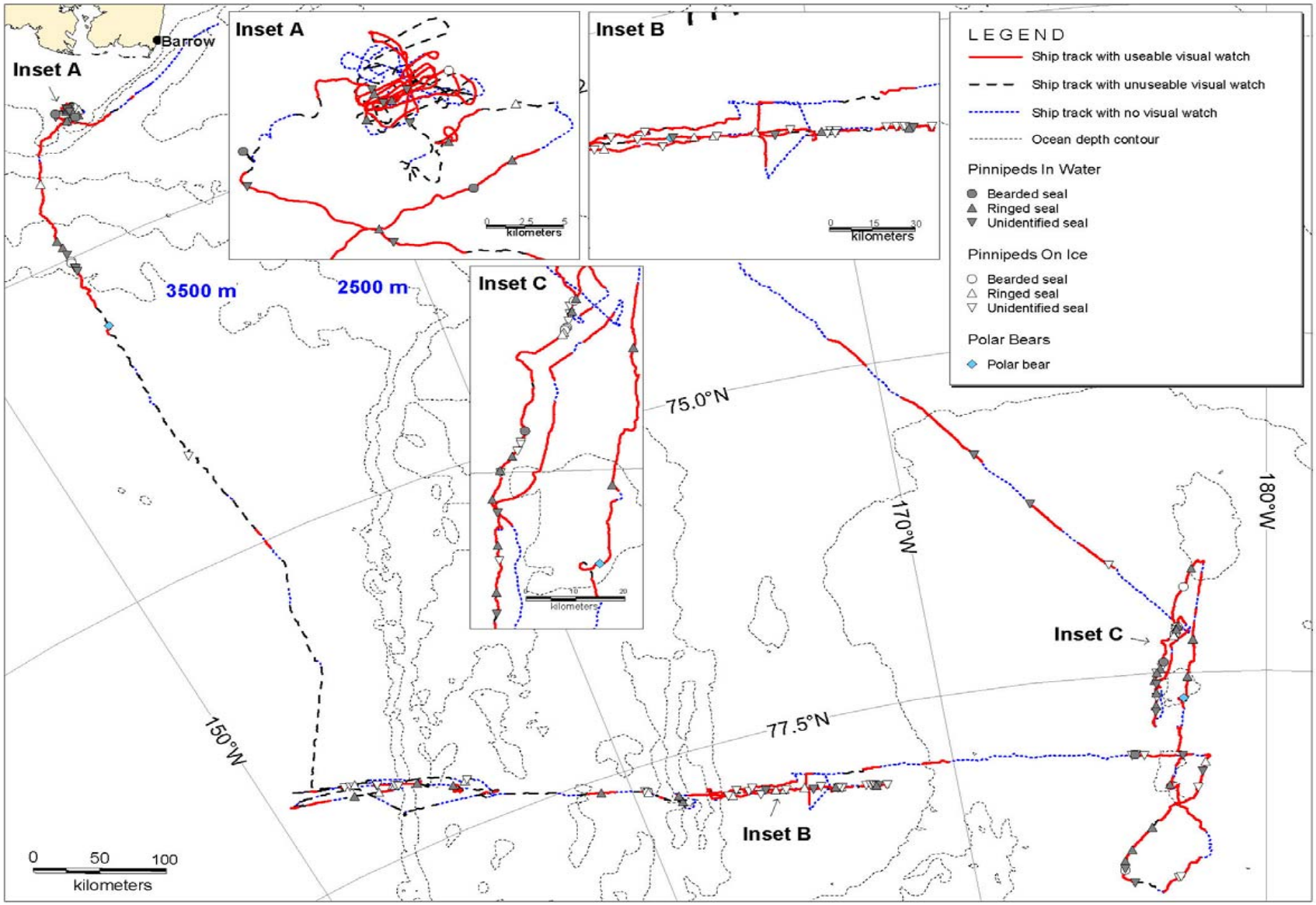

FIGURE 4.1. The *Healy* ship track and Arctic Ocean study area showing periods when airguns were on and off during the Arctic Ocean seismic survey, 19 July – 23 Aug. 2006.

was due to ice cover and paucity of open water throughout the survey. None of the observations within the study area were deemed "non-useable" because of high Beaufort Wind Force.

Visual Sightings of Marine Mammals and Other Vessels

Numbers of Marine Mammals Seen.—An estimated 158 individual marine mammals were recorded in 133 groups throughout the study area (Table 4.1). Three different marine mammal species were identified. The ringed seal was the most abundant species (n = 57 identified individuals in 48 groups), followed by bearded seals (n = 15 identified in 14 groups; Table 4.1). In addition, three groups (9 individuals) of polar bears were observed. Of the 72 seals identified in the study area, 57 (or 79%) were ringed seals. Most of the unidentified seals (n = 77 individuals in 68 groups) were likely ringed seals, given the visual monitoring results and the known occurrence of this species throughout the study area. A detailed list of sightings is provided in Appendix I.3.

Most of the 133 sightings (72% or 96 groups) made within the study area were "useable" (Table 4.1, 4.2). These "useable" sightings, along with the corresponding effort data, are the basis for the ensuing analyses comparing sighting rates and behaviors of marine mammals during seismic and non-seismic periods.

Sightings with Airguns On.—Of the total 133 sightings, 30 were made while the airguns were operating, 97 were made during non-seismic periods, and the remaining 6 were noted during "post-seismic" periods (Tables ES.1, 4.1).

Sighting Rates.—Sighting rates (# groups sighted per unit effort) during various types of MMO effort are presented in Table 4.3. The "useable" sighting rate for pinnipeds in the water was about two times higher during seismic than during non-seismic periods, and for pinnipeds on ice, about three times higher during seismic than non-seismic periods. The tendency for seismic operations to occur in leads and polynyas, where seals and polar bears may be more abundant, could account at least in part for higher sighting rates during seismic operations. These results are potentially unrepresentative of the broader area of pack ice given the tendency for the ship to travel through areas with less ice, and given the disproportionate amounts of visual effort in seismic vs. non-seismic periods (Tables ES.1, 4.3). The highest 'useable' sighting rate during our surveys was for pinnipeds on ice during seismic periods (62.5 seals/1000 km). Based on the number of groups seen per kilometer, the sighting rate during post seismic periods (with very limited effort) was three times higher than the sighting rate during non-seismic periods and slightly greater than the sighting rate during seismic periods (Table 4.3).

The presence of fog (visibility <2 km) was the most common reason that sightings were considered non-useable. During seismic periods, the sighting rate in non-useable periods was about 30% of that in useable periods, consistent with what would be expected during periods of poor vs. good visibility (Table 4.3). For non-seismic periods, the difference in sighting rate between non-useable and useable periods was not very great; the non-useable sighting rate was ~64% of the useable sighting rate (Table 4.3).

Other Vessels—The *Healy* and the vessel *Polar Sea* rendezvoused for approximately 30 min on 6 Aug. when a helicopter was deployed to take photographs. The *Polar Sea*, another USCG icebreaker, was practicing maneuvers in the Arctic Ocean. The ships approached as close as 100 m. No marine mammals were observed while the vessels were in proximity. Other than that brief encounter, no other vessel was observed by the MMOs during watches.

TABLE 4.1. Numbers of sightings and of individual marine mammals, both ***(A)*** total and ***(B)*** useable[a], observed from the *Healy* during the Arctic Ocean survey, 19 July–23 Aug. 2006.

	Non-Seismic		Post-Seismic		Seismic		Total	
	Groups	Indiv.	Groups	Indiv.	Groups	Indiv.	Groups	Indiv.
A. All Sightings								
Pinnipeds in Water								
Bearded Seal	3	3	0	0	1	1	4	4
Ringed Seal	20	20	4	4	7	7	31	31
Unidentified Seal	17	17	0	0	3	3	20	20
Pinnipeds on Ice								
Bearded Seal	6	6	0	0	4	5	10	11
Ringed Seal	13	22	1	1	3	3	17	26
Unidentified Seal	35	41	1	1	12	15	48	57
Total Pinnipeds	94	109	6	6	30	34	130	149
Ursids								
Polar Bears	3	9	0	0	0	0	3	9
B. Useable[a] Sightings								
Operations in h	158		N/A		61		219	
Operations in km	1490		N/A		272		1762	
Pinnipeds in Water								
Bearded Seal	2	2	N/A	N/A	1	1	3	3
Ringed Seal	15	15	N/A	N/A	7	7	22	22
Unidentified Seal	15	15	N/A	N/A	3	3	18	18
Pinnipeds on Ice								
Bearded Seal	3	3	N/A	N/A	2	3	5	6
Ringed Seal	8	8	N/A	N/A	3	3	11	11
Unidentified Seal	22	26	N/A	N/A	12	15	34	41
Total Pinnipeds	65	69	N/A	N/A	28	32	93	101
Ursids								
Polar Bears	3	9	N/A	N/A	0	0	3	9

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

TABLE 4.2. Number of marine mammal sightings from the *Healy* during the Arctic Ocean seismic survey, 19 July – 23 Aug. 2006, and number that were "useable" in analyses[a]. Numbers in parentheses are numbers of individuals.

	Sightings	
	Groups Sighted (# Indiv.)	
Species	All	Useablea
Bearded seal	14 (15)	8 (9)
Ringed seal	48 (57)	33 (33)
Unidentified seal	68 (77)	52 (59)
Polar bear	3 (9)	3 (9)
Total	**133 (158)**	**96 (110)**

[a] Useable detections are those made during useable daylight visual observations; see *Acronyms and Abbreviations* for the definition of "useable" observation effort.

TABLE 4.3. Encounter rates for sightings from the *Healy* during the Arctic Ocean seismic survey, 19 July – 23 Aug. 2006.

		Non-Seismic			Post-Seismic			Seismic			Total		
Effort Type		No. of Detect.	Effort (km)	Detection Rate (No./1000 km)	No. of Detect.	Effort (km)	Detection Rate (No./1000 km)	No. of Detect.	Effort (km)	Detection Rate (No./1000 km)	No. of Detect.	Effort (km)	Detection Rate (No./1000 km)
Useable[a]	Pinnipeds in water	32	1490	21.5	-	-	-	11	272	40.4	43	1762	24.4
	Pinnipeds on ice	33	1490	22.1	-	-	-	17	272	62.5	50	1762	28.4
	Polar bears	3	1490	2.0	-	-	-	-	-	-	3	1762	1.7
Total useable		*68*	*1490*	*45.6*	-	-	-	*28*	*272*	*102.9*	*96*	*1762*	*54.5*
Non-Useable[b]	Pinnipeds in water	8	1033	7.7	4	50	80.0	-	-	-	12	1150	10.4
	Pinnipeds on ice	21	1033	20.3	2	50	40.0	2	67	29.9	25	1150	21.7
	Polar bears	-	-	-	-	-	-	-	-	-	-	-	-
Total non-useable		*30*	*1033*	*29.0*	*6*	*50*	*120.0*	*2*	*67*	*29.9*	*37*	*1150*	*32.2*
All		**98**	**2523**	**38.8**	**6**	**50**	**120**	**30**	**339**	**88.5**	**133**	**2912**	**45.7**

[a] Useable detections are those made during useable daylight visual observations; see *Acronyms and Abbreviations* for the definition of "useable" observation effort.

[b] Includes the "Post-seismic" category.

Distribution of Marine Mammals

Observations during the Arctic Ocean study indicate that, as expected, the ringed seal was the most abundant species in the study area. Ringed seals were seen throughout the survey area wherever visual observations were made, including before, during, and after seismic operations (Fig. 4.1; Appendix I.3). However, the greatest number of ringed seals were observed along the northern extent of the survey (north of 75°) where the ice cover was 70–98%. Ringed seals were seen only six times along the southern leg of the trackline where the ice cover was less than 60%.

Polar bears were sighted only three times during the 2006 *Healy* project. The locations of the observations were evenly dispersed along the trackline (Fig. 4.1). Each sighting was of a mother with at least one cub (one, three and two cubs). Polar bear observations occurred in areas where the ice cover ranged between 80 and 95%.

Marine Mammal Behavior

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

Closest Observed Point of Approach

There was no statistical difference between the distance at which pinnipeds in water or pinnipeds on ice were seen when the airguns were off versus on, considering only useable sightings (Wilcoxon rank-sum test, P=0.51 for seals in water, P=0.99 for seals on ice; Table 4.4). The mean CPA for pinnipeds on ice was significantly greater than the mean CPA for pinnipeds in water for both seismic and non-seismic periods (Wilcoxan rank-sum test, P=0.000 for seismic, P=0.000 for non-seismic). This is likely due to the fact that seals are much easier to detect when hauled out on the ice, and can be more

TABLE 4.4. Closest observed points of approach (CPA) of useable marine mammal sightings to the airguns during non-seismic and seismic periods during the Arctic Ocean cruise, 19 July–23 Aug. 2006.

		Non-seismic				Seismic			
Group[a]	**No. of Groups**	**Mean CPA (m)**	**s.d.**	***n***	**Range (m)**	**Mean CPA (m)**	**s.d.**	***n***	**Range (m)**
Pinnipeds in Water	43	465	464	32	155 - 2270	384	148	11	212 - 635
Pinnipeds on Ice	50	2127	1100	33	458 - 3796	2097	976	17	600 - 3651
Polar Bears	3	2138	838	3	1500 - 3087	-	-	-	-

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

easily seen at greater distances. Also, the *Healy* tended to follow leads through the ice so that open water areas would tend to be near the ship and areas of highest ice cover (where seals were most visible) tended to be farther to the side of the ship. The mean CPA during seismic periods, as presented in Table 4.4, would be affected by avoidance reactions if some animals avoided the airguns at distances beyond those detectable by MMOs. However, there was no evidence of such avoidance. Sighting rates were actually higher during seismic than non-seismic periods (Table 4.3), and mean CPAs for sighted animals were actually slightly closer during seismic operations, particularly for pinnipeds in water (Table 4.4).

Although most sample sizes are small, the sighting-distance data from this study are similar to the data from a 2005 survey across the Arctic Ocean on the *Healy* (Haley and Ireland 2006), and contrary to the pattern seen during many previous seismic studies. In the current study, seals tended to be observed at slightly greater average distances and lower encounter rates during non-seismic periods. In previous studies, marine mammals (primarily cetaceans) usually tended to be observed at greater distances from the vessel and at lower sighting rates when the airguns were operating than when the airguns are silent (e.g., Smultea et al. 2004; Haley and Koski 2004; MacLean and Koski 2005; Holst et al. 2005a,b). The unique environmental conditions (ice cover with leads and polynyas) and the animal species present in this study area (mainly ringed seals) are believed to have been responsible for these differences.

- The ship tended to follow the areas of less ice, open water leads and polynyas, where densities of marine mammals are expected to be higher than in the pack ice, particularly during seismic operations to reduce possibility of damage to the airguns.
- The ringed seal, the most common species of marine mammal in the area traversed during this study, is known from prior studies to be relatively non-responsive to airgun sounds (Harris et al. 2001; Miller et al. 2005).

Categories of Behavior

Marine mammal behavior is difficult to observe from a transiting ship because individuals and/or groups are often at the surface and visible only briefly. This results in difficulties resighting those animals, and in determining whether two sightings some minutes apart are repeat sightings of the same individual(s). Only limited behavioral data were collected during this project because marine mammals were often seen at a distance from the vessel, and they were typically not tracked for long distances or durations while the vessel was underway. The two parameters that were examined quantitatively to assess potential seismic effects on behavior were the categories of behavior and of movement when the animal(s) were first observed (see Appendix G for variables and definitions). The CPA distance recorded for each sighting was also an indicator of behavior (see above and Appendix G).

Sample sizes during the 2006 cruise were small and we are aware of only one project, last year's *Healy* study, that has provided comparable data on marine mammal behavior in response to airgun operations within the polar ice. The data from the 2005 *Healy* project were also sparse; that project provided data from 37 "useable" sightings within the same range of latitudes (below 79.1ºN) as the 2006 project. However, when the results from the 2005 and 2006 *Healy* cruises are combined with results from any future comparable cruises in predominantly ice-covered areas, the data may be useful in assessing behavioral reactions of arctic marine mammals to seismic sounds. Results from the 2006 *Healy* cruise are summarized in Tables 4.5 and 4.6 and are briefly discussed below.

Movement.—During both seismic and non-seismic periods, pinnipeds (mainly ringed seals) in the water were most often seen milling, not moving relative to the vessel (28% of sightings, n=12; Table 4.5) in contrast to the results of the 2005 Healy project in which most seals (39%, or n=22) were recorded swimming away from the Healy. For the 2006 Healy seismic survey, the second most frequently-observed type of movement in relation to the vessel was swimming away from the vessel (21% sightings). The third most observed movement of seals relative to the ship during the 2006 project was swimming toward.

The movement of polar bears and pinnipeds first observed on ice was always categorized as hauled out and is therefore not present in Table 4.5. However, these animals' reactions (or lack of reactions) to the vessel, during both seismic and non-seismic periods, are evident from the behavior data presented below (Table 4.6).

First Observed Behavior.—In the case of pinnipeds in water, the most common "first observed behavior" during both seismic and non-seismic periods was swimming (47%; Table 4.6). The second-most-common category was looking toward the vessel (26%; Table 4.6). In contrast, for pinnipeds on ice, logging/resting was the most common first-observed behavior; it was noted for 78% of sightings during seismic and non-seismic periods combined (Table 4.6). Pinnipeds first observed on the ice usually remained hauled out while the vessel passed. There were too few polar bear sightings (*n*=3) for generalizations about their behavior, but of the three sightings, all were on the ice; in one case the animals "looked", in another they were walking on ice traveling parallel to the ship.

Mitigation Measures Implemented

A total of three power downs and five shut downs of the airguns were requested due to sightings of single seals approaching or within the nominal safety radii during the Arctic Ocean cruise (Table 4.7). The five shut downs were requested when the animal was within the safety radius around the full eight-airgun array, but outside of the 190 dB radius of a single G. gun. In each of these cases, a power down to a single G. gun would have sufficed to meet the mitigation requirements; the five full shut downs went beyond the level of mitigation required. The three power downs and one of the five shut downs were requested in water >1000 m where the defined safety radius for pinnipeds was 230 m (Table 3.2). Four shut downs were requested in intermediate water depths (100–1000 m), where the defined safety radius for pinnipeds was 500 m (Table 3.2). It is important to remind readers that the **safety radii** were larger than the estimated **sound level radii**, except under specific conditions. Those specific operating conditions were that the full 8-airgun array was operating in deep water (>1000 m), which occurred only ~0.2% of the survey (~1 km of 339). The safety radii applied for sightings in intermediate water depths (100 – 1000 m) had already been expanded as a conservative measure for the 8-airgun array. In addition, the airgun array almost always operated at lower discharge volumes than the 8-airgun array (sometimes significantly lower, e.g. 840 in^3 vs. 2840 in^3), and the sound radii would have been further reduced. Usually, animals seen within a safety radius were not within the 190 dB radius for the operating conditions.

TABLE 4.5. Movements of useable marine mammal sightings during non-seismic and seismic periods during the Arctic Ocean cruise, 19 July–23 Aug. 2006. Seals and polar bears hauled out on the ice are not included. See Appendix G for definitions of movement categories.

	Movement Relative to Vessel							
Group[a]	**Mill**	**Swim Perpen-dicular**	**Swim Away**	**Swim Parallel**	**Swim Toward**	**No movement**	**Unknown**	**Total**
Pinnipeds in Water								
Non-seismic	9	2	7	3	5	3	3	**32**
Seismic	3	0	2	1	3	1	1	**11**
Total	**12**	**2**	**9**	**4**	**8**	**4**	**4**	**43**

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

TABLE 4.6. Comparison of first observed behavior of useable marine mammal groups during non-seismic and seismic periods within the study area of the Arctic cruise, 19 July–23 Aug. 2006. See Appendix G for definitions of behavior.

Group[a]	**Forward Dive**	**Swim**	**Dive**	**Flipper Slap**	**Look**	**None**	**Log / Rest**	**Mill**	**Swim Away**	**Bob**	**Sink**	**Thrash**	**Unknown**	**Walk Parallel**	**Total**
Pinnipeds in Water															
Non-seismic	0	15	2	1	7	0	2	0	1	0	3	0	0	-	**31**
Seismic	1	5	0	0	4	0	0	0	0	1	0	1	0	-	**12**
Total	**1**	**20**	**2**	**1**	**11**	**0**	**2**	**0**	**1**	**1**	**3**	**1**	**0**	**-**	**43**
Pinnipeds on Ice															
Non-seismic	0	0	0	0	6	0	24	0	0	0	1	0	2	-	**33**
Seismic	0	0	0	0	2	0	15	0	0	0	0	0	0	-	**17**
Total	**0**	**0**	**0**	**0**	**8**	**0**	**39**	**0**	**0**	**0**	**1**	**0**	**2**	**-**	**50**
Polar Bears															
Non-seismic	0	0	0	0	1	1	0	0	0	0	0	0	0	1	**3**
Seismic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Total	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**3**

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

A power down was requested 16 Aug. for a bearded seal (sighting 3 in Table 4.7) that was originally observed diving away from the ship outside of the safety radius. The vessel was surveying in 1290 m water where the safety radius was 230 m around the airguns (Table 3.2). The estimated 190 dB sound level radius for the array, firing at a volume of 2340 in^3, was 200 m (Table 3.1). The bearded seal was seen again 191 m away from the active airguns, within the 190 dB radius. A power down was requested, but because the seal had already entered the 190 dB safety zone underwater, it is likely that it was exposed to sound levels >190 dB. Another power down was attributable to a ringed seal that was approaching the safety zone when first sighted 16 Aug. (sighting 6 in Table 4.7). This seal was seen diving ~25 s before the power down was implemented, 212 m away from the active sound source. The seal was observed in deep water (>1000 m) where the 190 dB radius for the array (2340 in^3) was estimated to be 200 m. The extent of the 190 dB received level for the airguns deepens as distance from the source increases (Figure C.1). The seal was outside of the edge of the 190 dB received sound level radius (200 m) by ~12 m. It is unlikely that the seal was exposed to >190 dB because it would have had to reach well below the surface while swimming swiftly toward the array before the airguns were powered down. The third seal for which a power down was requested (sighting 4 in Table 4.7), was beyond the 190 dB sound radius and was unlikely to have been exposed to 190 dB.

Four of the five shut downs were implemented after ringed seals were seen diving within the safety radius (Table 4.7). However, only one of those seals was observed within the 190 dB sound radius (sighting 7 in Table 4.7) and likely exposed to noise levels ≥190 dB. All of the other seals for which shut downs were called were outside of the 190 dB received sound level radius (150 - 300 m, Table 4.7) and unlikely exposed to a noise level ≥190 dB. It is worth noting that the seismic array was never at full volume (2840 in^3, the level at which the safety radii were modeled) when marine mammals were sighted. However, the MMOs applied the 190 dB radii modeled for the full array in deep water (>1000 m), and expanded safety radii for the full volume array intermediate water depths. Appendix J provides further details concerning the power downs and shut down.

Estimated Number of Marine Mammals Present and Potentially Affected

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

In this study, there were additional factors to consider. Many of the sightings were of animals (pinnipeds and polar bears) on pack ice, where they were not exposed to underwater sound. Also, the fact that the ship tended to travel along leads and through polynyas, especially when operating the airguns, means that sighting rates during seismic and non-seismic periods were not directly comparable. Both seals and polar bears would be expected to be more common in the leads and polynyas where seismic operations tended to occur. Within the study area, no cetaceans were seen, and all polar bears observed within the study area were on the ice where they would not be exposed to high sound levels from the airguns.

TABLE 4.7. List of power downs (PD) and shut downs (SZ) of the airguns implemented for marine mammals sighted in or near the safety radii during the Arctic Ocean seismic cruise, 19 July– 23 Aug. 2006.

Species	Grp Size	Date (2006)	Water Depth (m)	Initial Sighting Distance (m) from observer	Initial Move-ment[a]	Dove? (yes/no)	Total airgun Vol. prior to SZ or PD (in in^3)[g]	Applied safety radius	Estimated 190 dB sound level radius	CPA[b] to operating airguns before mitigation (m)	Mitigation measure taken (SZ, PD,)[h]	Exposed to >190 dB re 1 μPa (rms)[b]?
1. Ringed Seal	1	08-Aug	465	579	HO	yes	840	500	150	264	SZ	very unlikely
2. Ringed Seal	1	15-Aug	944	400	MI	no	2340	500	300	458	SZ	very unlikely
3. Bearded Seal	1	16-Aug	1290	303	SP	yes	2340	230	200	191	PD	likely
4. Ringed Seal	1	16-Aug	1270	170	MI	yes	2340	230	200	236	PD	unlikely
5. Ringed Seal	1	16-Aug	1253	120	MI	yes	1840	230	200	212	PD	unlikely
6. Ringed Seal	1	17-Aug	940	350	ST	yes	2340	500	300	438	SZ	very unlikely
7. Ringed Seal	1	17-Aug	961	150	SA	yes	1840	500	300	250	SZ	likely
8.Unidentified Seal	1	17-Aug	1287	150	ST	yes	1840	230	200	242	SZ	unlikely

[a]Initial movement of group relative to the vessel: HO = hauled out, MI = milling, SP = swimming parallel, ST = swimming toward, SA = swimming away.

Disturbance and Safety Criteria

Table 3.1 shows the distances at which various sound levels were estimated to be received from the 4-G. gun and 7- and 8-airgun arrays, distinguishing between two different water depth categories. The predicted 160 and 170-dB radii are assumed disturbance criteria, and were based on modeling and limited acoustic measurements in the northern Gulf of Mexico (Tolstoy et al. 2004a,b). 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.

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

Estimates from Direct Observations

The number of marine mammals observed from the *Healy* during the Arctic Ocean survey provides a minimum estimate of the number potentially affected by seismic sounds. This is likely an underestimate of the actual number potentially affected. Some animals probably moved away before coming within visual range, and not all of those that remained would have been seen by observers.

Seals Potentially Exposed to Sounds ≥190 dB re 1 μPa (rms).—During this project, six marine mammals were sighted within the safety radius around the airguns (Table 3.2). Five of the seals were seen diving within the safety radius. However, in only two of these cases did the seals submerge within the perimeter of the 190 dB sound zone (Table 3.1). Both of the two seals observed diving within the 190 dB radius likely received sound levels in excess of 190 dB

The estimated 180-dB and 190 dB sound radii shown in Table 3.1 are the *maximum* distances from the airguns within which sound levels were expected to be ≥180 or ≥190 dB re 1 μPa (rms). These distances would apply at the water depth (and in the directions) with maximum received level. Thus, there are complications in assessing the maximum level to which any specific individual mammal might have been exposed:

- Near the water surface, received sound levels are considerably reduced because of pressure-release effects. In many cases, it is unknown whether animals seen at the surface were earlier (or later) exposed to the maximum levels that they would receive if they dove.
- Some marine mammals may have been within the predicted safety radii while underwater and not visible to observers, and subsequently seen outside these radii. The direction of movement as noted by MMOs can give some indication of this.
- The MMO station on the bridge was ~100 m forward of the airguns, and the tip of the *Healy's* bow was ~128 m away from the airguns. The safety zone was not centered on the observer's station, but rather on the airguns. This offset in location between airguns and observer was

accounted for in the observer's decisions regarding whether it was necessary to shut down the airguns for sightings immediately forward or astern.

Marine Mammals Potentially Exposed to Sounds ≥160 dB re 1 μPa (rms).—Eleven groups of pinnipeds were sighted in the water under "useable" conditions during the Arctic Ocean cruise when the airguns were operating (Table ES.1; Appendix I.3). All 11 groups were believed to be unique. Each of those 11 groups (11 individuals) is believed to have entered the ≥160 dB radius (see Appendix I.3 for sightings). Each of these 11 individual seals is also presumed to have been exposed to ≥170 dB sound levels, based on water depth and closest observed point to the airguns. Five of the total "useable" pinniped sightings occurred in intermediate-depth (100-1000 m) water and six sightings occurred in deep (>1000 m) water.

Estimates Extrapolated from Density

The numbers of mammals directly sighted during the Arctic Ocean study underestimated the actual numbers present because some animals present near the trackline would not have been seen by the observers. Some cetaceans may have been present despite the lack of cetacean sightings. During daylight, animals can be missed if they are below the surface. Also, others, even if they surface near the vessel, may be missed because of limited visibility, intervening ice, glare, or other factors limiting sightability. High sea state (Bf) was not a significant factor during this cruise because waves were dampened by the ice.

Within the assumed 160–170 dB radii around the source (i.e., for the 7- airgun array ~9375–2850 m in water >1000 m; ~10646–3402 m in water 100-1000 m deep), the distribution and behavior of pinnipeds and cetaceans may have been altered as a result of the seismic survey. This could occur as a result of reactions to the airguns, or as a result of reactions to the *Healy*. Some animals may have avoided the area near the seismic vessel while the airguns were firing (Richardson et al. 1995; Stone 2003; Gordon et al. 2004; Smultea et al. 2004). The extent to which the distribution and behavior of pinnipeds might be affected by the airguns is uncertain, given variable results from previous studies (Thompson et al. 1998; Harris et al. 2001; Miller et al. 2005). However, it is safe to assume that some pinnipeds that were on the ice as the ship approached would have gone into the water in response to the *Healy*. Likewise, it is safe to assume that—if any cetaceans were approached during the seismic survey—some of those animals would have moved away before they were in view.

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, *Analyses*, and in further depth in Appendix G. Two density values were calculated. Densities were based on earlier surveys conducted in the pack ice in the Beaufort Sea (Kingsley 1986) and elsewhere. It is not known how these densities might have compared to the actual densities in the survey area, as the previous work did not extend as far north. A second set of densities was derived from the use of sighting data (§ 3. Monitoring and Mitigation Methods and Appendix G.)

The aforementioned densities were used to estimate the number of marine mammals exposed to 160, 170, 180, and 190 dB. The densities from previous surveys were also used to calculate the number of *individual* marine mammals exposed to different received sound levels. (Because the present survey was more or less linear, with little doubling back across or near previous tracklines, there was little difference in the two types of estimates.) These density numbers provided estimates of the number of animals potentially affected by seismic operations, as described in Chapter 3 and Appendix G. Densities derived from the data collected during this project were not used to determine *overall* exposures, but not *individual* exposures,

because our estimates depended on the area of open water ensonified. We did not determine the area of open water ensonified when the trackline overlapped during periods of various ice cover .

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 (LGL Ltd. 2006a,b,c) were based on the then-anticipated amount of survey, with an allowance for the possibility that some lines would be surveyed more than once. The estimates in the IHA applications and EA assumed that there would be more seismic surveying than actually occurred. Thus, the present estimates derived from the published densities are lower than those in the EA and IHA applications, even though one set of take estimates is based on the same assumed density data. In addition, the following estimates assume that all mammals present were well below the surface where they would be exposed to the sound levels predicted in Table 3.1 at a given distance. 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 *Healy* before it arrived because of an avoidance response to the approaching *Healy* and its airguns. Thus, the following estimates, though lower than those in the IHA application and EA, are nonetheless likely to overstate actual numbers of marine mammals exposed to various received sound levels.

Pinnipeds.—Tables 4.8 and 4.9 summarize the estimated numbers of ringed seals, bearded seals, spotted seals, and walruses that might have been exposed to received sounds with levels ≥160 dB and ≥170 dB relative to the number of "takes" requested in the IHA applications, based on densities from prior surveys. The data used from earlier surveys to calculate these numbers, for non-seismic as well as seismic periods, are presented in Appendix K for the criteria of interest. As in the NMFS IHA application and EA, we have assumed that ringed seal density in the polar pack ice was 1/20th of that in the Beaufort Sea (Appendix K). The estimated numbers of exposures based on densities from earlier studies, are based on the assumption that all pinnipeds present were in the water. Some of those animals calculated to be in the ≥160 - or ≥170 dB zones would be on the ice and not exposed to the underwater sounds. Table 4.10 summarizes estimated exposures of seals based on this survey's open-water density data, applied to ensonified areas of open water. Note that the estimated numbers in Tables 4.8-4.10 represent the pinnipeds that would have been exposed had the animals not shown localized avoidance of the airguns or the ship itself. Many of the animals calculated (based on densities) to be within the ≥180- or ≥190-dB zones would likely move away before being exposed to sounds that strong.

NMFS commonly specifies that marine mammals exposed to pulsed sounds with received levels ≥160 dB re 1 μPa (rms) should be considered potentially disturbed. However, most pinnipeds (and delphinids) are unlikely to be disturbed appreciably by airgun sounds unless exposed to received levels ≥170 dB. These are not considered to be "all-or-nothing" criteria; some individual mammals may react strongly at lower received levels, but others are unlikely to react strongly unless levels are substantially above 160 or 170 dB.

Estimates of the densities of pinnipeds in marginal ice areas and in the polar pack ice are given in Appendices K.1 and K.2, including approximate corrections for sightability biases. These corrected densities from prior surveys were used to estimate the number of marine mammals that were exposed to various received levels of airgun sound, and thus potentially affected by seismic operations (Table 4.8). Sighting data were used to estimate a second set of pinniped densities within the survey area. This method was flawed in that the sightings were influenced by ice which affected the lateral distribution of animals from the ship, but we calculated the different values for comparison.

(A) ≥160 dB (rms): Using densities from previous surveys, we estimated that there would have been ~204 exposures of ~196 different individual seals (ringed, bearded, and spotted) to airgun pulses

TABLE 4.8. Estimated numbers of exposures, and estimated minimum numbers of individual seals (ringed seals, spotted seals and bearded seals) that might have been exposed to seismic sounds with received levels >160, >170, >180 and >190 dB re 1 μPa (rms) if they did not move away from the airguns. Estimates are based on densities of pinnipeds in marginal pack ice from Kingsley (1986; Appendix K) with downward adjustment for the lower densities in the polar pack ice. No spotted seals were expected to occur within the polar ice pack (above 75°). Also shown in boldface is the "harassment take" requested from NMFS in the IHA application.

Exposure level in dB re 1 μPa (rms)	Estimated numbers in pack ice margin areas		Estimated numbers in polar pack ice		Estimated total		**Requested take**
	Exposures	Individuals	Exposures	Individuals	Exposures	Individuals	
≥160	6	6	197	189	204	196	**8426**
≥170	2	2	50	50	52	52	
≥180	1	1	14	14	15	15	
≥190	<1	<1	4	4	5	5	

with received levels ≥160 dB re 1 μPa (rms) during the survey, if all seals were in the water but otherwise showed no avoidance (Table 4.8). The majority of the exposures (160) would have been of ringed seals. Bearded seals were estimated to have been exposed to ≥160 dB on 44 occasions. It is possible that a single spotted seal would have been exposed to a sound level ≥160 dB. Based on densities from Brueggeman et al. (1990; Appendix K), the number of walruses exposed to sounds ≥160 dB re 1 μPa (rms) during the survey, was two (Table 4.9). The requested "take" was much higher (3960 walruses) than the estimated take here (2) because several kms of seismic survey had been planned further south within walrus habitat were not surveyed.

Estimates of seal exposure to sound levels ≥160 dB, based on sightings during the 2006 *Healy* project, were higher than the estimates based on previous surveys (Table 4.10). Seal "takes" based on sighting data during seismic periods were 299 and during non-seismic periods were 463. It is expected that the estimate of takes using the 2006 survey data may be overestimated because the values are calculated with an inflated estimate of the open-water area in the outer part of the 160 dB radius as compared with the open-water area near the ship, which is where the density data were obtained (Chapter 3, Appendix G. No walruses were estimated to have been exposed to seismic sound during the 2006 *Healy* survey based on the 2006 sighting data because none were observed.

(B) ≥170 dB (rms): On average, pinnipeds may be disturbed only if exposed to received levels of airgun sounds ≥170 dB re 1 μPa (rms). If so, then the estimated number of exposures (based on densities from prior surveys) would be ~26% of the corresponding estimates for ≥160 dB, based on the proportionally smaller areas exposed to ≥170 dB. Overall, there would have been 52 exposures of seals, involving 52 individuals, to seismic sounds ≥170 dB (Table 4.8). It is possible that at most, one walrus was exposed to sound levels ≥170 dB (Table 4.9) based on Brueggeman et al. (1990; Appendix K) densities.

TABLE 4.9 Estimated numbers of exposures, and estimated minimum numbers of individual animals under the jurisdiction of USFWS (polar bears and walruses) that might have been exposed to seismic sounds with received levels >160, >170, >180 and >190 dB re 1 μPa (rms) if they were in the water and did not move away from the airguns. Estimates are based on densities from previous surveys with adjustment for the different densities in the polar pack ice (Appendix K). No walruses were expected to occur within the polar ice pack (above 75°). Also shown in boldface is the "harassment take" requested from USFWS in the IHA application.

Exposure level in dB re 1 μPa (rms)	Estimated numbers in pack ice margin areas		Estimated numbers in polar pack ice		Estimated total		**Requested take**
	Exposures	Individuals	Exposures	Individuals	Exposures	Individuals	
Polar Bear							
≥160	<1	<1	2	2	3	3	**55**
≥170	<1	<1	<1	<1	<1	<1	
≥180	<1	<1	<1	<1	<1	<1	
≥190	<1	<1	<1	<1	<1	<1	
Walrus							
≥160	2	2	0	0	2	2	**3960**
≥170	<1	<1	0	0	1	1	
≥180	<1	<1	0	0	<1	<1	
≥190	<1	<1	0	0	<1	<1	

The number of seal exposures to ≥170 dB re 1 μPa (rms) is, again, higher when derived from sightings during the 2006 project. One hundred four seals would have been exposed to sound levels ≥170 dB, based on non-seismic sightings; 67 seals would have been exposed to sound levels ≥170 dB based on seismic sightings. Again, we believe that the take estimates are high because of the intrinsic error caused by extrapolating ice cover within 2 km of the vessel (which followed open water when possible) out to >20 km into the ice pack.

(C) ≥180 dB (rms): Some pinnipeds were within the 180 dB radius (for the 7-airgun array, estimated as 620 to 930 m, depending on water depth) around the operating airguns but were missed by the observers even though all airgun operations were in daylight. There is a low probability that a single exposure of one walrus to 180 dB might have occurred. No walruses were observed during the survey and the extrapolation form the Brueggeman et al. (1990) density data is much lower than one (Table 4.9). Based on the densities of pinnipeds assumed in the EA and IHA applications, ~15 exposures of seals, involving ~15 individuals, would have been expected to occur within the 180 dB radius (Table 4.8). The latter estimate is higher than the number of different individual seals (n = 9) that direct observations indicated were possiblyexposed to ≥180 dB (Table G.3). The difference resulted (at least in part) from the fact that the estimates in Table 4.8 included any animals that

TABLE 4.10. Estimated numbers of exposures, and estimated minimum numbers of seals that might have been exposed to seismic sounds with received levels >160, >170, >180 and >190 dB re 1 µPa (rms) if they did not move away from the airguns. Estimates are based on observed densities during the 2006 Arctic Ocean cruise. Also shown in boldface is the "harassment take" requested from NMFS in the IHA application.

Exposure level in dB re 1 µPa (rms)	Estimated numbers of exposures based on observations during **non-seismic** periods	Estimated numbers of exposures based on observations during **seismic** periods	**Requested take**
≥160	463	299	**8426**
≥170	104	67	
≥180	19	19	
≥190	9	6	

- avoided exposure to ≥180 dB by swimming away from the approaching seismic vessel, or
- were present but missed by visual observers because of the inevitable difficulties in sighting small seals in the water in the presence of ice, glare, wave action, etc. [Earlier studies have shown that the detectability of ringed seals in the water diminishes rapidly as distance increases beyond about 50 m—Harris et al. (2001); Moulton and Lawson (2002). However, because the present surveys were conducted in areas of heavy pack ice, visibility conditions were much better than in open-water areas and the proportion of seals missed was likely lower during this study than during earlier studies.]

(D) ≥190 dB (rms): MMOs watched for pinnipeds near the seismic vessel while it was conducting seismic operations as part of the monitoring and mitigation procedures. As noted earlier, the safety radii were very conservative and so most mitigation measures were initiated well before pinnipeds might have been exposed to 190 dB seismic sounds. However, some pinnipeds within the safety radius, which was nominally 230–500 m (Table 3.1), might not have been seen when they were at the surface. However, because some pinnipeds likely swam away to avoid exposure to such strong seismic sounds, the actual number of exposures was probably considerably lower than the above estimates which include up to five exposures of five individual seals and much less than one exposure of a walrus. Using sighting data to calculate densities, the estimate of seal exposures to sound ≥190 dB was six, based on seismic periods; and nine, based on non-seismic periods (Table 4.10).

Cetaceans.—Although no cetaceans were observed in the study area *per se* during the survey, it is possible that some cetaceans, undetected by the MMOs, were exposed to sound levels ≥160 dB. Based on densities derived from prior surveys in the eastern Alaskan Beaufort Sea in summer, and the anticipated level of seismic with allowance for repeating some lines, we anticipated that as many as 229 exposures of cetaceans (bowheads, belugas, and narwhals) to sound levels ≥160 dB re 1 µPa rms might occur during the 2006 survey (LGL Ltd. 2006a,b,c). Table 4.11 summarizes the estimated numbers of cetacean exposures to ≥160 dB and other received sound levels for the area actually surveyed, which was smaller and included less seismic activity in pack ice margin areas than was assumed in the EA and IHA

TABLE 4.11. Estimated numbers of exposures, and estimated minimum numbers of individual cetaceans (beluga, bowhead whale and gray whale) that might have been exposed to seismic sounds with received levels >160, >170, >180 and >190 dB re 1 µPa (rms) if they did not move away from the airguns. Estimates are based on densities from previous surveys (Appendix K) with downward adjustment for the lower densities in the polar pack ice. No gray whales were expected to occur within the polar ice pack (above 75°). Also shown in boldface is the "harassment take" requested from NMFS in the IHA application. The notation "<*x*" = <x and ≥[(x-1) + 0.5]; the notation "<<x" = >(x-1) and <[(x-1) + 0.5].

Exposure level in dB re 1 µPa (rms)	Estimated numbers in pack ice margin areas		Estimated numbers in polar pack ice		Estimated total		**Requested take**
	Exposures	Individuals	Exposures	Individuals	Exposures	Individuals	
≥160	<1	<1	5	5	6	6	**256**
≥170	<1	<1	2	2	3	3	
≥180	<1	<1	<1	<1	2	2	
≥190	<1	<1	<1	<1	<1	<1	

applications. The estimate for cetaceans exposed to ≥160 dB, based on densities from prior surveys, are six exposures and six individuals (maximum). Given the lack of any cetacean sightings, and the fact that many cetaceans likely avoid an approaching seismic vessel, the actual number of cetaceans exposed to ≥160 dB was, presumably, less than six. Two cetaceans may have been exposed to ≥180 dB, but most arctic cetaceans would be expected to avoid the approaching airguns and vessel(s) before received levels of the pulses reached 180 dB (rms).

Polar bears.—Three groups of polar bears (nine individuals) were observed during the study. No polar bears were observed during seismic activity (Table 4.1). None of the polar bears were in the water where they could have received appreciable sound levels from operating airguns. However, based on densities from prior surveys (Moulton and Williams 2003; Appendix K), three bears might have been close enough to the airguns to be exposed to sound levels ≥160 dB, and one may have been close enough to be exposed to sounds ≥190 dB (Table 4.9).

Summary and Conclusions

UTIG's marine mammal monitoring program provided a concentrated survey effort in the Arctic Ocean. Over 219 h (1762 km) of visual observations were made during the cruise; ~61% of the effort (in terms of distance) was during "useable" conditions, i.e., when visibility was appropriate for systematic surveys. A total of 158 individual marine mammals in 133 groups was observed during the survey. The analysis considered "useable" sightings, consisting of 110 individual marine mammals in 96 groups (Tables 4.1 and 4.2). Of these, 43 groups and 43 individuals (all seals) were in the water; the other seals and all the polar bears were on pack ice (Table ES.1). No injured marine mammals potentially associated with the operations were sighted.

Three different marine mammal species were identified within the study area. As expected, the ringed seal was the most abundant species, with 57 individuals identified. (Most of the 77 unidentified seals were undoubtedly ringed seals as well.) Fourteen individual bearded seals were observed during the project. Very few polar bears (three sightings of nine individuals) were seen throughout the project area; none were observed during seismic operations. All polar bears seen were on the ice and would not have been exposed to underwater sounds. No walruses were observed during the study.

During the Arctic Ocean study, 30 groups of marine mammals involving 34 individuals were seen during seismic operations. Three power downs and five shut downs were initiated when six individual seals were determined to be in the water within the safety radius and two seals appeared to be approaching the safety radius around the operating airguns. Based on direct observations, two of those seals were likely exposed to underwater sound with levels ≥190 dB re 1 μPa (rms). The other four seals were observed within the safety radius, but outside of the 190 dB sound radius. It is unlikely that those four animals were exposed to sound levels ≥190 dB.

Densities of marine mammals within the seismic study area were estimated based on (1) a literature review of previous marine mammal surveys in the Arctic Ocean and (2) a cautious application of sighting data from the project. Estimates of numbers of pinnipeds in areas exposed to seismic sounds are shown in Tables 4.8-10. These estimates were based on the assumed densities and the areas that were ensonified to different sound levels during the Arctic Ocean survey. Also shown, for comparison, are the numbers of "harassment takes" to pinnipeds that were requested in the IHA applications. No cetaceans were detected by the MMOs during the seismic survey; however, some undetected cetaceans might have been exposed to sound levels ≥160 dB. Based on density estimates calculated from previous surveys, as many as six cetaceans (bowheads, belugas, and narwhals) might have received sound pulses with levels ≥160 dB during the Arctic Ocean seismic survey. That estimate is likely high, given the fact that no cetaceans were observed in the area and that some cetaceans were expected to avoid an approaching vessel. Polar bears were observed on three occasions on pack ice during non-seismic periods. Based on previous survey data, we estimated that three bears may have been within the 190 dB safety radius of the operating airguns but they would not have been exposed to these sound levels unless they entered the water.

Overall, the seismic operations performed during the project are believed to have resulted in fewer animals being disturbed than estimated prior to the cruise. The observations confirmed that the marine mammal community in the Arctic Ocean is not diverse, with ringed seals being the most abundant species.

Implementation of Terms of the Biological Opinion and IHAs

UTIG successfully implemented the mitigation and monitoring conditions stipulated in the IHAs for the Arctic Ocean seismic survey. Provision 6(a)(4) of the NMFS IHA calls for a description of the implementation and effectiveness of the terms of the Biological Opinion (BO) issued by NMFS and the mitigation measures specified in the IHA. Earlier sections of this report provide details on these matters, and the following summarizes the key points.

NMFS' IHA's Mitigation and Monitoring Measures

(a) ***Utilize MMOs***.—Four marine mammal observers were employed to monitor for mammals and implement the appropriate mitigation measures as necessary during the Arctic Ocean seismic project (Chapter 3). Three of the observers were trained biologists, each of whom had previous experience working as a vessel-based marine mammal observer (Appendix I). The fourth

observer was an Inupiat, hired through the Barrow Arctic Science Consortium, who had decades of experience living and hunting in the Arctic and had worked as a marine mammal observer during the *Healy* 2005 survey (Appendix I). The observers monitored during all seismic operations and prior to all start ups for 30 minutes. Shifts were scheduled to overlap as much as possible and two observers were on watch ~46% of the time when visual watches were conducted (Chapter 3). Watches were scheduled to be no longer than 4 hours.

(b) ***Monitor Safety Radius During Ramp Ups***.—At least one observer monitored for marine mammals during every ramp up. Prior to, and during ramp ups, the full extent of the safety radius (190 dB for pinnipeds and 180 dB for cetaceans) had to be visible. Ramp ups were not allowed to commence if a marine mammal was seen near, approaching, or within the safety radius, during the previous 30 minutes. A ramp up would have been terminated if a marine mammal had been seen near, approaching, or within the safety radius.

(c) ***Implement Ramp-Ups in Prescribed Manner***.—Ramp ups were implemented whenever operation of the airguns began. The airgun operators communicated with the MMOs before initiating operations and then waited for permission from the MMOs before each increase in airgun volume.

(d) ***Mitigation for Mammals Encountered during Seismic Operations***.—The MMOs initiated methods of mitigation for marine mammals that were likely to enter the safety zone during this seismic activity. Mitigation options included course or speed alteration, which was impractical while in the ice pack, and power downs or shut downs (Chapter 3, Appendix E).

(e) ***Shut-down or Power-down***.—On eight occasions during the Arctic Ocean seismic survey, a seal was observed approaching or within the safety zone. Power downs were requested three times and shut downs were requested on five occasions (Chapter 4, Appendix J). The power downs consisted of reducing the volume of the airguns from ~1840-2340 in^3 to 210 in^3 (a single G. gun) and the shut downs were a complete shut down of all airguns. After two power downs, seismic activity was allowed to resume at full power because the mammal was seen to have left the 190 dB safety radius within five minutes of the power down. For the third power down, full-volume seismic operations did not continue until the seal was not seen within the safety radius for at least 15 minutes. Likewise, after the shut downs, seismic operations (ramp up) did not commence until the MMOs did not see the seal within the safety radius for more than 15 minutes.

(f) ***Helicopters used to deploy and retrieve sea ice seismometers***.—Helicopters followed the Healy's trackline, never landed within ~305 m (1000 ft) of an observed animal, and flew at an altitude of ~305 m (1000 ft) when practicable.

(g) ***90-Day Report***.—The present report provides the specified information.

Terms and Conditions of Biological Opinion

Notice to NMFS re Any Changes or Deletions.—No changes or deletions were made to the monitoring plan or NMFS IHA during the 2006 Arctic Ocean survey.

Effectiveness of Mitigation.— To the best of our knowledge, the procedures recommended in the Biological Opinion and the IHA for the Arctic Ocean seismic survey were implemented successfully. At least one marine mammal observer was on watch during all seismic operations. Whenever a marine mammal was observed approaching or within the safety radius, the appropriate mitigation measures were implemented. No cetaceans were observed, and none are believed to have been adversely effected.

Report Results to NMFS Endangered Species Division.—A copy of this report shall be provided to the Chief of the Endangered Species Division.

USFWS' IHA's Monitoring and Reporting Requirements

a) ***Cooperate with USFWS***.—Representatives from NSF, UTIG and the MMOs cooperated fully with USFWS monitoring the seismic activities and what impact they might have on polar bears and walruses.

b) ***File a site-specific polar bear interaction plan.*** – NSF developed a polar bear interaction plan with a representative from USFWS. The principal investigator discussed the plan with USFWS to ensure it was acceptable to USFWS, before it was adopted.

c) ***Utilize MMOS***.—see (a) above.

d) ***Allow USFWS to place an observer on site***. – This was never requested, but the request would have been accommodated as best as possible.

e) ***Report all observations within 48 hours***. – The MMOs on board the *Healy* reported all observations of polar bears and walruses within 48 hours.

f) ***90-Day Report***.—The present report provides the specified information.

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APPENDIX A:
INCIDENTAL HARASSMENT AUTHORIZATION ISSUED TO UTIG FOR A MARINE GEOPHYSICAL SURVEY IN THE ARCTIC OCEAN FROM ISSUED BY NMFS

DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NATIONAL MARINE FISHERIES SERVICE

Incidental Harassment Authorization

The University of Texas at Austin Institute of Geophysics (UTIG), 4412 Spicewood Springs Road #600, Austin, Texas 78759-8500 is hereby authorized under section 101(a)(5)(D) of the Marine Mammal Protection Act (16 U.S.C. 1371(a)(5)(D)) and 50 CFR 216.107, to harass a small number of marine mammals incidental to a seismic survey conducted by the U.S. Coast Guard Cutter *Healy* in the Arctic Ocean, July-August, 2006:

1. This Authorization is valid from July 15, 2005, through August 29, 2006.

2. This Authorization is valid only for the *Healy's* seismic survey in the Arctic Ocean, as described in the application, from July-August, 2006.

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

(i) Odontocete Whales - Killer whale *(Orcinus orca)*, Beluga whale *(Delphinapterus leucas)*, Narwhal *(Monodon monoceros)*, and Harbor Porpoise (Phocoena phocoena)

(ii) Mysticete Whales - Bowhead whale *(Balaena mysticetus)* and Gray whale *(Eschrichinus robustus)*

(iii) Pinnipeds - Bearded seal *(Erignathus barbatus)*, Spotted seal *(Phoca largha)*, and Ringed seal *(Phoca fasciata)*

The taking by injury or death of any of these species, or the taking by harassment, injury or death of any other species of marine mammal, is prohibited and may result in the modification, suspension or revocation of this Authorization.

(b) The taking of any marine mammal in a manner prohibited under this Authorization must be reported immediately to the Alaska Regional Office, Anchorage, National Marine Fisheries Service (NMFS), at (907) 271-5006, and the Office of Protected Resources (NMFS), at (301) 713-2289.

4. 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.

5. Mitigation and Monitoring

The holder of this Authorization is required to:

(a) Utilize four NMFS-approved marine mammal observers (MMOs) to monitor marine mammals near the seismic source vessel during all daytime hours and during any start ups of the airgun(s) at night. Two observers will simultaneously be on duty whenever possible, and as described in (b), below. Shifts will last no longer than 4 hours at a time.

(b) Visually observe the entire extent of the safety radius (Pinnipeds: 190-dB isopleth in deep water, 500 m in intermediate depth water, 1000 m in shallow water; Cetaceans: 180-dB isopleth in deep water, as far as can see (estimated 2-3 km) in intermediate depth or shallow water (see Attached Table 1)) using two marine mammal observers, at least 30 minutes prior to starting the airguns. If for any reason the entire radius cannot be seen for the entire 30 minutes (i.e. rough seas, fog, darkness), or if marine mammals are near, approaching, or in the safety radius, the airguns may not be started up. If one airgun is already running, UTIG may start the second gun without observing the entire safety radius for 30 minutes prior, provided no marine mammals are known to be near the safety radius.

(c) Implement a "ramp-up" procedure when starting up the two-gun array, which means start up one gun, and wait five minutes before starting up another.

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

(e) Shut-down or Power-down the airguns if a marine mammal approaches or enters the safety radius (as defined in the attached table). A shut-down means all operating airguns are shut down. A power-down means shutting down one or more airguns and reducing the safety radius. Following a power-down, if the marine mammal approaches the smaller designated safety radius, the airguns must then be completely shut down. Airgun activity will not resume until the marine mammal has cleared the safety radius, which means it was visually observed to have left the safety radius, or has not been seen within the radius for 15 min (small odontocetes and pinnipeds) or 30 min (mysticetes and large odontocetes, including killer whales).

(f) Helicopters used to deploy and retrieve sea ice seismometers will: (i) follow the *Healy's* trackline; (ii) avoid landing within 1000 ft of an observed marine mammal; and (iii) maintain a minimum altitude of 1000 ft (unless, in the case of (ii) or (iii), weather or other circumstances require differently for human safety).

6. Reporting

The holder of this authorization is required to:

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

(1) Dates of, times of, locations of, and weather during (including Beaufort Sea State) all seismic operations;

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

(3) An estimate of the number (by species) of marine mammals that may have been disturbed by the seismic activity with a discussion of the specific behaviors associated with the disturbances.

(4) A description of the implementation and effectiveness of the; (a) terms and conditions of the biological opinion (BO) (attached), and (b) mitigation measures of the IHA. For the biological opinion, the report will confirm the implementation of each term and condition and describe the effectiveness, as well as any conservation measures, for minimizing the adverse effects of the action on listed whales.

7. In the unanticipated event that any cases of marine mammal injury or mortality are judged to result from these activities, UTIG will cease operating seismic airguns and report the incident to the Office of Protected Resources, NMFS, and the Alaska Regional Administrator, NMFS, immediately.

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

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

JUL 4 2006
Date

Seismic Source	Water Depth	Pinnipeds		Cetaceans	
		Power-down	Shut-down	Power-down	Shut-down
105 in^3	>1000 m	NA	10 m	NA	27
GI gun	100–1000 m	NA	500 m	any distance (est. 2-3 km)	500 m
	<100 m	NA	1000 m	any distance (est. 2-3 km)	1000 m
210 in^3	>1000 m	20 m (190 dB)	reduced 190-dB isopleth	78 m (180 dB)	reduced 180-dB isopleth
G. gun	100–1000 m	NA	500 m	any distance (est. 2-3 km)	500 m
	<100 m	NA	1000 m	any distance (est. 2-3 km)	1000 m
420 in^3	>1000 m	75 m (190 dB)	reduced 190-dB isopleth	246 m (180 dB)	reduced 180-dB isopleth
(4-GI gun array)	100–1000 m	NA	500 m	any distance (est. 2-3 km)	1000 m
	<100 m	NA	1000 m	any distance (est. 2-3 km)	2000 m
2840 in^3	>1000 m	dB)	reduced 190-dB isopleth	716 m (180 dB)	reduced 180-dB isopleth
(8-airgun array)	100–1000 m	NA	500 m	NA	any distance (est. 2-3 km)
	<100 m	NA	NA	NA	NA

Table Desginated shut-down and power-down stances.

Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the Act, NSF, NOAA Fisheries' Permits Division and UTIG must comply with the following terms and conditions, which implement the reasonable and prudent measures described above. These terms and conditions are non-discretionary.

To implement Reasonable and Prudent Measure 1, the NSF and NOAA Fisheries Service, Permits Division shall ensure that:

UTIG implements the mitigation, monitoring, and reporting conditions contained in the IHA.

- The NOAA Fisheries Service ESA Division is immediately informed of any changes or deletions to any portions of the monitoring plan or IHA.

To implement Reasonable and Prudent Measure 2, the NSF and NOAA Fisheries Service, Permits Division shall ensure that:

- All reports shall include a description of the implementation and effectiveness of the terms and conditions. The reports shall confirm the implementation of each term and condition; and describe the effectiveness of the terms and conditions and conservation measures contained within the proposed actions for minimizing the adverse effects of the project on listed whales.

- Reports shall be provided to the Chief of the Endangered Species Division (F/PR3), National Marine Fisheries Service, 1315 East-West Hwy, Silver Spring, MD 20910

APPENDIX B:

INCIDENTAL HARASSMENT AUTHORIZATION ISSUED TO UTIG FOR A MARINE GEOPHYSICAL SURVEY IN THE ARCTIC OCEAN ISSUED BY USFWS

United States Department of the Interior

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

IN REMY REFER TO

JUL 2 4 2006

Dr. Lawrence Lawyer
Chief Scientist, *USCGC Healy* 0602
University of Texas at Austin
4412 Spicewood Springs Road #600
Austin, Texas 78759-8500

Dear Dr. Lawyer:

This letter responds to your request dated, March 14, 2006, for an incidental harassment authorization for the non-lethal, incidental take of polar bears and Pacific walrus. This letter is to transmit the final IHA and its relevant operational conditions, monitoring, and reporting requirements. This authorization is for USCGC *Healy* cruise 0602 to conduct geological and geophysical work in the Chukchi Borderland and Mendeleev Ridge regions of the Arctic Ocean from July to August 2006.

This incidental take authorization is issued in accordance with provisions of the Marine Mammal Protection Act, as amended, described in the U.S. Fish and Wildlife Service publication listed at 71 FR 35928, dated June 22, 2006. Should you have any further questions, contact Mr. Craig Perham of our Marine Mammals Management Office at (907) 786-3800 or 786-3810.

Sincerely,

Thomas O. Melius
Regional Director

Enclosure

cc: FFWFO
LE
Polly A. Penhale, National Science Foundation
Renee Cram, National Science Foundation

AFES/MMM

ISSUED: July 24, 2006
EXPIRES: August 25, 2006

INCIDENTAL HARASSMENT AUTHORIZATION
(IHA-06-03)

The University of Texas at Austin Institute for Geophysics (UTIG) is hereby authorized to take small numbers of polar bears and Pacific walrus incidental to the UTIG/Healy cruise 0602, which is identified within your IHA request (March 14, 2006). This IHA (IHA-06-03) allows UTIG to take small numbers of Pacific walrus and polar bears incidental to research in association with the geological and geophysical work in the Chukchi Borderland and Mendeleev Ridge regions of the Arctic Ocean from July to August 2006. A description of the project is presented in 71 FR 35928.

Authorization is subject to the following conditions:

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

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

3. Intentional take is prohibited.

4. This authorization is valid only for those activities identified in the request for an IHA dated March 14, 2006.

5. Conditions that will be required to minimize the potential for harassment include the following:

(1) Vessel must observe a 0.5-mile (800-rn) exclusion zone around walrus and polar bears observed on land or ice during travel status.

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

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

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

7. Polar bear and walrus monitoring, reporting, and survey activities will be conducted in accordance with those outlined in 71 FR 35928. The basic monitoring and reporting requirements follow:

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

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

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

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

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

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

8. This authorization expires August 25, 2006.

Thomas O. Melius
Regional Director, USFWS

7/24/2006
Date

APPENDIX C:

LETTER OF AUTHORIZATION TO TAKE, BY HARASSMENT, POLAR BEARS ISSUED TO UTIG FOR A MARINE GEOPHYSICAL SURVEY IN THE ARCTIC OCEAN FROM USFWS

United States Department of the Interior

FISH AND WILDLIFE SERVICE
1011 E. Tudor Rd.
Anchorage, Alaska 995036199

IN REPLY REFER TO:

AFES/MMM

Dr. Lawrence Lawyer
Chief Scientist, USCGC *Healy 0602*
University of Texas at Austin
4412 Spicewood Springs Road #600
Austin, Texas 78.759-8500

Dear Dr. Lawyer:

This responds to your May 3, 2006, request for Letters of Authorization (LOA) for intentional take of polar bears in regards to the University of Texas'at Austin Institute for Geophysics (UTIG)IHealy cruise 0602 to conduct geological and geophysical work in the Chukchi Borderland and Mendeleev Ridge regions of the Arctic Ocean from July to August 2006. Enclosed is an authorization under sections 109(h) and 112(c) of the Marine Mammal Protection Act (MMPA) that allows researchers from UTIG to intentionally take polar bears by harassment (deterrent activities) for the protection of both human life and animals while conducting activities in polar bear habitat. This authorization is issued for activities occurring during the cruise Healy 0602, which includes marine surveys, geophysical, geotechnical studies and supporting lease development activities.

This intentional take authorization is issued specifically to UTIG representatives on the Healy who are responsible for ensuring that trained and qualified personnel are assigned the task to harass (deter) polar bears. All polar bear harassment events and opportunistic sightings of polar bears are to be reported to our Marine Mammals Management Office within 24 hours. Furthermore, daily reports specific to marine mammal observations and related information from the boats associated with UT's Chukchi Borderland and Mendeleev Ridge Program. These reports will help the U.S. Fish and Wildlife Service (Service) monitor activities in relation this authorization and the preceding IHA (71 FR 35928).

The Service believes that protection measures for marine mammals described in the UTIGINSF Interaction plan are also appropriate safeguards to limit human/bear interactions. The UTIG personnel can limit encounters of polar bears by being observant of approaching animals (i.e., the use of marine mammal observers) and breaking off interactions, if practicable, by allowing the animals to continue their travel. The Service biologists are available for consultation if questions or concerns arise regarding polar bears during the project period at the phone numbers listed below.

AFES/MMM

U.S. Fish and Wildlife Service

AUTHORIZATION TO TAKE, BY HARASSMENT, POLAR BEARS

By Sections 109(h) and 112(c) of the Marine Mammal Protection Act of 1972, as amended, the University of Texas at Austin Institute for Geophysics (UTIG) and its representatives are authorized to take, by harassment, polar bears during activities in association with the Healy cruise 0602 to conduct geological and geophysical work in the Chukchi Borderland and Mendeleev Ridge regions of the Arctic Ocean from July to August 2006. This authorization is restricted to harassment activities. Authorized individuals are responsible for documenting and reporting to the U.S. Fish and Wildlife Service, Marine Mammals Management Office, (907) 786-3800, instances involving harassment activities as soon as possible and not later than 24 hours from the occurrence. A final report of all encounters and hazing events is due 60 days from the expiration of this authorization. This Authorization is valid from the date of issuance to December 31, 2006, unless terminated in writing.

Signed: _____

Date: 7/26/06

APPENDIX D:
POLAR BEAR INTERACTION PLAN FOR UTIG'S MARINE GEOPHYSICAL SURVEY IN THE ARCTIC OCEAN (APPROVED BY USFWS)

Polar Bear Interaction Plan

Marine Geophysical Survey of the Western Canada Basin, Chukchi Borderland and Mendeleev Ridge of the Arctic Ocean

Dr. Lawrence Lawver, Principal Investigator
University of Texas Geophysical Institute
Sponsored by the National Science Foundation
USGC *Healy* Cruise
July – August 2006

Prepared By: Renee D. Crain
Office of Polar Programs
National Science Foundation

Approved By: Dr. Polly Penhale
Environmental Officer
Office of Polar Programs
National Science Foundation

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Polar Bear Interaction Plan

University of Texas Geophysical Institute

USGC Healy Cruise
July – August 2006

I. Summary

The University of Texas at Austin Institute for Geophysics (UTIG), with research funding from the National Science Foundation (NSF), plans to conduct a marine seismic survey in the western Canada basin, Chukchi Borderland and Mendeleev Ridge, Arctic Ocean, during the period 18 July to 28 August 2006 (approximately). The vessel will board in Barrow, Alaska, then sail north and the survey will begin >150 km off the coast north of Barrow (Figure 1). The purpose of the seismic survey is to study the origin and movement of the Amerasian Basin's opening. This research effort includes seismic activities and scientific coring by scientists from UTIG and the United States Geological Survey. The chief scientists are Dr. Lawrence Lawver and Dr. Harm van Avendonk of UTIG and Dr. Art Grantz of the USGS. The vessel will be self-contained, and the crew will live aboard the vessel for the entire cruise. Incidental Harassment Authorization has been granted by NOAA/NMFS and requested from USFWS for Polar Bears (*Ursus maritimus*) and Pacific Walrus (*Odobenus rosmarus*). This Polar Bear Interaction Plan is a necessary component of the Intentional Take permit sought from FWS for this cruise. The science team and the research vessel will abide by the protocols described in this document.

II. Description of the Field Study

The seismic survey will use a portable seismic system. As the energy source, the vessel will deploy an eight-airgun array in deep water areas consisting of four Bolt airguns, each discharging 500 in^3, and four G. guns, each discharging 210 in^3, for a total discharge volume of 2840 in^3. In shallow water areas at the beginning and end of the cruise, a four 105 in^3 GI gun array with a total discharge volume of 420 in^3 will be used. The airgun arrays will discharge about once every 60 s. Onboard compressors will supply the compressed air. The *Healy* will also tow a hydrophone streamer 100–150 m behind the ship, depending on ice conditions. The hydrophone streamer will be up to 200 m long. As the source operates along the survey lines, the hydrophone receiving system will receive and record the returning acoustic signals. Sea ice seismometers (SIS) will be deployed on ice floes ahead of the ship using a vessel-based helicopter, and then retrieved from behind the ship once it has passed the SIS locations. SISs will be deployed as much as 120 km ahead of the ship, and recovered when as much as 120 km behind the ship. The seismometers will be placed on top of ice floes with a hydrophone lowered into the water through a small hole drilled in the ice. These instruments will allow seismic refraction data to be collected in the heavily ice-covered waters of the region.

Overall, the program will consist of a total of ~3625 km of surveys, not including transits when the airguns are not operating. The area of interest for this application is the southwest leg, which extends 478 km into the Chukchi Sea (south of 75°N). Little more than 15% (~73 km) of the Chukchi Sea survey segment will occur in water deeper than 1000 m; while 21% (~102 km) will be conducted in water 100–1000 m deep, and most (~64%, ~303 km) of the Chukchi survey track will occur in water less than 100 m. The Principal Investigators (PIs) plan to use the larger, 8-airgun array for only 24 km along the northernmost reach of the Chukchi survey line in deep water (>1000 m; Fig. 1). There will be additional seismic operations associated with airgun testing, start up, and repeat coverage of any areas where initial data quality is sub-standard. In addition to the airgun array, a multibeam sonar and subbottom profiler will be used during the seismic profiling and continuously when underway.

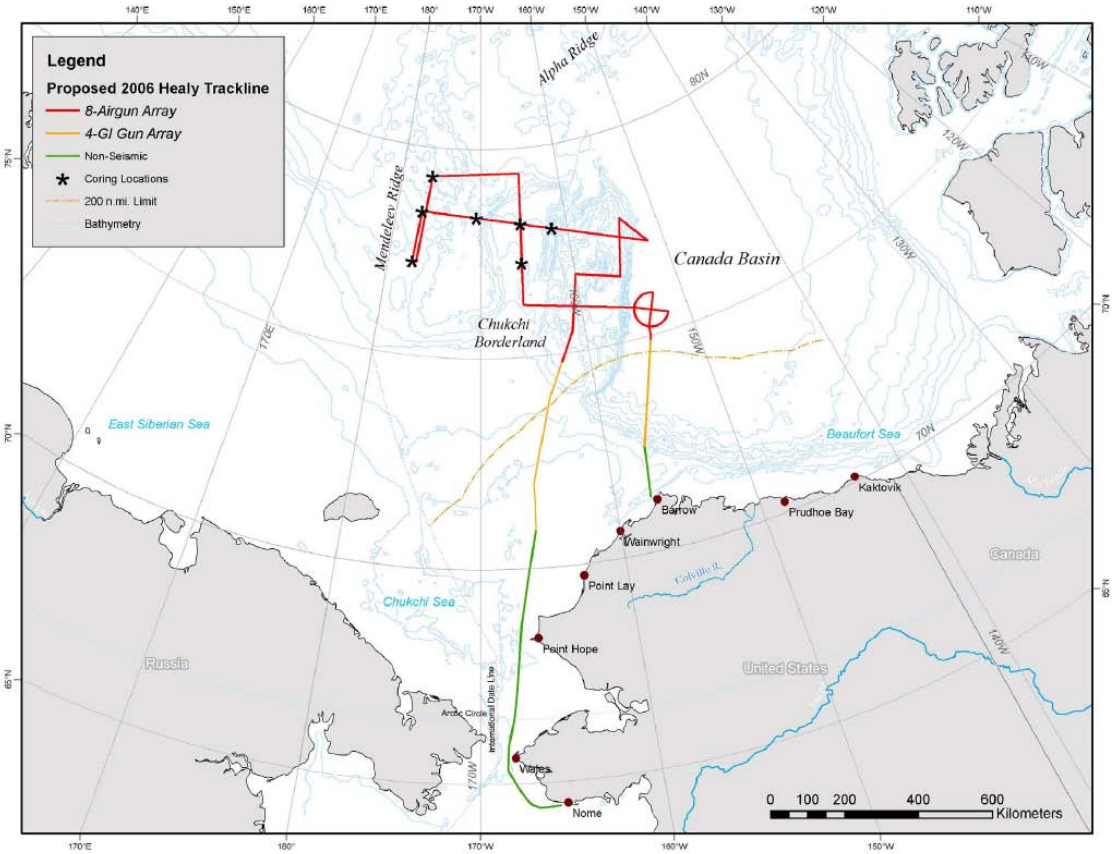

FIGURE 1. Proposed location of UTIG's July–August 2006 Arctic Ocean seismic survey lines and coring areas. The area of interest is the survey track that occurs in the Chukchi Sea area, south of 75°N. The precise track may vary somewhat from this nominal version depending on ice conditions.

The purpose of the proposed study is to collect seismic reflection and refraction data that reveal the crustal structure and composition of submarine plateaus in the western Amerasia Basin in the Arctic Ocean. Past studies have led many researchers to support the idea that the Amerasia Basin opened about a pivot point near the Mackenzie Delta. However, the crustal character of the Chukchi Borderlands could determine whether that scenario is correct, or whether more complicated tectonic scenarios must be devised to explain the presence of the Amerasia Basin. These data will assist in the determination of the tectonic evolution of the Amerasia Basin and Canada Basin, which is fundamental to such basic concerns as sea level fluctuations, past and future, and reconstructing paleoclimate in the Mesozoic era.

III. Polar Bears in the Study Area

Polar bears typically range as far north as 88°N (Ray 1971; Durner and Amstrup 1995), at about 88°N their population thins dramatically. However, polar bears have been observed across the Arctic, including close to the North Pole (van Meurs and Splettstoesser 2003). Stirling (1990) reported that of 181 sightings of bears, only three were above 82°N. Three polar bears were observed from the *Healy* in the northern Chukchi Sea during a survey through this area in August of 2005 (Haley and Ireland 2006). These three sightings occurred along 2401 km of observed trackline over 14 days between 70°N and 81°N.

Historically, polar bears have preferred the pack ice over coastal areas during the summer (Amstrup 1995). However, since the late 1980s, polar bears have been observed in greater numbers near coastal areas during late summer and fall in the central Beaufort Sea (Schliebe et al. 2004). This recent observation of bear behavior may be related to the 30-year moratorium on polar bear hunting and the recent success of subsistence whale harvests, the scraps of which appear to have become a reliable, annual food source for polar bears (Schliebe et al. 2004). The Bering/Chukchi Sea population ranges from Point Barrow, Alaska, in the east to the Eastern Siberian Sea in the west. These two populations overlap between Point Hope and Point Barrow, Alaska, centered near Point Lay (Amstrup 1995). Both of these populations have been extensively studied by tracking the movement of tagged females (Garner et al. 1990). Radio-tracking studies indicate significant movement within populations and occasional movement between populations (Garner et al. 1990; Amstrup 1995). The *Healy* is likely to encounter polar bears when it enters the pack ice. However, small numbers of bears could be encountered anywhere along the entire trackline.

Current world population estimates for the polar bear range from ~20,000–30,000 bears (Derocher et al. 1998). Amstrup (1995) estimated the minimum population of polar bears for the Beaufort Sea to be ~1500–1800 individuals, with an average density of about one bear per 38.6 to 77.2 square miles (100–200 km^2). There are no reliable data on the population status of polar bears in the Bering/Chukchi Sea; an estimate was derived by subtracting the total estimated Alaska polar bear population from the Beaufort Sea population, thus yielding an estimate of 1200–3200 animals (Amstrup 1995).

The Alaskan polar bear population is considered to be stable or increasing slightly (USFWS 2000a,b). Polar bear populations located in the Southern Beaufort Sea have been estimated to have an annual growth rate of 2.2–2.4% with an annual harvest of only 1.9% (Amstrup 1995). Currently, neither stock is listed as “depleted” under the Marine Mammal Protection Act, or as “Threatened” or “Endangered” under the ESA (USFWS 2000a,b). Polar bear populations are protected under the MMPA, as well as by the International Agreement on the Conservation of Polar Bears, ratified in 1976. Countries participating in the latter treaty include Canada, Denmark, Norway, Russia (former USSR), and the USA. Article II of the agreement states, “Each contracting party …shall manage polar bear populations in accordance with sound conservation practices based on the best scientific data.”

Effects on polar bears are anticipated to be minor at most. Although the maximum estimate of polar bears that may be encountered during the survey is 55, almost all of these are expected to be on the ice, and therefore unaffected by underwater sound from the airguns. For the few bears that are in the water, levels of airgun and sonar sound would be attenuated because polar bears generally do not dive much below the surface. Received levels of airgun sounds are reduced near the surface because of the pressure release effect at the water’s surface (Greene and Richardson 1988; Richardson et al. 1995). The IHA to FWS details the sound source used in the seismic work and actions appropriate to avoid and mitigate incidental harassment of bears.

IV. Subsistence Harvest Considerations

Hunting typically occurs during periods of heavy ice coverage (winter and spring;
USDI/BLM 2003), not during the open-water season when the seismic survey will be conducted. Therefore, the proposed survey is not expected to disrupt subsistence hunting of polar bears. In the event that both marine mammals and hunters were near the *Healy* when it begins surveying, the proposed project potentially could impact the availability of marine mammals for the harvest in a very small area immediately around the *Healy*. However, the majority of marine mammals are taken by hunters within ~24-33 km off shore (USDI/BLM 2005), and the *Healy* will conduct its survey operations significantly farther offshore than that. After debarking from Barrow, the UTIG cruise takes place in a region far north of where polar bear subsistence hunting is known to occur, transiting to >150 km north of Barrow, the bears that may be encountered by *Healy* are so far from any subsistence hunting villages in Alaska and Russia that no ongoing hunt is expected to be interrupted. The Nanuuq Commission was sent a copy of the environmental assessment for this cruise and did not communicate any concerns either privately or through the public comment period. Considering that, and the limited times and location where the planned seismic survey overlaps with hunting areas, the proposed project is not expected to have any significant impacts to the availability of marine mammals for subsistence harvest.

Helicopter operations will occur far offshore where the seismic operations take place in the ice pack. Thus any reactions of marine mammals to the helicopter operations will have no effects on availability of marine mammals for subsistence. Futhermore, helicopter operations will be conducted in a manner that will minimize helicopter effects

on marine mammals. However, if a bear approaches the ship, the on-ice researchers or in other ways appears to be a potential threat, the helicopter may be used as a noise source or in an extreme case, a method of hazing the bear away from people or vital equipment.

V. Polar Bear Interaction Strategy

The objective is to avoid human-bear interactions by identifying bears in the area as early as possible during ship and on-ice operations and taking action to avoid interactions. Attachment A details the notification flow chart. The captain and operations officers of *Healy*, the science team and the marine mammal observers will all have copies of this polar bear interaction plan. The *Healy* will avoid bears to the greatest extent possible while maintaining safe operations in sea ice conditions. While breaking heavy ice, it may not be possible for *Healy* to steer away from bears, but every effort will be made by *Healy's* crew to avoid bears.

At least one, if possible two, marine mammal observers will be on watch 30 minutes before and during seismic operations. They will be observing from the upper deck of *Healy* to allow them to see farther and will accompany the on-ice team to deploy the seismometers to ensure marine mammals are outside the accepted safety radii defined in the IHAs from NOAA/NMFS and FWS. The marine mammal observers will record all marine mammal observations and share these data with the managing agencies and others upon request, including polar bear and walrus observations.

In addition to the four trained marine mammal observers onboard *Healy*, during on-ice operations there is a designated polar bear observer and an armed bear guard with the science team. Every attempt is made to ensure there are no polar bears in the area before conducting operations. If a polar bear is sighted, the crew and science team will wait to see if the bear moves away on its own.

If polar bears are habitually present, acceptable means to haze the bears away includes using the ships horn, firing cracker shells near the bear, starting up the helicopter engines, firing rubber bullets at the bear. If deemed necessary, the helicopter may be used to haze the bear away from the ship using safe and practical flight techniques. Under no circumstances are polar bears to be sought out or harassed unless they are creating a hazard or remain habitually present. Craig Perham at USFWS should be contacted if a problem bear is encountered. In the event of an intentional take, the marine mammal observers will:

- Record all details of the event including time, exact location, bear's behavior, preventive measures followed, etc.;
- Record all witness statements; and
- Immediately notify Craig Perham with USFWS at (907) 786-3810 or alternate office number at (907) 786-3800 or email Craig_Perham@fws.gov. If there is a lethal "take", transport the entire animal carcass to Deadhorse for sealing and processing under the direction of a responsible USFWS agent designee. USFWS will determine disposition of useable meat (e.g. donation to a Native village).

Incidental 'takes' will be reported as well as according to the provisions in the IHA from FWS.

The notification flow chart in Attachment A will be posted throughout Healy, in the laboratories and on the bridge for reference. The Healy and the science team on board are aware of both the dangers posed by polar bears and their protected status as marine mammals. Every attempt will be made to avoid polar bears, and the incidental or intentional harassment of them.

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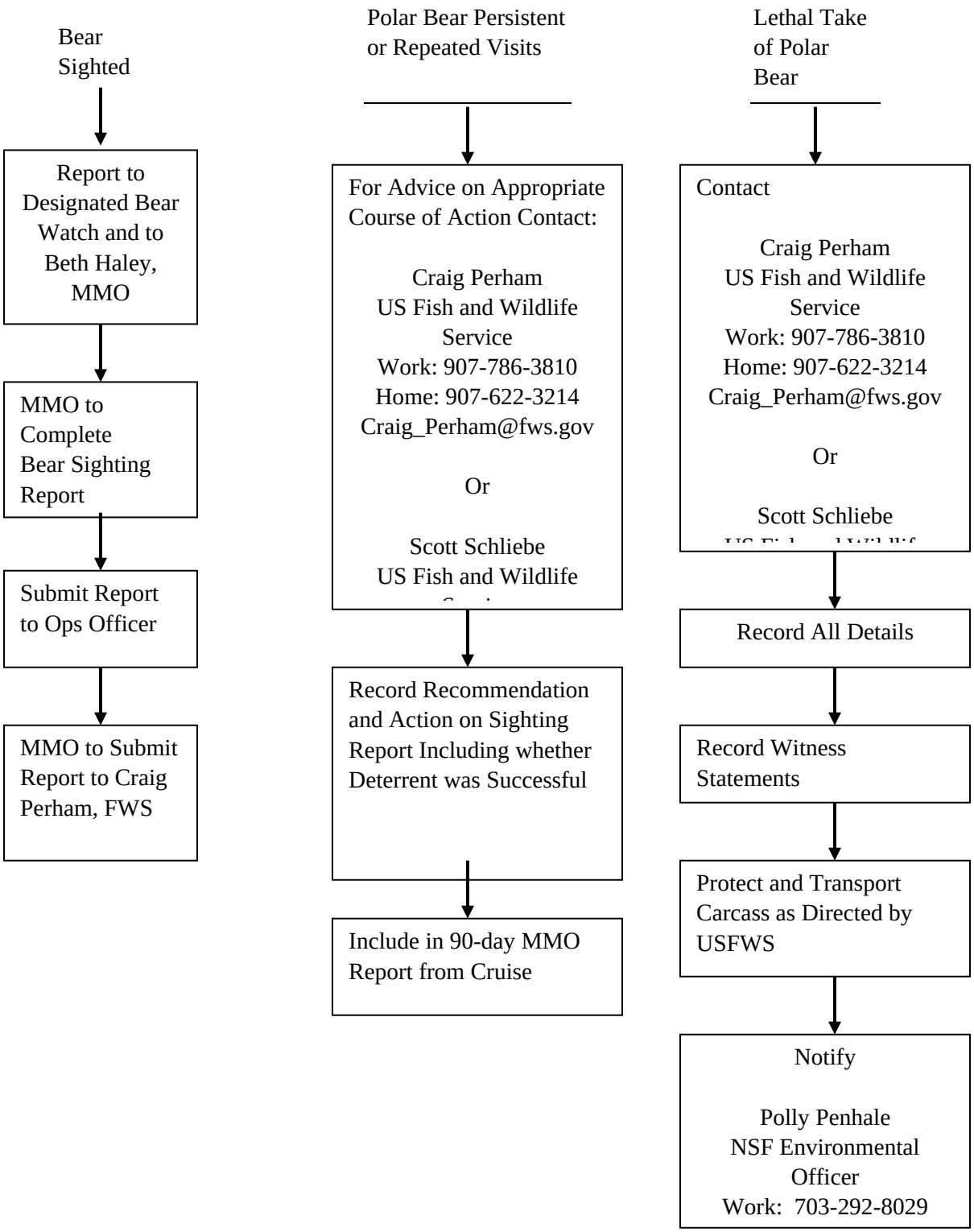
Attachment A

Polar Bear Interaction Notification Diagram

POLAR BEAR AVOIDANCE AND INTERACTION PLAN

Notification Flow Chart



Attachment B

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
_____ Sub-adult
_____ Unknown
_____ Sow/cub(s)
_____ Sow/yearling(s)
_____ 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
_____ CrackerShell
_____ Rubber bullet
_____ Bean bag
_____ Horn/siren
_____ Spotlight/Headlight
_____Other
_____

Agency/Contacts:

USFWS_____ Time_____ Date_____
ADF&G_____ Time_____ Date_____
CLIENT_____ Time_____ Date_____

Attachment C

Protocol for Hazing Polar Bears by Helicopter

U.S. Fish and Wildlife Service
Marine Mammals Management

Protocol for the Hazing of Polar Bears by Helicopter

Helicopter hazing can be conducted to move polar bears away from facilities or field personnel in order to maintain human safety and bear safety.

- Keep a distance of approximately ¼ mile between bear and helicopter, moving the bear in a direction away from people and facilities. You may need to initially approach within the 1/4 mile distance (but not aggressively) to get the bear moving, especially if it's resting, and then back off to the 1/4 mile distance.
- Push the bear at a steady walk. A running bear, especially large bears, can rapidly overheat.
- Don't haze a bear with a helicopter when ambient temperature is over 70°F (20°C).
- Don't aggressively push a bear. Bears may hunker down and not move if pushed or chased too aggressively. A slow approach is usually all it takes, especially if hovering near the ground creates snow cloud due to the prop wash.
- Move the bear at least 2-3 miles from the point of initiation or occupied facilities, as a rule of thumb. This will depend on the situation – location of facilities, bear behavior, weather, and geographic features. The key element is to keep the bear moving on its own.
- Monitor the bear, if possible, to make sure the bear does not return.

Please Note: The criteria above are to be used for Bell 212 and 206 helicopters or larger. If a R-44 helicopter is to be used, this helicopter may have to move in much closer to initiate the hazing because these machines are smaller and quieter than the 212s and 206s.

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 UTIG seismic study discussed in this report. Additional information on L-DEO's calibration study conducted with various configurations of airgun arrays is also provided. Further information on these topics can be found in Smultea and Holst (2003), Tolstoy (2004a,b), and the project IHA applications and EA (LGL 2006a,b,c).

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.

Radii within which received levels were expected to diminish to various values relevant to NMFS criteria mentioned above were estimated by L-DEO for UTIG based on a combination of acoustic modeling and empirical measurements. Empirical data were obtained by Tolstoy et al. (2004a,b) for sounds from two 105 in^3 GI (generator injector) guns, a 20-airgun array, and various intermediate-sized airgun arrays, including six and ten airgun arrays. The empirical data were collected in the Gulf of Mexico from 27 May to 3 June 2003, with separate measurements in deep and shallow water (Tolstoy et al. 2004a,b).

The rms received levels in the near field around various airgun configurations used by L-DEO have been predicted based on an L-DEO model. Figure E.1 shows the predicted sound field for eight airguns with a combined volume of 2840 in^3, on which the safety radii for the Arctic Ocean study were based.

The sound fields shown in Figure E.1 pertain primarily to deep water, and the model does not allow for bottom interactions.

For mitigation purposes during seismic studies, three strata of water depth are distinguished: shallow (<100 m), intermediate (100–1000 m), and deep (>1000 m). The calibration study showed that sounds from L-DEO's larger airgun sources (i.e., 6–20 airguns) operating in deep water tended to have lower received levels than estimated by the model. In other words, the model tends to overestimate the actual distances at various sound levels in deep water (Tolstoy et al. 2004a,b). Conversely, in shallow water, the model substantially underestimates the actual measured radii for various source configurations ranging from 2 to 20 airguns. More specifically, the primary conclusions of L-DEO's calibration study relevant to this and other recent projects are summarized below, along with comments on how those conclusions were used in estimating radii for the eight airguns used in the *Healy* study:

- Empirical measurements were made in the Gulf of Mexico for two 105 in^3 GI guns operating in shallow water (<100 m). Those data showed that modeled values underestimated actual levels in shallow water at corresponding distances of ~0.5 to 1.5 km by a factor of ~3× (Tolstoy et al. 2004b). Sound level measurements for the two 105 in^3 GI guns were not available for distances <0.5 km from the source. The radii estimated here for a single 210 in^3 G. gun operating in shallow waters are derived from L-DEO's deep water estimates, with the same adjustments for depth-related differences in sound propagation used for 2 GI guns in earlier applications. Thus, the 190 and 180 dB radii in shallow water are assumed to be 20 m and 78 m, respectively, for a single G. guns (LGL Ltd. 2005a,b). UTIG decided not to use the eight airgun array for *Healy* cruise operations in water <100 m deep, so shallow-water safety or disturbance radii were not estimated for the eight airgun array. An array of four GI guns was to be used in shallow water, but no operations were conducted in shallow water.
- Empirical measurements were not conducted for ***intermediate depths*** (100–1000 m). On the expectation that results will be intermediate between those from shallow and deep water, L-DEO has applied a 1.5× correction factor to the estimates provided by the model for deep-water situations for several surveys. This factor that has been applied to the model estimates during L-DEO seismic operations in intermediate-depth water from 2003 through 2005. In a conservative measure, UTIG expanded the safety radius for seismic operations in intermediate-depth water by a factor of 2.2 for the 190 dB level. The safety radius for the 180 dB level was expanded to as far as visible, with 2 km the lowest acceptable visibility during seismic activity. The assumed 190 dB radius in intermediate-depth water was 500 m for the eight airgun system.
- The empirical data indicated that, for ***deep water*** (>1000 m), the L-DEO model tends to overestimate the received sound levels at a given distance (Tolstoy et al. 2004a,b). However, to be precautionary pending acquisition of additional empirical data, the safety radii used during airgun operations in deep water during the 2006 Arctic Ocean survey were the values predicted by L-DEO's modeling of those energy sources (Table 3.2; Figure E.1).

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, Dall's 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. For those taxa, the numbers exposed to ≥170 dB are also estimated.

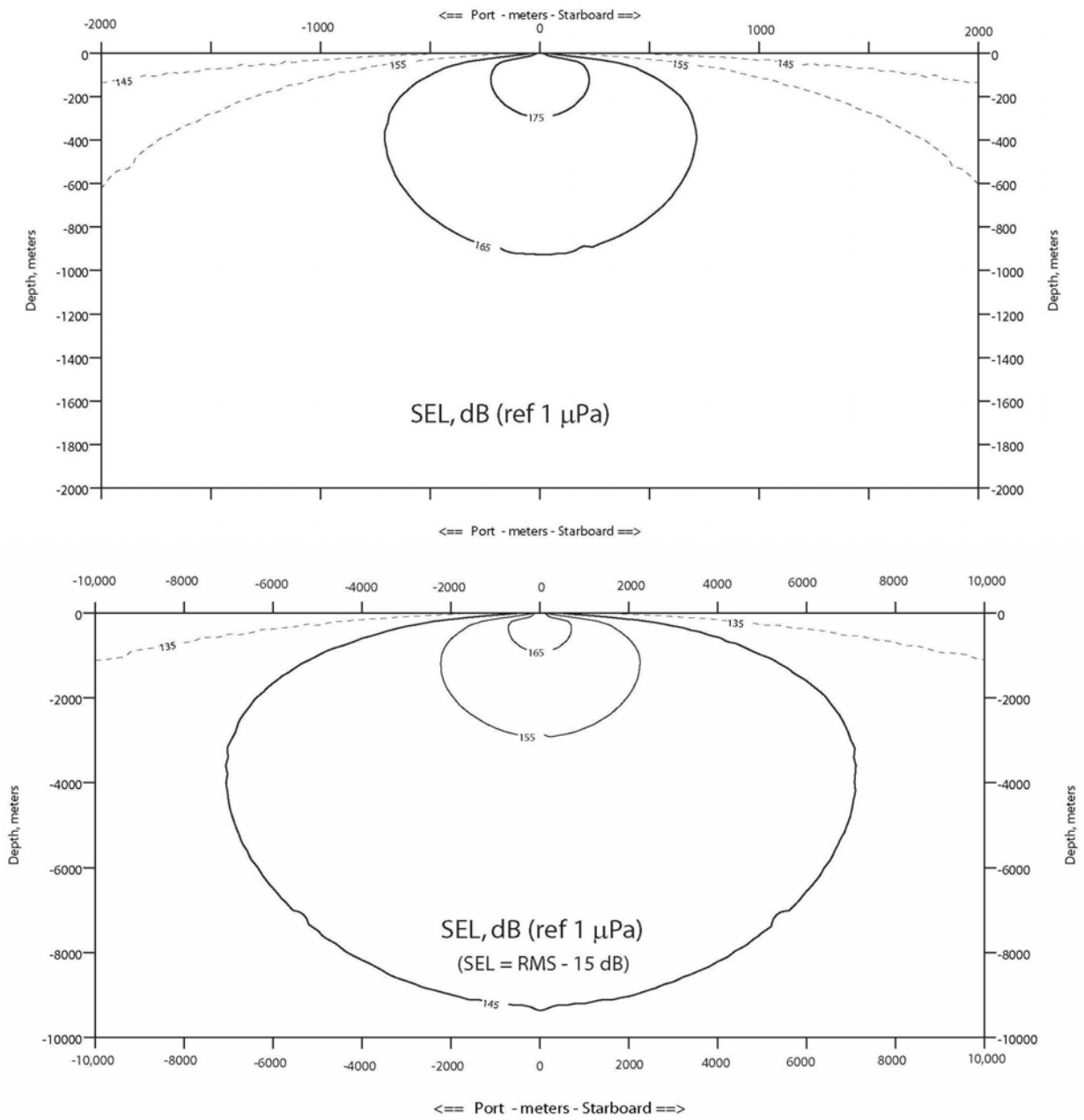


FIGURE E.1. Modeled received sound levels from the eight 2840 in^3 airguns (4 x 500 in^3 Bolt airguns and 4 x 210 in^3 G. guns) that were used during the UTIG survey in the Arctic Ocean during 2006, assuming an operating depth of 9 m. The two graphs depict the same model output plotted for different maximum ranges and depths. The model does not allow for bottom interactions, so is most directly applicable to deep-water situations. Model results are provided by the Lamont-Doherty Earth Observatory of Columbia University.

APPENDIX F:
DESCRIPTION OF USCG CUTTER *HEALY* AND EQUIPMENT USED DURING THE 2006 PROJECT

This appendix provides a detailed description of the standard equipment used during this and previous L-DEO seismic studies aboard the USCG cutter *Healy*.

USCG Cutter Healy *Vessel Specifications*

UTIG used the USCG cutter *Healy* for the seismic study to tow the airguns and hydrophone streamer. 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 (Fig. F 2). 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 operation speed during seismic acquisition was, on average, ~7.4 km/h (4 knots). When not towing seismic survey gear or breaking ice, 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).

Other details of the *Healy* include the following:

Owner:	USCG
Operator:	USCG
Flag:	United States of America
Date Built:	15 November 1997
Gross Tonnage:	16,000 LT
Bathymetric Survey Systems:	SeaBeam 2112 Bottom Mapping Sonar; Odec Bathy 2000; Knudsen 320 B/R Sub-bottom Profilers
Compressors for Airguns:	Portable University ob Bergen Junker compressors; capacity of 10 liters/min at 140 bar
Accommodation Capacity:	138 including ~50 scientists

The *Healy* served as a platform from which vessel-based MMOs watched for marine mammals. The flying bridge and bridge were the best available vantage points on the ship and afforded good visibility for the observers (Fig. F.1). However, visibility immediately astern of the *Healy* from the flying bridge and bridge was restricted because of intervening superstructures (Figs. F.3, F.4). The Aloft Conn offered an unobstructed view for the observers, but was not available while the ship was not underway through ice.

FIGURE F.1. The source vessel, the USCG cutter Healy, showing the locations of the flying bridge and bridge from which visual observations were made by the marine mammal observers.

Bathymetric Sonar and Sub-bottom Profilers

Along with the airgun operations, five additional acoustic systems operated during the cruise. A 12-kHz SeaBeam multibeam bathymetric (MBB) sonar 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. During seismic operations, these sources typically operated simultaneously with the airgun array. An Acoustic Doppler Current Profiler operated constantly as an additional depth sounder, especially when the *Healy* was operating in shallow areas.

Multi-beam Echosounder (SeaBeam 2112)

A SeaBeam 2112 multi-beam 12 kHz bathymetric sonar system was used on the *Healy*, with a source output of 237 dB re 1 µPa at one meter. The transmit frequency was a very narrow band, less than 200 Hz, and centered at 12 kHz. Pulse lengths ranged from less than one millisecond to 12 ms. The transmit interval ranged from 1.5 s to 20 s, depending on the water depth, and was longer in deeper water. The SeaBeam 2112 system consisted of a set of underhull projectors and hydrophones. The transmitted beam was narrow (~2°) in the fore-aft direction but broad (~132°) in the cross-track direction. The system used the signals from an array of receiving hydrophones oriented perpendicular to the array of source transducers, and calculated bathymetric data (sea floor depth and some indications about the character of the seafloor) with an effective two-degree by two-degree foot print on the seafloor. The SeaBeam 2112 system on the *Healy* produced a useable swath width of slightly more than 2 times the water depth. This was narrower than normal because of the ice-protection features incorporated into the system on the *Healy*.

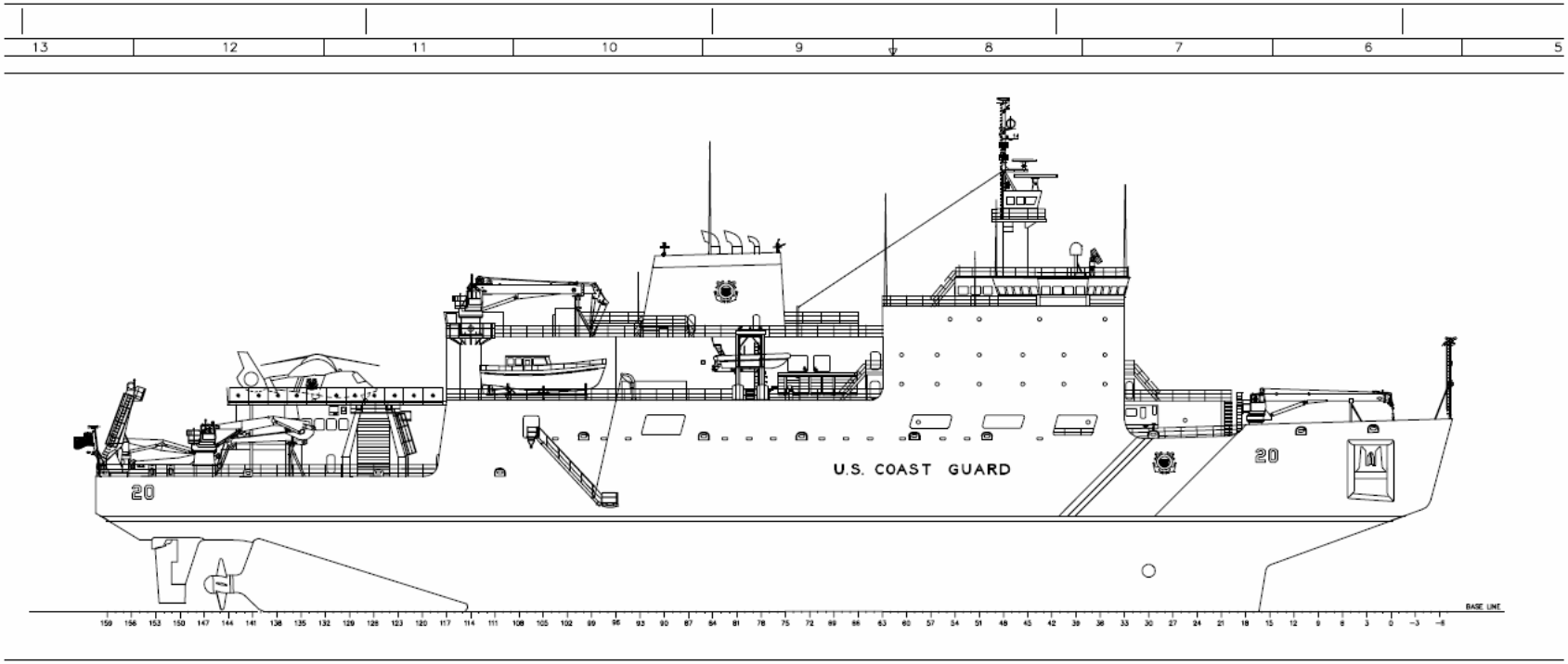


FIGURE F.2. Schematic starboard profile of the USCG cutter *Healy*.

FIGURE F.3. A view looking toward the stern from the starboard side of the flying bridge of the *Healy*, showing the ship structures that partially block the view to the stern.

FIGURE F.4. A view looking toward the stern from the port side of the bridge of the *Healy*, showing the ship structures that partially block the view to the stern.

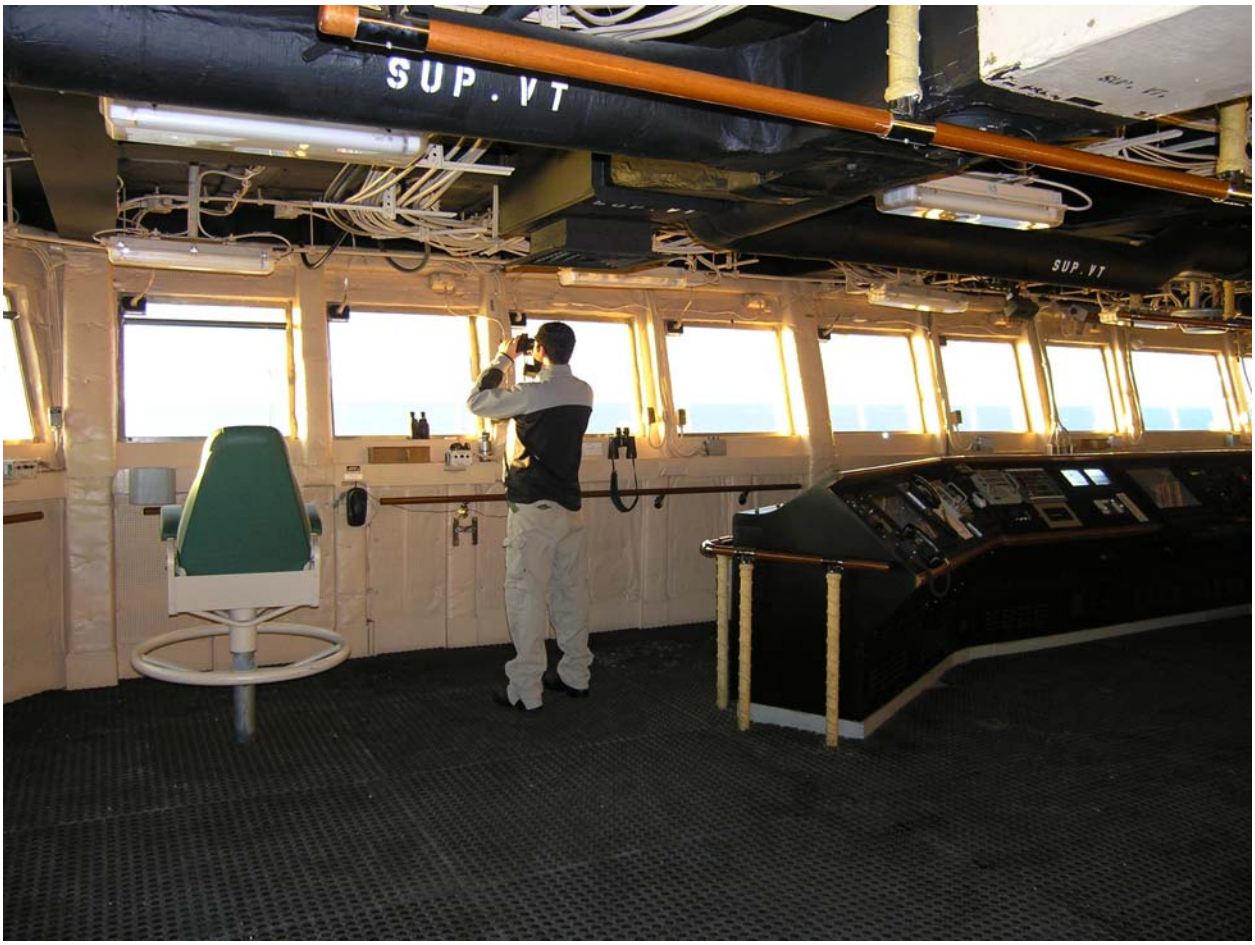


FIGURE F.5. A view of the bridge of the *Healy* showing the visual observer station.

Sub-bottom Profiler (Knudsen 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 bathymetric sonar 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. The Knudsen 320BR was the primary unit used for seafloor sub-bottom mapping and the Bathy 2000 (see below) was used as back-up.

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. This was used for either the Knudsen 320BR or the ODEC Bathy 2000 (see below). The beamwidth propagated by the transducers was the same for both

sonar units. 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°.

Sub-bottom Profiler (ODEC Bathy 2000)

The Ocean Data Equipment Corporation (ODEC) Bathy 2000 provided information on sedimentary layering down to between 20 and 70 m below the bottom, depending on bottom type and slope. The ODEC system had a maximum 7 kW transmitting capacity into the underhull array. Pulse duration ranged from 0.5 to 25 milliseconds and the interval between pulses can range between 0.25 s and 10 s depending upon water depth. The swept (chirp) frequency ranged from 2.75 kHz to 6 kHz. See above for beamwidth information.

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 G:
DETAILS OF MONITORING, MITIGATION, AND ANALYSIS METHODS

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

Four marine mammal observers (MMOs) were aboard the *Healy* throughout the cruise. Three MMOs were biologists experienced in marine mammal identification and observation methods. Those three individuals had served as MMOs during previous NSF-sponsored seismic programs conducted under IHAs issued by NMFS. Résumés detailing their qualifications were provided to NMFS in the past. The fourth MMO was an Inupiat with decades of experience living and hunting in the Arctic.

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 vessel prior to seismic operations. MMO duties included

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

Visual Monitoring Methods

Visual watches took place in the seismic survey area and during transits to and from the study area. In addition to conducting watches during all seismic operations, MMOs also conducted daytime watches on a part-time basis when the source vessel was underway but the airguns were not firing. This included ***(1)*** a short "pre-seismic period" while equipment was being deployed, ***(2)*** periods when the seismic source stopped firing while equipment was being repaired or coring was to take place, and ***(3)*** a short "post-seismic" period.

Visual observations were made from the *Healy's* bridge or flying bridge (Fig. G.1), the most suitable vantage points available on the *Healy*. The observer's eye level was ~21.2 m above sea level on the *Healy's* bridge and 24 m on the flying bridge. Both the bridge and flying bridge afforded a view of ~270º centered on the front of the *Healy*, with obstructions to the stern (Figs. G.3, G.4). When two or more observers were standing watch, one stationed on the port and one on the starboard side of the vessel, the partial obstruction was reduced to some extent. The Aloft Conn provided a 360º view, but even from there, the area ~150 m aft of the stern (within which the airguns were located) was not visible due to the height of the stern. The Aloft Conn was not available to the MMOs while the ship was breaking ice. Other locations toward the stern of the ship were available to MMOs, including the helicopter shack just above the flight deck, and the flight deck. However, from those locations, ~100 m of the sea surface directly off the stern was also not visible.

Watches were conducted throughout all periods of seismic surveys (all in daylight). Darkness was not encountered during the project. Each MMO watched for at least 9 or 10 h per day during full-operation days. Visual watches aboard the *Healy* were usually conducted in 2 h shifts with 1 h breaks. At least 9 hrs were scheduled off watch for sleep. MMO(s) scanned around the vessel, alternating between unaided eyes and

7×50 Fujinon binoculars. Occasionally scans were also made using the 25×150 Big-eye binoculars when MMOs were observing from the flying bridge, to detect animals and to identify species or group size during sightings. Both the Fujinon and Big-eye binoculars were equipped with reticles on the ocular lens to measure depression angles relative to the horizon, an indicator of distance. During the day, at least one and (if possible) two MMOs were on duty. Two observers were on watch during 74% of the watches encompassing the 30-min period just before seismic operations began and during the ensuing ramp ups.

The *Healy* is a participant in NMFS' Platforms of Opportunity program, and her crew regularly records marine mammal sightings and reports them to NMFS. When MMO(s) were not on active duty, the *Healy* bridge personnel watched for marine mammals during their regular watches. The bridge crew had been given instructions on how to fill out specific marine mammal sighting forms to collect pertinent information on sightings when MMOs were not on active duty. The *Healy* crew would have been relied upon for collecting marine mammal sighting data at night (except before and during ramp-ups) if any seismic operations had been conducted during nighttime. In addition to the several marine mammal sources and identification guides available on the bridge, the crew was provided with a copy of the observer instruction manual. Bridge personnel also looked for marine mammals during the day, when MMO(s) were on duty.

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

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

Operational activities that were recorded by MMOs included the number of airguns in use, total volume of the airguns in use, and type of vessel/seismic activity. The position of the vessel was automatically logged every 60 seconds by the *Healy's* navigation system. Those data were copied from the electronic database into the MMO database, using recorded time as the identifier. Specific information regarding the seismic activities (number of guns and volume) was collected from a log that the gunners maintained. Inter-ship communication among the geophysicists, seismic technicians, *Healy* crew Marine Science Technicians and the MMOs was conducted via radio or telephone and used to alert the MMOs to any changes in operations.

TABLE G.1. Summary of data codes used during the July– Aug. 2006 Arctic Ocean seismic survey.

WS	Watch Start
WE	Watch End

OBS. LOCATION

BR	Bridge
FB	Flying bridge
AC	Aloft conn
AFC	Aft conn

LINE

Enter Line ID or leave blank

SEISMIC ACTIVITY

RU	Ramping up
LS	Line Shooting
SH	Shooting Between/Off.Lines
ST	Seismic Testing
PD	Power Down
SZ	Safety Zone Shut-Down
SD	Shut-Down
DP	Deploying equipment
RC	Recovering equipment
OT	Other (comment and describe)

 # GUNS

Enter Number of Operating Airguns,

ARRAY VOLUME

Enter operating volume,

(BEAUFORT) SEA STATE

See Beaufort Scale sheet.

LIGHT OR DARK

L	Light (day)
D	Darkness

GLARE AMOUNT

NO	None
LI	Little
MO	Moderate
SE	Severe

POSITION

Clock Position, or

99	Variable (vessel turning)

WATER DEPTH

In meters

MARINE MAMMAL SPECIES

Baleen Whales

BHW	Bowhead Whale
BLW	Blue Whale
FW	Fin Whale
GW	Gray Whale
SW	Sei Whale
HW	Humpback Whale
MW	Minke Whale
NARW	North Atlantic Right Wh
UMW	Unidentified Mysticete Whale
UW	Unidentified Whale

Large Toothed Whales

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

Dolphins

AWS	Atlantic White-Sided Dolphin
AWBD	Atlantic White-Beaked Dolphin
UD	Unidentified Dolphin

Porpoises

HP	Harbor Porpoise
DP	Dall's Porpoise

Pinnipeds

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

TURTLE SPECIES

LB	Leatherback Turtle

MOVEMENT

PE	Across Bow
ST	Swim Toward
SA	Swim Away
FL	Flee
SP	Swim Parallel
MI	Mill
HO	Hauled Out
WT	Walk Toward
NO	No movement
DE	Dead
UN	Unknown
WP	Walk parallel

INDIVIDUAL BEHAVIOR

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

GROUP BEHAVIOR (BEHAVIORAL STATES)

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

 # RETICLES or ESTIMATE

(of Initial Distance, etc.; Indicate Big-eye or Fujinons or clinometer in comments)

0 to 16	Number of reticles
E	Estimate, by eye
CLINO #	reading of degrees through clinometer

SIGHTING CUE

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

IDENTIFICATION RELIABILITY

MA	Maybe
PR	Probably
PO	Positive

BEHAVIOR PACE

SE	Sedate
MO	Moderate
VI	Vigorous

ACOUSTIC MONITORING

BL	Begin listening
L	Listening
EL	End listening

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

Mitigation

Ramp-up, power-down, and shut-down procedures, which are described briefly in Chapter 3, are described in detail below. These were the primary forms of mitigation implemented during seismic operations

Ramp-up Procedures

A "ramp-up" procedure was implemented at the commencement of seismic operations and anytime after the guns had been shut down for a specified duration. Under normal operating conditions (average vessel speed ~2.6 kt), a ramp up of the airguns was conducted after a shut down longer than 5 min.

The IHA required that, during the daytime, the entire safety radius be visible (i.e., not obscured by fog, etc.), and monitored for 30 min prior to and during ramp up, and that the ramp up could only commence if no marine mammals were detected within the safety radius during this period. Throughout the ramp ups, the safety zone was considered to be that appropriate for the guns operating at full volume in the water depth occurring at the time. Ramp up was to be suspended if marine mammals were detected within the safety radius. Ramp up of the airguns was not permitted at night given the provisions of the IHA, i.e., no powering up unless the entire safety zone was visible. However, during this high-latitude cruise, there was no night (darkness) during the cruise.

Power-down and Shut-down Procedures

Airgun operations were immediately shut down or powered down to one G. gun (210 in^3), i.e., from 2840 in^3, when one or more marine mammals were detected within, or judged about to enter, the appropriate safety radius (see Table 3.2 in Chapter 3).

The power-down procedure was to be accomplished within several seconds (or a "one-shot" period) of the determination that a marine mammal was within or about to enter the safety radius. Full airgun operations were not to resume until the animal was outside the safety radius, or had not been seen for a specified amount of time (15 min for dolphins and pinnipeds, and 30 min for whales). Once the safety radius was judged to be clear of marine mammals based on those criteria, the MMOs advised the airgun operators and full-volume operations resumed.

In contrast to a power down, a shut down refers to the complete cessation of firing by all airguns. If a marine mammal was seen within the designated safety radius applicable to powered-down airguns during either full seismic operations or during a power down, a complete shut down was necessary. The shut-down procedure was to be accomplished within several seconds (or a "one-shot" period) of the determination that a marine mammal was within or about to enter the safety radius. Seismic operations were not to resume until the animal was outside the safety radius, or had not been seen for a specified amount of time (15 min for dolphins and 30 min for whales). Once the safety radius was judged to be clear of marine mammals based on those criteria, the MMO advised the gun operators that seismic surveys could re-commence, and ramp up was initiated. Shut downs were implemented in error five times during the 2006 Arctic Ocean survey. A power down would have sufficed in each case because the animals

observed were not within the safety radius of a power down. The lead MMO did not realize this until the last day of operations.

The MMOs were stationed on the flying bridge or bridge about 100 m ahead of the closest airgun in the array; the closest airgun was located ~5 m aft of the *Healy's* stern. The decision to initiate a power down or shut down was based on the distance of the marine mammal from the observers rather than from the airguns, unless the animals were sighted closer to the airguns than to the observers. This was another precautionary measure, given that most sightings were ahead of the vessel.

Analyses

This section describes the analyses of the marine mammal sightings and survey effort as documented during the cruise. It also describes the methods used to calculate densities and estimate the number of marine mammals potentially exposed to seismic sounds associated with the seismic survey. Sightings of marine mammals hauled out on the ice were included with sightings of marine mammals in the water for the density estimates from previous surveys. To calculate exposures based on densities from earlier studies, all the animals calculated in the density estimates were assumed to be in the water. Only marine mammals observed in the water were included in the estimates of animals exposed to seismic pulses, based on densities estimated from the 2006 *Healy* survey data. The analysis categories that were used were identified in Chapter 3. The primary analysis categories used to assess potential effects of seismic sounds on marine mammals were the "seismic" (airguns operating with shots at <3 min spacing) and "non-seismic" categories (periods before seismic started or >2 h after airguns were turned off). The analyses excluded the "post-seismic" period 3 min to 2 h after the airguns were turned off. The justification for the selection of these criteria is based on the size of the array in use and is provided below. These criteria were discussed in earlier L-DEO cruise reports to NMFS (see Haley and Koski 2004; Smultea et al. 2004, 2005; MacLean and Koski 2005; Holst et al. 2005a,b; Haley and Ireland 2006):

- The period up to 3 min after the last seismic shot is ~9× the normal shot interval. Mammal distribution and behavior during that short period are assumed to be similar to those while seismic surveying is ongoing.
- It is likely that any marine mammals near the vessel between 3 min and 30 min after the cessation of seismic activities would have been "recently exposed" (i.e., within the past 30 min) to sounds from the seismic survey. During at least a part of that period, the distribution and perhaps behavior of the marine mammals may still be influenced by the (previous) sounds.
- For some unknown part of the period from 30 min to 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 2 h after the cessation of seismic operations, the distribution and behavior of marine mammals would be expected to be indistinguishable from "normal" because of (a) waning of responses to past seismic activity, (b) re-distribution of mobile animals, and (c) movement of the ship and thus the MMOs. Given those considerations, plus the limited observed responses of most marine mammals to seismic surveys (e.g., Stone 2003; Smultea et al. 2004; Haley and Koski 2004; MacLean and Koski 2005; Holst et al. 2005a,b, Haley and Ireland 2006), it is unlikely that the distribution or behavior of marine mammals near the vessel >2 h post-seismic would be appreciably different from "normal" even if they had been exposed to seismic sounds earlier. This is especially true for pinnipeds which have shown very little response to seismic activities during past studies (Harris et

al. 2001, Miller et al. 2005). Therefore, we consider animals seen >2 h after cessation of seismic operations to be unaffected by the (previous) seismic sounds.

As summarized in Chapter 3, marine mammal density was one of the parameters examined to assess differences in the distribution of marine mammals relative to the seismic vessel between seismic and non-seismic periods. Two different density values were used. We calculated densities (with caution, given the fact that ice could have bound sightability of animals in the water) using sighting data from this survey. To allow for animals missed during daylight, we corrected our visual observations for missed marine mammals by using an approximate correction factor derived from previous studies. (It was not practical to derive study-specific correction factors during a survey of this type and duration.) It is recognized that the most appropriate correction factors will depend on specific observation procedures during different studies, ship speed, and other variables. Thus, use of correction factors derived from other studies is not ideal, but it provides more realistic estimates of numbers present than could be obtained without the use of correction factors at all. We also used density values from previous surveys in the pack ice and in the Beaufort Sea (Kingsley 1986), most of which were corrected.

The formulas for calculating densities using this procedure were briefly described in Chapter 3 and are described in more detail below. Densities from the 2006 *Healy* sighting data were corrected for the following parameter before they were further analyzed: g(0), a measure of detection bias. This factor allows for the fact that less than 100% of the animals present along a trackline are detected. $F(0)$, another standard correction factor for trackline data, was not used to adjust the 2006 *Healy* trackline data. $F(0)$ modifies the data in consideration of the reduced probability of detecting an animal with increasing distance from a trackline. The correction factor for $f(0)$ was not included in the density estimates because of the unpredictable variability of the surveyed swath during the *Healy* survey, due to changeable ice conditions. Although the $f(0)$ correction was not applied to the sightings during this cruise, most animals within the narrow band of open water adjacent to the ship would have been detected at a probability near the trackline detection probability. Therefore, failure to account for lateral fall off in sighting detection would not have resulted in underestimating densities. Based on *Healy* 2006 sighting data, densities during the seismic and non-seismic periods [corrected by $g(0)$] were 0.157 and 0.243 animals/km^2, respectively. The densities from previous studies that we applied to calculate exposures factored in both $g(0)$ and $f(0)$ (Appendix K).

The $g(0)$ and $f(0)$ factors used in this study were taken from results of previous work, not from observations made during this study. Sighting rates during the present study were either too small or, at most, marginal to provide meaningful data on $f(0)$ based on group size. Further, this type of project cannot provide data on $g(0)$. Estimates of these correction factors were derived from Martin and Smith (1992), Koski et al. (1998), Harwood et al. (1996), Barlow (1999), Thomas et al. (2002), and Heide-Jørgensen et al., for corresponding species and Bf. Marine mammal sightings were subjected to species-specific truncation criteria obtained from the above studies.

Number of Exposures — Estimates of the numbers of potential *exposures* of marine mammals to sound levels ≥160 dB re 1 µPa (rms) were calculated by multiplying the total area of open water ensonified to that degree, by the density of marine mammals in open water estimated by survey data; a second estimate of potential exposures was calculated by multiplying densities published from earlier surveys by the area ensonified. We calculated the area of open water based on ice cover observations. We excluded the area with ice cover when we applied the densities derived from the 2006 *Healy* project because we based those densities on sightings of mammals in the water, exclusively. The density estimates from earlier surveys include all marine mammals, in the water or on ice. The exposure estimates assume that the numbers of animals

estimated from those densities are all in the water. The area of water ensonified was calculated using MapInfo Geographic Information System (GIS) software to create a "buffer" that extended on both sides of the vessel's trackline to the predicted 160-dB radius. Because the 160-dB radius varied with the water depth, the width of the buffer also varied with water depth (Table 3.1). The buffer included areas that were exposed to airgun sounds ≥160 dB one or more times (as a result of crossing tracklines or tracklines that were close enough for their 160 dB zones to overlap). Areas of water ensonified on more than one occasion, due to overlapping tracklines, were repeatedly counted in the area calculation as many times as they were ensonified. "Corrected" densities of marine mammals were estimated as described in the above section.

TABLE G.2. The areas (km^2) potentially ensonified to various levels by the airguns operating in two water depth strata within the study area north of 75°N, considered to be the pack ice, (intermediate depths, 100–1000 m, and deep, >1000 m) during seismic periods of the Arctic Ocean cruise, 19 July–23 Aug. 2006. ***(A)*** Maximum area ensonified, with overlapping areas counted multiple times. ***(B)*** Total area ensonified at least once, with overlapping areas counted only once. No seismic activities were conducted in water <100 m deep, north of 75°N.

	Water Depth 100 - 1000 m				Water Depth >1000 m				
Area (km^2)	160 dB	170 dB	180 dB	190 dB	160 dB	170 dB	180 dB	190 dB	Total
A. Including Overlap Area	3866	1048	282	80	3608	858	241	73	10057
B. Excluding Overlap Area	3685	1063	281	80	3459	851	241	73	9733

TABLE G.3. The areas (km^2) potentially ensonified to various levels by a single 210 in^3 G. gun operating in shallow (<100 m) water depth within the study area south of 75°N, considered to be the pack ice margin area, during seismic periods of the Arctic Ocean cruise, 19 July–23 Aug. 2006. ***(A)*** Maximum area ensonified, with overlapping areas counted multiple times. ***(B)*** Total area ensonified at least once, with overlapping areas counted only once. No seismic activities were conducted in water >100 m deep, south of 75°N.

	Water Depth <100 m				
Area (km^2)	160 dB	170 dB	180 dB	190 dB	Total
A. Including Overlap Area	19.2	6.5	3.4	1.2	30.3
B. Excluding Overlap Area	19.2	6.5	3.4	1.2	30.3

TABLE G.4. The areas of open water (km^2) potentially ensonified to various levels by the airguns operating in three water depth strata within the study area (shallow depths, <100 m, intermediate, 100–1000 m, and deep, >1000 m). The only seismic activity in shallow water was the testing of a single 210 in^3 G. gun during the Arctic Ocean cruise, 19 July–23 Aug. 2006. All other seismic operations occurred in intermediate to deep water. All estimates include overlap area.

	Water depth <100 m				Water depth 100 - 1000 m				Water depth >1000 m				
Area (km^2)	160 dB	170 dB	180 dB	190 dB	160 dB	170 dB	180 dB	190 dB	160 dB	170 dB	180 dB	190 dB	Total
	13.5	4.6	2.4	0.9	1046.8	220.3	58.9	16.8	847.8	202.6	57.6	17.6	2489.8

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

- number of kilometers of seismic survey,
- width around trackline ensonified to ≥160 dB re 1 µPa (rms) including *repeated counts* of areas ensonified on more than on occasion (both total area and open water area), and
- observed densities of marine mammals – "corrected" as summarized above. Two sets of densities were used, densities from earlier surveys and densities derived from trackline sighting data.
- This value provides a maximum estimate of the number of exposures to sound levels ≥160 dB re 1 µPa (rms) if marine mammals did not show avoidance reactions.

Number of Individuals Exposed — The method described above likely overestimates the number of different *individual* marine mammals exposed to airgun sounds at received levels ≥160 dB. To provide an estimate of individuals exposed, using density from previous surveys, the same calculation described above was performed, except that areas ensonified to ≥160 dB on more than one occasion, due to overlapping tracklines, were counted only once. In this project, involving mainly a linear trackline, the amount of overlap was slight, but for consistency with earlier projects, the following procedure was applied nonetheless. Number of individuals exposed was not calculated using the project open-water sighting data, because ice cover variation confounded the exclusion of ensonified areas that overlapped. The application of ice cover data to estimate the area of ensonified open water reduced the total area ensonified appreciably (Tables G.2 and 4).

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

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

The area of water considered ensonified in this calculation is therefore smaller than in the first calculation. During this cruise, the estimated number of individuals exposed is similar to the estimated number of exposure incidents because seismic lines were not closely spaced and therefore little overlap of ensonified areas occurred (see Fig. 4.1). The calculated number of different individual marine mammals

exposed to ≥160 dB re 1 µPa (rms) is considered a minimum estimate because it does not account for the movement of marine mammals during the course of the study.

The process outlined above was repeated for pinnipeds and delphinids, assuming that for those animals, the estimated 170 dB radius (see Table 3.1) was a more realistic estimate of the maximum distance at which significant disturbance would occur. That radius was used to estimate both the number of exposures and the number of individuals exposed to seismic sounds with received levels ≥170 dB re 1 µPa (rms). The process was also repeated for all cetacean species based on the estimated 180-db radius. That was done to estimate the numbers of animals that would have been subjected to sounds with received levels ≥180 dB re 1 µPa (rms) if they had not altered their course to avoid those sound levels (or the ship).

APPENDIX H:
BACKGROUND ON MARINE MAMMALS IN THE 2006 ARCTIC OCEAN PROJECT REGION

TABLE H.1. The habitat, abundance, and conservation status of marine mammals inhabiting the 2006 Arctic Ocean survey area.

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

[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] Total Western Alaska population, including Beaufort Sea animals that occur there in winter (Small and DeMaster 1995).

[5] Beaufort Sea population (IWC 2000).

[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] North Pacific gray whale population (Rugh 2003 *in* Keller and Gerber 2004).

[10] Pacific walrus population (USFWS 2000a).

[11] Alaska population (USDI/MMS 1996).

[12] Eastern Chukchi Sea population (NMML, unpublished data).

[13] Alaska Beaufort Sea population (USDI, MMS 1996).

[14] Alaska estimate (Frost et al. 1988 *in* Angliss and Lodge 2004).

[15] Bering/Chukchi Sea population (Bengston et al. 2000).

[16] Alaskan Beaufort Sea population estimate (Amstrup 1995).

[17] Amstrup et al (2001).

[18] NWT Wildlife and Fisheries, http://www.nwtwildlife.rwed.gov.nt.ca/Publications/speciesatriskweb/polarbear.htm

APPENDIX I:
VISUAL MONITORING EFFORT AND DETECTIONS

TABLE I.1. All and useable[a] visual observation effort from the *Healy* within the Arctic Ocean survey area, 19 July–23 Aug. 2006, in ***(A)*** hours, and ***(B)*** kilometers, subdivided by water depth and airgun status. Ramp-up effort is included in the "Seismic" category.

	All Effort			Useable[a] Effort		
Water Depth (m)	<100	100-1000	>1000	<100	100-1000	>1000
(A) Effort in h						
Non-Seismic	48	98	212	19	52	87
Post Seismic	-	1	1	-	-	-
Seismic	1[b]	34	40	1[b]	31	30
Total	**49**	**133**	**253**	**18**	**83**	**117**
(B) Effort in km						
Non-Seismic	269	570	1732	168	468	855
Post Seismic	1	2	1	-	-	-
Seismic	2	143	192	2	132	137
Total	**272**	**715**	**1925**	**170**	**600**	**992**

[a] Includes only useable visual effort as defined in *Acronyms and Abbreviations.*
[b]value <1

TABLE I.2. All and useable[a] visual observation effort from the *Healy* within the Arctic Ocean study area, 19 July–23 Aug. 2006, in ***(A)*** hours, and ***(B)*** kilometers, subdivided by Beaufort Wind Force (Bf) and airgun status. Ramp-up effort is included in the "Seismic" category.

	All Effort						Useable[a] Effort				
Beaufort Wind Force	0	1	2	3	4	*Total*	0	1	2	3	*Total*
(A) Effort in h											
Non-Seismic	145	133	55	25	1	*359*	56	64	26	11	*157*
Post Seismic	1[b]	1[b]	-	-	-	*2*	-	-	-	-	-
Seismic	26	31	18	3	-	*78*	22	19	17	3	*61*
Total	**171**	**164**	**73**	**28**	**1**	**437**	**78**	**83**	**43**	**14**	**218**
(B) Effort in km											
Non-Seismic	941	1076	415	138	2	*2572*	509	640	247	95	*1491*
Post Seismic	2	1	-	1	-	*4*	-	-	-	-	-
Seismic	113	136	77	12	-	*338*	100	85	75	12	*272*
Total	**1056**	**1212**	**492**	**151**	**2**	**2914**	**609**	**725**	**322**	**107**	**1763**

[a] Includes only useable visual effort as defined in *Acronyms and Abbreviations.*
[b]value <1

TABLE I.3. Sightings of marine mammals made from the USCG cutter *Healy* along the survey trackline 19 Jul. - 28 Aug. 2006. All marine mammal observations were visual.

Species	Useable (Y) or Non-Useable (N)[a]	Grp Size	Day in 2005	Time (GMT)	Latitude (°N)	Longitude (-=°W +=°E)	Initial Sighting Distance (m) from observer	CPA[b] Distance from G. Guns (m)	Initial Move-ment[c]	Initial Behav.[d]	Bf[e]	Water Depth (m)	Vessel Activ.[f]	Air-gun Vol. (in^3)[g]	Mitig. (SZ, PD, None)[h]
Unidentified Seal	Y	1	23-Jul	22:52	71.6027	-154.3442	120	212	UN	SI	1	<100	OT	0	None
Unidentified Seal	Y	1	23-Jul	23:50	71.5333	-154.1513	100	193	UN	SI	1	<100	OT	0	None
Bearded Seal	N	1	24-Jul	00:17	71.5233	-154.1840	750	850	PE	SW	1	<100	OT	0	None
Unidentified Seal	Y	1	24-Jul	04:14	71.5078	-154.4418	120	212	ST	SW	1	<100	OT	0	None
Ringed Seal	Y	1	24-Jul	04:17	71.5105	-154.4420	109	181	SP	SW	1	<100	OT	0	None
Unidentified Seal	Y	1	24-Jul	04:45	71.5165	-154.4982	150	218	ST	SW	1	<100	OT	0	None
Ringed Seal	N	1	24-Jul	09:29	71.5243	-154.4077	250	312	SA	LO	1	<100	OT	0	None
Ringed Seal	N	1	25-Jul	07:00	71.5188	-154.4687	150	242	SA	SW	2	<100	OT	0	None
Unidentified Seal	Y	1	25-Jul	09:19	71.5185	-154.4490	109	181	NO	LO	3	<100	OT	0	None
Bearded Seal	Y	1	25-Jul	09:52	71.5155	-154.5830	1240	579	HO	RE	2	<100	OT	0	None
Unidentified Seal	N	1	25-Jul	18:14	71.5353	-154.4738	79	173	UN	LG	2	<100	OT	0	None
Ringed Seal	Y	1	25-Jul	23:51	71.5572	-154.5208	242	226	PE	SA	3	<100	OT	0	None
Ringed Seal	N	1	26-Jul	03:10	71.5518	-154.6696	100	173	HO	LO	3	<100	OT	0	None
Ringed Seal	Y	1	26-Jul	06:03	71.5842	-154.6032	322	337	SP	LO	3	<100	OT	0	None
Bearded Seal	Y	1	26-Jul	06:21	71.5907	-154.5180	400	458	ST	DI	3	<100	OT	0	None
Ringed Seal	Y	1	26-Jul	07:11	71.5910	-154.3292	200	291	SA	SW	1	<100	OT	0	None
Ringed Seal	Y	1	26-Jul	14:23	71.9390	-153.1732	500	589	HO	LO	0	>1000	OT	0	None
Ringed Seal	Y	1	26-Jul	20:53	72.3717	-152.8687	339	217	SA	LO	0	>1000	OT	0	None
Ringed Seal	Y	1	26-Jul	21:50	72.4292	-152.9123	171	270	NO	LG	0	>1000	OT	0	None
Unidentified Seal	Y	1	26-Jul	22:43	72.4895	-152. 9110	607	707	NO	LG	0	>1000	OT	0	None
Bearded Seal	Y	1	26-Jul	23:29	72.5398	-152.9192	724	507	HO	LO	0	>1000	OT	0	None
Bearded Seal	Y	1	26-Jul	23:50	72.5567	-152.9048	510	507	HO	LO	0	>1000	OT	0	None
Unidentified Seal	Y	1	27-Jul	00:17	72.6003	-152.9218	1448	1535	HO	UN	0	>1000	OT	0	None
Unidentified Seal	N	2	27-Jul	00:27	72.6055	-152.9222	668	635	HO	RE	0	>1000	OT	0	None
Unidentified Seal	Y	1	27-Jul	00:27	72.6055	-152.9222	668	756	MI	LO	0	>1000	OT	0	None
Unidentified Seal	Y	1	27-Jul	00:59	72.6300	-152.9283	150	242	ST	SW	0	>1000	OT	0	None
Polar Bear	Y	2	27-Jul	06:31	73.0850	-152.9285	3000	1138	WA	LO	0	>1000	OT	0	None
Unidentified Seal	N	1	27-Jul	20:25	74.1950	-153.0412	202	266	HO	RE	1	>1000	OT	0	None
Unidentified Seal	N	1	29-Jul	02:00	76.8667	-152.1828	8801	8851	HO	RE	0	>1000	OT	0	None
Unidentified Seal	Y	1	29-Jul	02:15	76.8793	-152.3258	3697	3796	HO	SI	0	>1000	OT	0	None

TABLE I.3. (continued).

Species	Useable (Y) or Non-Useable (N)[a]	Grp Size	Day in 2005	Time (GMT)	Latitude (°N)	Longitude (-=°W +=°E)	Initial Sighting Distance (m) from observer	CPA[b] Distance from G. Guns (m)	Initial Move-ment[c]	Initial Behav.[d]	Bf[e]	Water Depth (m)	Vessel Activ.[f]	Air-gun Vol. (in^3)[g]	Mitig. (SZ, PD, None)[h]
Unidentified Seal	N	1	29-Jul	02:25	76.8887	-152.4143	3337	3387	HO	RE	0	>1000	OT	0	None
Unidentified Seal	Y	1	29-Jul	03:45	76.9492	-153.0420	1240	1053	HO	RE	0	>1000	OT	0	None
Unidentified Seal	Y	2	29-Jul	03:46	76.9497	-153.0480	579	667	HO	RE	0	>1000	OT	0	None
Ringed Seal	Y	1	29-Jul	05:38	77.0003	-153.4895	400	438	HO	LO	0	>1000	OT	0	None
Ringed Seal	Y	10	29-Jul	05:57	77.0058	-153.5408	5000	380	HO	RE	0	>1000	OT	0	None
Unidentified Seal	Y	1	29-Jul	06:02	77.0045	-153.5247	2183	2234	HO	RE	0	>1000	OT	0	None
Unidentified Seal	N	2	29-Jul	06:47	77.0168	-153.6112	4552	4652	HO	RE	0	>1000	OT	0	None
Unidentified Seal	N	1	29-Jul	06:54	77.0170	-153.6093	4552	4603	HO	RE	0	>1000	OT	0	None
Ringed Seal	N	1	29-Jul	16:36	77.0037	-153.0030	607	557	HO	RE	0	>1000	OT	0	None
Ringed Seal	N	1	29-Jul	18:23	76.9560	-152.3038	242	209	MI	LO	0	>1000	OT	0	None
Ringed Seal	N	1	01-Aug	23:58	77.1770	-155.0665	151	251	MI	LO	1	>1000	RC	0	None
Ringed Seal	Y	1	02-Aug	17:21	77.0578	-154.1235	60	125	MI	LO	1	>1000	OT	0	None
Ringed Seal	N	1	02-Aug	22:01	76.8813	-152.4775	1708	1759	HO	NO	1	>1000	OT	0	None
Ringed Seal	N	1	04-Aug	12:30	77.1750	-155.4490	600	340	HO	RE	1	>1000	OT	0	None
Unidentified Seal	N	1	04-Aug	12:38	77.1737	-155.5220	900	688	HO	RE	1	>1000	OT	0	None
Ringed Seal	Y	1	05-Aug	10:13	77.6090	-159.0910	400	269	SP	SW	0	100-1000	OT	0	None
Unidentified Seal	Y	1	05-Aug	13:27	77.6983	-160.3668	1946	2045	HO	LO	0	>1000	OT	0	None
Unidentified Seal	N	1	05-Aug	13:44	77.7088	-160.4230	1191	1243	HO	RE	0	>1000	OT	0	None
Bearded Seal	N	1	05-Aug	13:47	77.7113	-160.4360	4150	4200	HO	RE	0	>1000	OT	0	None
Ringed Seal	N	1	05-Aug	13:55	77.7167	-160.4535	516	525	HO	RE	0	>1000	OT	0	None
Ringed Seal	N	1	06-Aug	01:03	77.8527	-161.3727	60	115	MI	SW	o	>1000	OT	0	None
Ringed Seal	Y	1	06-Aug	09:32	77.8048	-161.3063	195	285	PE	SW	1	>1000	OT	0	None
Unidentified Seal	Y	1	06-Aug	18:32	77.9123	-163.4755	2937	2988	HO	UN	0	100-1000	OT	0	None
Polar Bear	Y	4	06-Aug	20:00	77.9350	-163.9440	1448	1379	HO	NO	0	100-1000	OT	0	None
Unidentified Seal	Y	1	06-Aug	20:23	77.9365	-163.9767	1367	1428	MI	SW	0	100-1000	OT	0	None
Ringed Seal	Y	1	06-Aug	21:17	77.9528	-164.2865	1085	723	HO	LO	0	100-1000	OT	0	None
Ringed Seal	Y	1	06-Aug	22:22	77.9667	-164.5778	790	878	HO	RE	0	100-1000	OT	0	None
Unidentified Seal	N	1	06-Aug	22:30	77.9692	-164.6352	4552	3037	HO	RE	0	100-1000	OT	0	None
Unidentified Seal	Y	1	07-Aug	00:32	78.0127	-165.4553	378	223	MI	SW	0	100-1000	OT	0	None
Ringed Seal	Y	1	07-Aug	02:16	78.0347	-166.1395	150	218	SA	LO	0	100-1000	OT	0	None

TABLE I.3. (continued).

Species	Useable (Y) or Non-Useable (N)[a]	Grp Size	Day in 2005	Time (GMT)	Latitude (°N)	Longitude (-=°W +=°E)	Initial Sighting Distance (m) from observer	CPA[b] Distance from G. Guns (m)	Initial Move-ment[c]	Initial Behav.[d]	Bf[e]	Water Depth (m)	Vessel Activ.[f]	Air-guns Vol. (in^3)[g]	Mitig. (SZ, PD, None)[h]
Ringed Seal	Y	1	07-Aug	02:27	78.0378	-166.2278	1500	1600	HO	RE	0	100-1000	OT	0	None
Unidentified Seal	Y	2	07-Aug	02:32	78.0390	-166.2732	2500	364	HO	RE	0	100-1000	OT	0	None
Ringed Seal	Y	1	07-Aug	02:40	78.0410	-166.3268	3337	2552	HO	RE	0	100-1000	OT	0	None
Unidentified Seal	Y	1	07-Aug	02:47	78.0423	-166.3510	3042	3141	HO	RE	0	100-1000	OT	0	None
Unidentified Seal	Y	1	07-Aug	02:50	78.0435	-166.3615	3337	3387	HO	RE	0	100-1000	OT	0	None
Unidentified Seal	N	1	07-Aug	03:10	78.0440	-166.3642	6738	6738	HO	RE	0	100-1000	OT	0	None
Unidentified Seal	Y	1	07-Aug	06:29	78.0658	-167.1053	3337	3387	HO	RE	0	100-1000	OT	0	None
Unidentified Seal	Y	2	07-Aug	06:47	78.0715	-167.2540	2589	584	HO	RE	0	100-1000	OT	0	None
Unidentified Seal	Y	1	07-Aug	06:59	78.0762	-167.3403	3697	1977	HO	RE	0	100-1000	OT	0	None
Unidentified Seal	Y	1	07-Aug	07:03	78.0777	-167.3753	4739	1285	HO	RE	0	100-1000	OT	0	None
Unidentified Seal	N	1	07-Aug	07:12	78.0827	-167.4425	4150	4200	HO	RE	0	100-1000	OT	0	None
Unidentified Seal	Y	1	07-Aug	07:51	78.0960	-167.7725	2589	2688	HO	RE	0	100-1000	OT	0	None
Unidentified Seal	Y	1	07-Aug	10:50	78.0865	-167.4695	511	600	NO	LO	0	100-1000	LS	1340	None
Ringed Seal	Y	1	07-Aug	11:11	78.0857	-167.4268	579	567	ST	SW	0	100-1000	LS	1340	None
Unidentified Seal	Y	1	08-Aug	03:10	78.0495	-166.2957	2583	2634	HO	RE	0	100-1000	LS	1840	None
Unidentified Seal	Y	2	08-Aug	03:49	78.0468	-166.2212	3337	2185	HO	RE	0	100-1000	LS	1840	None
Unidentified Seal	Y	1	08-Aug	20:56	78.0047	-165.6875	1448	110	HO	RE	1	100-1000	LS	99	None
Ringed Seal	Y	1	08-Aug	23:51	77.9853	-165.1812	579	264	HO	RE	1	100-1000	LS	840	SZ
Unidentified Seal	Y	1	09-Aug	04:33	77.9572	-163.7800	1392	1479	HO	RE	1	100-1000	OT	0	None
Ringed Seal	Y	1	09-Aug	06:33	77.9127	-162.9372	1240	1173	HO	RE	1	100-1000	OT	0	None
Unidentified Seal	Y	1	09-Aug	06:53	77.9073	-162.7905	1085	1138	HO	RE	1	100-1000	OT	0	None
Unidentified Seal	Y	1	10-Aug	04:53	77.8810	-163.0918	1085	1138	HO	RE	2	100-1000	LS	1840	None
Unidentified Seal	Y	1	10-Aug	08:02	77.8938	-163.5967	1740	1340	HO	RE	2	100-1000	LS	1340	None
Unidentified Seal	Y	1	12-Aug	02:02	78.1135	-175.6940	2937	3037	HO	RE	1	>1000	OT	0	None
Bearded Seal	Y	1	12-Aug	02:17	78.1075	-175.7998	2183	2270	MI	SW	1	>1000	OT	0	None
Unidentified Seal	Y	1	12-Aug	02:19	78.1075	-175.8288	4552	4639	HO	RE	1	>1000	OT	0	None
Unidentified Seal	Y	1	12-Aug	02:59	78.1180	-176.0718	4000	3287	HO	RE	1	>1000	OT	0	None
Unidentified Seal	Y	1	12-Aug	06:17	78.1327	-177.2972	1500	1587	MI	LO	1	>1000	OT	0	None
Ringed Seal	Y	1	12-Aug	09:03	78.1812	-178.0377	1740	426	HO	RE	1	>1000	OT	0	None

TABLE I.3. (continued).

Species	Useable (Y) or Non-Useable (N)[a]	Grp Size	Day in 2005	Time (GMT)	Latitude (°N)	Longitude (-=°W +=°E)	Initial Sighting Distance (m) from observer	CPA[b] Distance from G. Guns (m)	Initial Move-ment[c]	Initial Behav.[d]	Bf[e]	Water Depth (m)	Vessel Activ.[f]	Air-guns Vol. (in^3)[g]	Mitig. (SZ, PD, None)[h]
Unidentified Seal	Y	1	12-Aug	09:58	78.2530	-177.9273	200	220	ST	OT	1	>1000	OT	0	None
Unidentified Seal	Y	1	12-Aug	11:31	78.3723	-177.7603	3200	3251	HO	LO	1	>1000	OT	0	None
Ringed Seal	Y	1	12-Aug	17:29	78.6563	-176.1552	414	514	MI	SW	1	>1000	OT	0	None
Ringed Seal	Y	1	12-Aug	20:00	78.8125	-175.4197	378	467	MI	SW	1	>1000	OT	0	None
Ringed Seal	Y	1	12-Aug	20:59	78.8960	-175.1455	120	191	MI	FD	1	>1000	OT	0	None
Unidentified Seal	Y	1	12-Aug	21:30	78.9537	-175.1177	435	524	SA	SW	1	>1000	OT	0	None
Bearded Seal	Y	1	12-Aug	21:35	78.9625	-175.1232	965	1053	HO	RE	1	>1000	OT	0	None
Unidentified seal	N	1	13-Aug	00:32	79.0600	-175.4200	134	203	SA	SW	1	>1000	OT	0	None
Unidentified seal	Y	1	13-Aug	9:52	79.0415	-176.9373	3500	3551	HO	RE	1	>1000	OT	0	None
Unidentified seal	N	2	13-Aug	10:07	79.0370	-177.0322	4552	4603	HO	RE	1	>1000	OT	0	None
Ringed seal	N	1	14-Aug	02:08	78.3453	-176.8442	7	93	ST	MI	3	100-1000	OT	0	None
Polar Bear	Y	3	14-Aug	17:10	77.7030	-177.4360	1740	796	WP	OT	2	100-1000	OT	0	None
Ringed Seal	Y	1	14-Aug	19:43	77.5398	-177.5785	62	157	UN	DI	2	100-1000	OT	0	None
Ringed Seal	Y	1	14-Aug	23:39	77.2668	-177.7988	120	212	SA	SW	2	>1000	OT	0	None
Ringed Seal	Y	1	15-Aug	09:42	76.7393	-177.8267	400	438	MI	SH	2	>1000	LS	2340	SZ
Bearded Seal	N	1	15-Aug	15:30	76.8738	-177.5790	4500	4639	HO	RE	2	>1000	LS	2340	None
Ringed Seal	Y	1	16-Aug	01:00	77.1628	-177.3533	300	390	UN	FD	1	>1000	LS	1340	None
Unidentified Seal	Y	1	16-Aug	01:29	77.1797	-177.1797	1740	1827	HO	RE	1	>1000	LS	1340	None
Ringed Seal	N	1	16-Aug	01:47	77.1893	-177.3102	322	412	ST	DI	1	>1000	RC	0	None
Ringed Seal	N	1	16-Aug	01:50	77.1903	-177.3160	200	291	MI	DI	1	>1000	OT	0	None
Bearded Seal	N	1	16-Aug	10:12	77.1693	-177.3330	4000	4087	HO	RE	1	>1000	OT	0	None
Unidentified Seal	Y	1	16-Aug	10:59	77.1942	-177.2948	2500	2283	HO	RE	1	>1000	RU	840	None
Unidentified Seal	Y	2	16-Aug	11:22	77.2095	-177.2815	3000	3100	HO	RE	1	>1000	LS	1840	None
Bearded Seal	N	1	16-Aug	11:39	77.2160	-177.2647	3800	3887	HO	RE	0	>1000	LS	2340	None
Bearded Seal	Y	2	16-Aug	11:43	77.2238	-177.2567	3600	3651	HO	RE	0	>1000	LS	2340	None
Bearded Seal	Y	1	16-Aug	11:49	77.2277	-177.2495	2500	2600	HO	RE	0	>1000	LS	2340	None
Ringed Seal	Y	1	16-Aug	11:56	77.2318	-177.2410	3500	3501	HO	RE	0	>1000	LS	2340	None
Ringed Seal	Y	1	16-Aug	12:03	77.2355	-177.2255	1740	1100	HO	RE	0	>1000	OT	0	None
Bearded Seal	Y	1	16-Aug	18:43	77.4285	-176.8788	303	191	SP	LO	0	>1000	LS	2340	PD

TABLE I.3. (continued).

Species	Useable (Y) or Non-Useable (N)[a]	Grp Size	Day in 2005	Time (GMT)	Latitude (°N)	Longitude (-=°W +=°E)	Initial Sighting Distance (m) from observer	CPA[b] Distance from G. Guns (m)	Initial Move-ment[c]	Initial Behav.[d]	Bf[e]	Water Depth (m)	Vessel Activ.[f]	Air-guns Vol. (in^3)[g]	Mitig. (SZ, PD, None)[h]
Unidentified Seal	Y	1	16-Aug	19:18	77.4507	-176.8377	965	1053	HO	LO	0	>1000	LS	2340	None
Unidentified Seal	Y	1	16-Aug	19:23	77.4545	-176.8347	511	600	HO	LO	0	>1000	LS	2340	None
Unidentified Seal	Y	1	16-Aug	19:45	77.4715	-176.7808	2100	1244	HO	RE	0	>1000	LS	2340	None
Ringed Seal	Y	1	16-Aug	20:06	77.4787	-176.7553	170	236	MI	SW	0	>1000	LS	2340	PD
Ringed Seal	N	1	16-Aug	21:00	77.5055	-176.6490	200	291	MI	SW	0	>1000	OT	0	None
Unidentified Seal	N	1	16-Aug	21:21	77.5098	-176.6523	2900	2938	HO	RE	0	>1000	OT	0	None
Ringed Seal	Y	1	16-Aug	23:20	77.5640	-176.5683	120	212	MI	LO	0	>1000	LS	1840	PD
Unidentified Seal	Y	1	17-Aug	00:08	77.5925	-176.6105	242	332	SA	LO	0	>1000	LS	1840	None
Ringed Seal	Y	1	17-Aug	04:10	77.6570	-176.5880	350	438	ST	SW	0	100-1000	LS	2340	SZ
Unidentified Seal	Y	1	17-Aug	05:01	77.6880	-176.5960	1448	1451	HO	RE	0	100-1000	LS	2340	None
Ringed Seal	Y	1	17-Aug	06:44	77.7522	-176.5498	150	250	SA	TH	1	100-1000	LS	1840	SZ
Unidentified Seal	Y	1	17-Aug	07:55	77.7950	-176.5418	150	242	ST	SW	1	>1000	LS	1840	SZ
Unidentified Seal	Y	1	18-Aug	08:16	76.6805	-175.4752	3000	3087	HO	RE	0	>1000	OT	0	None
Unidentified Seal	Y	1	18-Aug	12:53	76.1797	-173.4620	242	332	SA	SW	0	>1000	OT	0	None
Unidentified Seal	Y	1	18-Aug	15:58	75.7668	-172.1320	2400	304	SA	SI	1	>1000	OT	0	None

[a]Usable or Nonuseable sightings. Y=Visual sightings made during daylight periods, N=periods 3 min to 2 h after guns were turned off (post-seismic), poor visibility conditions (visibility <2 km), and periods with Beaufort Wind Force >5. Also excluded were periods when >1 radian of severe glare occurred between 90º left and 90º right of the bow.

[b]CPA is the distance at the closest observed point of approach to the nearest airgun. This is not necessarily the distance at which the individual or group was initially seen nor the closest it was observed to the vessel.

[c]The initial movement of the individual or group relative to the vessel. HO=hauled out, MI=milling, PE=swimming perpendicular to ship or across bow, SA=swimming away, SP=swimming parallel, ST=swimming toward, UN=unknown, NO = none, WA = walk away, WP = walk parallel.

[d]The initial behavior observed; DI=diving, FD=front dive, LO=looking, MI=milling, NO=no movement, RE=resting, SI=sink, SW=swimming, SA=swimming away, LG= logging or resting at the surface, SH=spyhopping or bobbing, UN=unknown, WA=walk, WT=walk toward, OT=other.

[e]Beaufort Wind Force scale (which is not the same as the "Sea State" scale).

[f]Activity of the vessel at the time of the sighting; LS=operating G. gun on a seismic survey line and collecting geophysical data, OT=other (a period of no seismic activity), DP=deploying seismic gear, RC= recovering seismic gear,).

[g]The airguns operated at a volume of 105 in3 to 2840 in3.

[h]Mitigating measures. SZ= safety zone shut down, PD=power down, None.

APPENDIX J:
SIGHTINGS WITH POWER DOWNS AND SHUT DOWNS DURING THE 2006 ARCTIC OCEAN CRUISE

A total of three power downs and five shut downs of the airguns were requested due to sightings of marine mammals approaching or within the nominal 180 and 190 dB safety radii during the Arctic Ocean cruise. All eight sightings were of individual pinnipeds. Four sightings occurred in intermediate water depths (100-1000 m) where the defined safety radius for pinnipeds was 500 m; four sightings occurred in deep water depths (>1000 m) where the defined safety radius for pinnipeds was 230 m (Table 3.2). A bearded seal and a ringed seal may have been exposed to sound pressure levels ≥190 dB; all other observed seals were outside of the estimated 190 dB sound level and were unlikely exposed to noise levels ≥190 dB. (See Tables 3.1 and 3.2 for sound level radii and safety radii):

- A single ringed seal was observed 8 Aug. at 23:51 GMT while the airguns were operating in 465 m deep water. The safety radius for pinnipeds in intermediate water depths (100-1000 m) was 500 m, however the modeled 190 dB sound radius was 150 m for the array firing at 840 in^3 (Tables 3.1, 4.7). The seal was hauled out on the ice, resting, ~575 m from the observer, or ~645 m from the active guns. The ringed seal looked toward the vessel several times and remained resting on the ice for eight minutes as the *Healy* proceeded along her track. Not until the ship was perpendicular to the seal at 23:59 GMT, did it react and dive in a calm manner into the water. By that time, the seal was within an estimated 264 m of the operating airguns. A shut down was implemented immediately. The animal was not seen again. Although the seal entered the water withing the safety radius while the airguns were firing, it was well outside the area where the sound level was ≥190dB. It is ***very unlikely*** that the ringed seal was exposed to sound levels ≥190 dB when it dove.
- On 15 Aug. at 9:44 GMT, an individual ringed seal was sighted in 944 m deep water while the airguns were firing. The defined airgun safety radius for pinnipeds in intermediate water depths (100-1000 m) was 500 m. The estimated 190 dB sound radius was 300 m around the active array firing at 2340 in^3. The seal was observed bobbing in what appeared to be a melt pond, looking at the vessel at approximately 458 m from the ship, just within the 500 m safety radius. A shut down was requested. The seal was observed bobbing in the pond for several seconds after the guns were shut down until ice obscured the MMOs view of the animal. The animal's closest point of approach to the operating airguns was 458 m. At that distance from the G. guns, predicted sound levels were less than 190 dB. It is ***very unlikely***, that the seal was briefly to sound levels ≥190 dB when it was bobbing at the surface of the water.
- A single bearded seal was observed swimming parallel to the *Healy* on 16 Aug. at 18:43 GMT, during seismic operations approximately 403 m from the airguns in 1290 m deep water. The safety radius for pinnipeds in deep water (>1000 m) for the 2006 survey was 230 m, the 190 dB sound level radius was 200 m (Tables 3.1 and 3.2). The MMO observed the animal look toward the *Healy* and then dive away from the ship. In three minutes, the animal resurfaced approximately 191 m away from the active airguns. A power down was initiated at 18:46 GMT. After the animal resurfaced it milled for a few seconds looking toward the ship and then dove. It resurfaced a second time after the power down and looked at the ship before it turned to swim away and then dive. Within two minutes, the animal was seen outside of the safety radius (~300 m from the airguns) and seismic activities were allowed to recommence. Because the seal was seen clear of the safety within five minutes, a ramp up was not necessary. It is ***likely*** that the bearded seal was exposed to sound levels ≥190 dB when it first dove from outside of the 190 dB radius and surfaced within the safety radius.
- On 16 Aug. at 20:06 GMT, a single ringed seal was observed while the airguns were operating in 1270 m deep water where the pinniped safety radius was 230 m and the 190 dB sound level radius was 200 m. The

seal was milling in a small area on the port side of the ship, ~236 m from the active airguns. A power down was initiated. The seal dove seconds after the initial sighting. After the ringed seal resurfaced approximately 130 m away from the airgun array, the seal was observed milling for several seconds before it dove away from the array. The ringed seal was finally observed 400 m away from the airguns at 20:10 GMT before it dove again. Seismic operations were allowed to recommence at full volume because the animal was seen to have left the safety radius within five minutes of the power down. The seal was seen ~236 m from the operating airguns in deep (>1000) water when the safety radius was 230 m and the 190 dB was 200. It is ***very unlikely*** that the ringed seal was exposed to sound levels ≥190 dB when it dove.

- On 16 Aug., at 23:20 GMT, a ringed seal was observed milling in the water approximately 212 m from the operating airguns in 1253 m deep water where the safety radius was 230 m and the 190 dB sound radius was 200 m. The seal dove just seconds after it was sighted and a power down was implemented. The seal resurfaced approximately 180 m from the airgun array one minute after the sighting and power down, and dove away from the airguns. The seal dove 12 m outside of the 190 dB sound level radius where it is ***unlikely*** that it was exposed to sound levels ≥190 dB.
- An individual ringed seal was sighted in 940 m deep water while the airguns were firing on 17 Aug. at 4:10 GMT. The defined airgun safety radius for pinnipeds in intermediate water depths (100-1000 m) was 500 m and the 190 dB sound radius was 300 m. The seal was observed swimming toward the *Healy*, 350 m from the bridge or ~438 m from the operating airguns. A shut down was immediately implemented. The seal dove into the water seconds after it was first observed. The ringed seal resurfaced approximately 300 m away from the airgun array three minutes after it first dove, milled while looking toward the ship for several seconds and dove toward the ship. After another minute, the seal was observed approximately 209 m from the array, looking toward the ship while milling for several seconds before it dove away from the vessel. The ringed seal's closest observed point of approach to the operating airguns was ~438 m when the 190 dB sound radius was 300 m. It is ***unlikely***, that the seal was briefly exposed to sound levels ≥190 dB when it dove into the water.
- A single ringed seal was sighted on 17 Aug. at 6:44 GMT in water 961 m deep while the airguns were operating. The seal was initially seen swimming away from the *Healy* at a vigorous pace at a distance of ~150 m from the bridge, or 250 m from the airguns. The safety radius under those conditions was 500 m and the 190 sound radius was 300 m. The individual seal thrashed as it dove away from the ship, seconds after its initial sighting. Because the seal was within the 500 m safety zone, a shut down was initiated. What is believed to be the same ringed seal was seen again at 6:50 GMT, 350 m off the port beam of the bridge, or ~450 m from the airguns. The ringed seal was seen diving within the 300 m 190 dB radius seconds before seismic activities were terminated in intermediate depth water. It is ***likely***, that the seal was briefly exposed to sound levels ≥190 dB when it dove.
- On 17 Aug. at 7:55 GMT, an unidentified seal was observed diving toward the *Healy*, approximately 242 m away from the airgun array while the airguns were operating. A shut down was implemented. The seal was not seen again. The seal was observed 242 m away from the active airgun array in 1287 m of water where the safety radius was 230 m and the 190 dB radius was 200 m. Because the array was shut down while the animal was well outside of the 190 dB radius, it is ***very unlikely*** that the animal was exposed to a 190 dB sound level.

APPENDIX K:
MARINE MAMMAL DENSITY AND EXPOSURE ESTIMATES

TABLE K.1. Expected densities of marine mammals in offshore areas of the Beaufort and Chukchi seas **near Barrow, Alaska**. Densities are corrected for *f*(0) and *g*(0) biases. Species listed under the U.S. Endangered Species Act (ESA) as endangered are in italics.

Species	Average Density (# / km^2) [a]	Maximum Density (# / km^2)
Odontocetes		
Beluga [b]	0.0034	0.0135
Narwhal	0.0000	0.0001
Delphinidae		
Killer whale	0.0000	0.0000
Phocoenidae		
Harbor porpoise [f]	0.0000	0.0002
Mysticetes		
Bowhead whale [c]	0.0032	0.0064
Gray whale [d]	0.0022	0.0045
Minke whale	0.0000	0.0000
Fin whale	0.0000	0.0000
Pinnipeds		
Walrus [i]	0.0731	0.6169
Bearded seal [e]	0.0128	0.0256
Spotted seal [g]	0.0001	0.0005
Ringed seal [f]	0.2510	1.0040
Carnivora		
Polar bear [h]	0.0016	0.0040

[a] Coefficients of variation (CVs) are not given because the density estimates come from various sources with widely differing methodologies so that CVs would not be comparable.

[b] Calculated from summer surveys of Moore et al. (2000a,b) in the Alaskan Beaufort Sea; most sightings were far to the east of the proposed seismic survey. Maximum densities are assumed to be half of the observed densities and mean densities are assumed to be 1/8th of observed densities. No beluga whales were sighted during surveys in the northern Chukchi Sea by Harwood et al. (2005), or Haley and Ireland (2006).

[c] Calculated from summer surveys of Moore et al. (2000a,b) in the Alaskan Beaufort Sea; most sightings were far to the east of the proposed seismic survey. Maximum densities are assumed to be 1/8th of the observed densities and mean densities are assumed to be 1/16th of observed densities. No bowhead whales were sighted during surveys in the northern Chukchi Sea by Brueggeman et al. (1991), Harwood et al. (2005), or Haley and Ireland (2006).

[d] Calculated from summer surveys of Moore et al. (2000b) in the Chukchi Sea; sightings only occurred near the southwest portion of the proposed seismic survey or along the coast near Pt. Barrow. Maximum densities are assumed to be 1/8th of the observed densities and mean densities are assumed to be 1/16th of observed densities and have only been applied to the southwest portion of the proposed seismic survey trackline with water depths <200 m, south of 75°N, in estimating takes (Table 6).

[e] Ringed seal density ×0.051 based on the ratio of ringed-to-bearded seals in Stirling et al. (1982).

[f] Average density is the mean pack-ice density from Kingsley (1986). Maximum density is average density ×4.

[g] There are no reliable survey data for these species in the project area. As spotted seals are known to occur in the

proposed seismic survey area (primarily near Barrow) we have arbitrarily inserted densities based on their relative abundance.

[h] Estimated from sightings and effort in Moulton and Williams (2003).

[i] Average density is the average open water density from Brueggeman et al. (1990). Maximum density is the average pack ice density from Brueggeman et al. (1990). Since walruses primarily occur along the pack-ice margin in water <200m deep, these densities were applied only to the southwest portion of the proposed seismic survey trackline with water depths <200 m south of 75°N in estimating takes (Table 6).

TABLE K.2. Expected densities of marine mammals in the **polar pack** ice north of Barrow. Densities are corrected for *f*(0) and *g*(0) biases. Species listed as endangered are in italics.

Species	**Average Density (# / km^2)** [a]	**Maximum Density (# / km^2)**
Odontocetes		
Beluga [b]	0.0003	0.0014
Narwhal	0.0000	0.0001
Mysticetes		
Bowhead whale [b]	0.0003	0.0006
Gray whale	0.0000	0.0000
Minke whale	0.0000	0.0000
Fin whale	0.0000	0.0000
Pinnipeds		
Walrus	0.0000	0.0001
Bearded seal [b]	0.0013	0.0023
Spotted seal	0.0000	0.0000
Ringed seal [b]	0.0251	0.1004
Carnivora		
Polar bear [b]	0.0002	0.0004

[a] Coefficients of variation (CVs) are not given because the density estimates come from various sources with widely differing methodologies so that CVs would not be comparable.

[b] Density is estimated as the density for the area north of Barrow/10